Passive House Multifamily Construction

Hook & Ladder – Minneapolis, Minnesota

Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.
Learning Objectives

1. Case study comparison
2. Why Passive House for multifamily affordable housing?
3. Review outcomes
4. Compare “standard” and Passive House requirements
5. Compare constructability and detailing
Project Context

- Art
- Energy
- Innovation

Holland Neighborhood Improvement Association

After

Before
Project Statistics

Building 1: Standard
- 59 Units (32-1BR, 16-2BR, 11-3BR)
- 3-story wood frame over 1 level precast
- 46,595 net rentable SF
- 59,553 GSF finished
- 19,768 GSF enclosed parking below

Building 2: Passive House
- 59 Units (32-1 BR, 16-2 BR, 11-3BR)
- 4-story wood frame over 1 level precast
- 47,856 net rentable SF
- 57,869 GSF finished
- 9,296 open parking below

Climate Zone: 6A
Primary Occupancy: R-2
Construction Type: “Standard” Building 1: VB
“Passive” Building 2: VA
**Project Site**

**Standard Building**
- 3-Stories over underground parking garage
- 59 Dwelling Units
- Rentable Unit Area = 45,628 SF

**Passive House**
- 5-stories with unenclosed parking on Level 1
- 59 Dwelling Units
- Rentable Unit Area = 45,883 SF

- Enclosed entry to below grade parking
- Stormwater feature
- Community connection trail
- Tot Lot
- On grade open parking below building
First Floor
Second – Third Floor
Fourth – Fifth Floor
Outcome
## ENERGY USE INTENSITY (EUI = kBtu/sf/yr)

<table>
<thead>
<tr>
<th></th>
<th>Standard Building (with enclosed parking)</th>
<th>Passive House Building (without enclosed parking)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUI Baseline</td>
<td>75.4</td>
<td>66.7</td>
</tr>
<tr>
<td>EUI Goal</td>
<td>62.3</td>
<td>40</td>
</tr>
<tr>
<td>EUI Predicted</td>
<td>56.7</td>
<td>23.75</td>
</tr>
</tbody>
</table>

## AIR TIGHTNESS (Blower Door Air Leakage Tests) Code Maximum: 3 ACH\textsubscript{50}

<table>
<thead>
<tr>
<th>Design Standard Max</th>
<th>Standard Building (with enclosed parking)</th>
<th>Passive House Building (without enclosed parking)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Energy Star Max = .3 cfm/50/ft</td>
<td>PHIUS = .05 cfm/50/ft</td>
</tr>
<tr>
<td></td>
<td>.15 cfm 50/ft\textsuperscript{2}</td>
<td>.038 cfm 50/ft\textsuperscript{2}</td>
</tr>
<tr>
<td></td>
<td>.95 ACH\textsubscript{50}</td>
<td>.3 ACH\textsubscript{50}</td>
</tr>
</tbody>
</table>

Standard Building
HERS Rating:
61 Target
51 Actual
Cost Containment: Finance Sources / Construction Cost

PHIUS BUILDING TOTAL COST
Excluding site
$10,020,951 = $149.20/GSF w/ parking
$163.53 GSF w/o parking

STANDARD BUILDING TOTAL COST
Excluding site
$9,547,675 = $120.37/GSF w/ parking
$140.41/GSF w/o parking
### PHIUS+ 2015 REQUIREMENTS
- High-performance building envelope
  - Thermal comfort
  - Moisture control
  - Durability
- Fresh air requirements
  - Direct bedroom supply
  - MERV 8 (MERV 12)
  - Limited exposure to combustion gas
- Balanced ventilator

### OCCUPANT BENEFITS
- Resilience
  - extreme weather
  - power outages
  - housing cost uncertainty
- Remediation of environmental pollution
- Increased occupant comfort
- Increased occupant health
  - reduction in mold, bacteria, dust, pests
  - cardiovascular
  - stress

### COMMUNITY BENEFITS
- Lower turnover = connection to community
- Resilience
- Proactive care for vulnerable populations
- Economics
- Emissions
- Prototype

### OWNER BENEFITS
- Funding opportunities
- Reduced maintenance/operation costs
  - utilities
  - envelope durability (3rd party verified)
- Reduced resident turnover
Integrated Design Critical to Success
Project Team

OWNER: NEWPORT PARTNERS LLC
• Becky Landon
• Sarah Larson

ARCHITECT: LHB, INC.
• Kim Bretheim, Project Principal
• Bailey Hanson, Architect
• Laura Heck, Project Assistant
• Jeff Hemer, Architect
• Melanie Kiihn, Architect
• Lindsey Kieffaber, Architect
• Andy Madson, Architect
• Bill Niebur, Architect
• Roger Purdy, Construction Administrator
• Jonathan Rozenbergs, Architect
• Stuart Shrimpton, Architectural Designer
• Ben Trousdale, Architect
• Elizabeth Turner, Architect
• David Williams, Energy Modeling

PASSIVE HOUSE CONSULTANT: PRECIPITATE
• Elizabeth Turner, Architect, PHIUS+ Consultant

CONTRACTOR: FRERICHS CONSTRUCTION
• Dave Einck, Senior Project Manager
• Mike Reineccius, Field Superintendent
• Aaron Zdon, Air Sealing Specialist

M&E CONTRACTORS
• J. Becher & Associates
• Kevin Miller & Reid Mathiason: Associated Mechanical Contractors

M&E: STEEN ENGINEERING
• John Hazuchia, Mechanical Engineer
• Jake Melbostad, Electrical Engineer

STRUCTURAL: MATTSON MACDONALD YOUNG
• Kirk Davis, Structural Engineer

CIVIL: WENCK ASSOCIATES
• Roshaan Grieme, Civil Engineer

LA: AUNE FERNANDEZ LANDSCAPE ARCHITECTURE
• Jason Aune, Landscape Architect
<table>
<thead>
<tr>
<th>Passive House Principles</th>
<th>PHIUS Certification Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize Thermal Loss/Gain</td>
<td>Certified Passive House Consultant</td>
</tr>
<tr>
<td>• Continuous Insulation</td>
<td>WUFI Passive Energy + Hygrothermal Modeling</td>
</tr>
<tr>
<td>Air-Tight Construction</td>
<td>Pre-certification Design Review by PHIUS</td>
</tr>
<tr>
<td>• Proper location and durability of air barrier</td>
<td>Testing by PHIUS+ Rater (HERS rater allowed first time)</td>
</tr>
<tr>
<td>and vapor retarder</td>
<td>• Detailed on-site inspection</td>
</tr>
<tr>
<td>High Performance Windows/Doors</td>
<td>– Slab + foundation insulation</td>
</tr>
<tr>
<td>Balanced Ventilation (ERV)</td>
<td>– Insulation</td>
</tr>
<tr>
<td>Minimized Space Conditioning</td>
<td>– Air barrier details</td>
</tr>
<tr>
<td></td>
<td>• Blower door test</td>
</tr>
<tr>
<td></td>
<td>• HVAC + DHW commissioning</td>
</tr>
</tbody>
</table>
### Design Performance Standards

**Thermal and Moisture Protection / Window Openings**

<table>
<thead>
<tr>
<th>Building: 1 Standard</th>
<th>Building: 2 PHIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>Energy Star Certified Homes, Version 3.1 rev.08 Maximum Assembly U value per ASHRAE 90.1-2010, appendix A per MN Residential Energy Code C401.2.</td>
</tr>
<tr>
<td><strong>Insulation level modeling</strong></td>
<td>Meet or exceed 2012 IECC insulation levels (ASHRAE 90.1-2010)</td>
</tr>
<tr>
<td><strong>Slabs on grade</strong></td>
<td>Slab edge R5 + per 2009 IECC below slab insulation: whole slab R20-28</td>
</tr>
<tr>
<td><strong>Wood Framed walls min.</strong></td>
<td>(U-.051) continuous exterior insulation +R5 (Walls: 39-51)</td>
</tr>
<tr>
<td><strong>Roof minimum</strong></td>
<td>1) Above deck: R30 (U-.032)/.048 (Roof/Ceilings: 70-90)</td>
</tr>
<tr>
<td><strong>Floors over unconditioned space (minimum)</strong></td>
<td>U=.033 (per energy star 3.1) U=.026 blown insulation in framing plank</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building: 1 Standard</th>
<th>Building: 2 PHIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>Ufactor and SHGC for northern zone meet PHIUS for cold climate zone (#6)</td>
</tr>
<tr>
<td><strong>U factor</strong></td>
<td>-.27 -.30 U Overall Installed Window U-value: &lt; 0.13 (Btu/h)/sf/F Center of Glass U-Values: &lt; 0.12 (Btu/h)/sf/F</td>
</tr>
<tr>
<td><strong>Air leakage</strong></td>
<td>.3 cfm 50/s.f. per Energy Star .05cfm 50/ft2 (whole building)</td>
</tr>
<tr>
<td><strong>SHGC</strong></td>
<td>.32 - .42 SHGC-South: &gt; 0.50 SHGC-North, East, West: Any</td>
</tr>
<tr>
<td><strong>Models meeting standard/certification</strong></td>
<td>Pella Impervia – Natural Sun Low-E IG (.29 U, .5 shgc) Pella 350 series (Advanced low-e argon triple pane – U=.17, shgc+.19)</td>
</tr>
</tbody>
</table>
Precedent: Vancouver – Envelope & Constructability
Takeaways for Cost Containment & Quality Control

- Source materials locally (e.g. windows)
- Train installers and site superintendents
- Simplify design and material selection
- Let trades do what they know how to build & design accordingly
- Design for “2-fers”: e.g. structure & moisture control, energy envelope & acoustics
### Assembly Comparison – Climate Zone 6 & 7

#### GOALS
- Minimized Thermal Bridging
- Increased Air Tightness
- Managed Vapor Plane
- Managed Drainage Plane

<table>
<thead>
<tr>
<th>TRADITIONAL WALL / RIM</th>
<th>TYPICAL WALL / RIM</th>
<th>ENHANCED WALL / RIM</th>
<th>INNOVATIVE WALL / RIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-1980</td>
<td>Current</td>
<td>Current</td>
<td>‘Next-Gen’</td>
</tr>
<tr>
<td>Platform Framed</td>
<td>Platform Framed</td>
<td>Platform Framed</td>
<td>Balloon Framed</td>
</tr>
<tr>
<td>Building EUI: 60+ kBtu/sf</td>
<td>Targeted Building EUI: 40</td>
<td>Targeted Building EUI: 30</td>
<td>Targeted Building EUI: 20</td>
</tr>
<tr>
<td></td>
<td>kBtu/sf outcome</td>
<td>kBtu/sf outcome</td>
<td>kBtu/sf outcome</td>
</tr>
</tbody>
</table>

#### GOALS
- Minimized Thermal Bridging
- Increased Air Tightness
- Managed Vapor Plane
- Managed Drainage Plane

### INTEGRATION OF BUILDING COMPONENTS

- Vapor Barrier
- Vapor Retarder
- Building Paper (as req’d)
- 2x4 Framing w/ Batt Insul
- Sheathing
- Insulated Rim

### CONTINUITY & INTEGRITY OF MOISTURE PLANES

- Sheet Membrane WRB
- Structural Sheathing
- Sealant at Exterior & Interior Seams
- Foamed Rim
- Blown-in Insulation
- Window Head at Rim

### ROLE OF WALL / ENVELOPE

- Sheet Membrane WRB
- Cont. Exterior Insulation
- Sealant at Interior Vapor Retarder Seams
- Structural Sheathing
- Foamed Rim
- Blown-in Insulation
- Window Head at Rim

### WHOLE-BUILDING & COMPONENT MODELING

- Fluid-applied WRB
- Cont. Insulated Sheathing
- Sealant at Interior Vapor Retarder Seams
- Cont. Interior Sheathing & Vapor Retarder
- Blown-in Insulation
- Window Head at Ceiling

### ENERGY CODE COMPLIANCE

- Evaluation of Performance
# Passive House

## High Performance Envelope & Mechanical System

### Envelope
- **Roof Insulation**: R-55
- **Wall Insulation**: R-19 + R-9.6 CI (R-29.7 total wall assembly)
- **Above Parking**: 50 CI
- **Slab Insulation**: R-20 CI
- **Awning Window**: U-0.17, SHGC 0.2
- **Fixed Window**: U-0.15, SHGC 0.27

### Systems
- **HVAC System (Cooling)**: VRF with Centralized ERV
- **HVAC System (Heating)**: Gas Fired Boilers
- **Dwelling HVAC Units**: Fancoils (4 Pipe)
- **Lighting**: LED
- **Dryers**: Heat Pump mixed with Standard
- **DHW**: Gas with VRF Preheat
- **Solar**: 40 kW system on rooftop
  *(located on Standard House Building due to orientation)*
Continuous Fresh Air Supply: Direct to Bedrooms

**Standard**
- Direct Exhaust
- Magic Pak

**Passive House**
- Fan Coil
- DOAS System
- Electric Duct (Backup heaters)
Continuous Fresh Air Supply

- Ventilation Ducts appear to be well sealed with mastic.
- DOAS Unit with Heat Recovery
- VRF Unit
- Typical Apartment Magic Pak
- Common Area Furnace
Building Assemblies

Standard Building
Roof R-Value = 49
Wall R-Value = 22
Window U-factor = .29
SHGC = .40

Passive House
Roof R-Value = 62.3
Wall R-Value = 29.7
Window U-factor = .15
SHGC = .27
Wall Sections
Floor to Wall Connection

**Standard Floor to Wall Connection**
- Exterior Finish (varies)
- Weather Resistant Barrier (Tyvek Membrane)
- 36 Piers
- Vapor Retarder, 0.6 mil Poly
- Continuous Sealant
- Floor Sheathing
- 1/2" Gyipcrete
- 1/4" Acoustic Matt
- Truss
- Closed Cell Low Expansion Spray Foam Insulation (R-24 MIN)

**Passive House Floor to Wall Connection**
- Exterior Finish (varies)
- Fluid Applied Air/Water Barrier (171 Perm)
- Insulated Exterior Sheathing (Hunter Panels)
- Wood Stud Wall with Batt Insulation
- Continuous Sealant
- Topcoat Joint, Fluid Applied
- Spray Foam
- Floor Sheathing
- 1/4" Joint with Continuous Seal
- 1/2" Gyipcrete
- 1/4" Acoustic Matt
- 5/8" Spacer
- Interior Sheathing (Vapor Barrier)
- Gypsum Board
- Truss Hanger
- Blown-in Insulation
- Ceiling Vapor Retarder (0.6 mil Poly)
- Typical Window Head Framing
- Gypsum Board Furring on Metal Studs
- Gypsum Board on Resilient Channels
Wall Details: Roof at Exterior Wall – Non-Bearing

Standard

Passive House
Wall Details at Garage

**Standard**

- Burnished Concrete Block
- Weather Resistant Barrier (AWB-5; Dashed)
- Concrete Slab
- Thru-Wall Flashing
- Rigid Insulation, Extruded Polystyrene
- Grade, Varies, See Civil
- Foundation Waterproofing System
- Concrete Block Foundation, See Structural

---

**Second Floor Above Open Garage - Non-Bearing**

- Wall, Cantilevers Over Edge of Plank, TYP
- Insulated Sheathing at Typical Thickness - See Wall Type, TYP
- Insulated Sheathing (Polyiso) Varnished on Plywood, Approx. H. Adjust with Plank Dimensional Tolerance (Over End of Plank, Align
  with Face of Sheathing Above, TYP
- Gypsum Topping Slab, TYP
- Concrete Plank, See Structural, TYP
- Spray Applied Vapor Barrier, On Plank Only
- 5/8" Plywood Sheathing, TYP
- Precast Concrete Beam, Dashed Beyond, See Structural
- Blow-in Insulation, TYP
- Metal Stud Soffit Framing, TYP
- Kicker, AS Req’d, TYP
- Metal or Fiber Cement Panel, See Elevation, TYP
- Liquid Applied Air/Water Barrier (Dash-Dot), TYP
- Insulated Sheathing (Polyiso) Varnished on Plywood, TYP
- Fiber Cement Board Soffit, TYP
Wall Details: Base of Wall

**Standard**

- **Base of Wall @ Vestibule**
  - Metal Panel, See Elevation
  - Flashing
  - Burnished Block Sill
  - Waterproofing Membrane
  - Begins Behind Flashing
  - Concrete Slab, See Structural Grade, Varies, See Civil

**Passive House**

- **Base of Wall Under Entry Canopy**
  - Metal or Fiber Cement Panel, See Elevation
  - Liquid Applied Air/Water Barrier (Dash Dot)
  - Insulated Sheathing
  - Flashing
  - Burnished Block Sill
  - Burnished Concrete Block Veneer
  - 4" Rigid Underslab Insulation Wraps Up To Top of Slab
  - Underslab Air/Water/Vapor barrier, Wrap Up Slab Edge
  - Steel Reinforcing - See Structural
  - Waterproofing Membrane, Run 1'-0" Below Grade
  - Concrete Block Foundation, See Structural
  - High Density Extruded Polystyrene Insulation Under Thickened Slab - See Structural
  - Precast Column, Dashed, Beyond, See Structural
  - Rigid Underslab Insulation
Framing

Standard - Platform

Passive - Balloon
Framing: Passive House Balloon Framing
Window Openings

Standard

Passive
Insulation Cavity

Standard - Openings

Passive – No Openings
Window Openings

Standard

Passive
Gypsum Board

Standard

Passive
Framing

Standard - Platform

Passive - Balloon
Weather Barrier

Standard - Sheet

Passive - Fluid
Passive House Fluid Vapor Barrier
Weather Barrier

Standard - Sheet

Passive - Fluid
Cladding

Standard – Rain Screen

Passive – Rain Screen
Exterior Wall Penetrations

Standard

Passive
Passive House Parking Garage Ceiling
## Blower Door Test Results: Passive House

<table>
<thead>
<tr>
<th>Final whole building blower door test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Square Foot of the Building Envelope</td>
<td>56200</td>
</tr>
<tr>
<td>Passive House Volume</td>
<td>420952</td>
</tr>
<tr>
<td>CFM50 test result - depressurization</td>
<td>2107</td>
</tr>
<tr>
<td>CFM50/Shell area</td>
<td>0.0375</td>
</tr>
<tr>
<td>ACH50 - depressurization</td>
<td>0.30</td>
</tr>
<tr>
<td>CFM50 test result - pressurization</td>
<td>2168</td>
</tr>
<tr>
<td>CFM50/Shell area</td>
<td>0.0386</td>
</tr>
<tr>
<td>ACH50 - pressurization</td>
<td>0.31</td>
</tr>
<tr>
<td>Average CFM50</td>
<td>2107</td>
</tr>
<tr>
<td>Average CFM50/Shell area</td>
<td>0.038</td>
</tr>
<tr>
<td>Average ACH50</td>
<td>0.30</td>
</tr>
</tbody>
</table>

*Source: Final Blower Door Test Results prepared by Eco Acheivers*
Energy Design Assistance: Modeling & Rebate Incentives

<table>
<thead>
<tr>
<th></th>
<th>Building 1: Standard</th>
<th>Building 2: PHIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Energy Cost Savings</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>Percent Electric Demand Savings</td>
<td>25%</td>
<td>19%</td>
</tr>
<tr>
<td>Percent Electric Consumption Savings</td>
<td>28%</td>
<td>41%</td>
</tr>
<tr>
<td>Percent Gas Consumption Savings</td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td>Total Incremental First Cost</td>
<td>$150,315</td>
<td>$495,724</td>
</tr>
<tr>
<td>Total Incentive</td>
<td>$31,806</td>
<td>$30319</td>
</tr>
<tr>
<td>Simple Payback with Incentive</td>
<td>3.1</td>
<td>8.6</td>
</tr>
<tr>
<td>Energy Use Intensity (EUI)</td>
<td>Baseline: 79.6 KBtu/ft²/yr As Built: 51.6 KBtu/ft²/yr</td>
<td>Baseline: 62.8 KBtu/ft²/yr As Built: 37.7 KBtu/ft²/yr</td>
</tr>
<tr>
<td>(modeled)</td>
<td>% Savings</td>
<td></td>
</tr>
<tr>
<td></td>
<td>35%</td>
<td>40%</td>
</tr>
</tbody>
</table>

53% from Standard baseline
27% better than Standard as built

Source: Verification Reports prepared by Willdan
## EDA Strategy Results: Standard Building

<table>
<thead>
<tr>
<th>Space Asset Area</th>
<th>Strategy Description</th>
<th>Peak kW Savings</th>
<th>kWh Savings</th>
<th>Gas Savings (Therm)</th>
<th>Energy Cost Savings</th>
<th>Inc. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office, Garage - Enclosed, Fitness, Apartments</td>
<td>Lighting power reductions</td>
<td>14.8</td>
<td>65,446</td>
<td>-1,135</td>
<td>$9,316</td>
<td>$9,309</td>
</tr>
<tr>
<td>Apartments</td>
<td>ENERGY STAR APPLIANCES</td>
<td>3.7</td>
<td>28,715</td>
<td>103</td>
<td>$4,459</td>
<td>$21,103</td>
</tr>
<tr>
<td>Facility</td>
<td>Machine roomless elevator</td>
<td>5.2</td>
<td>29,141</td>
<td>0</td>
<td>$4,446</td>
<td>$4,229</td>
</tr>
<tr>
<td>Magic Pak</td>
<td>Increased DX cooling efficiency</td>
<td>13.7</td>
<td>15,482</td>
<td>0</td>
<td>$2,476</td>
<td>$9,127</td>
</tr>
<tr>
<td>Magic Pak</td>
<td>Electronically commutated motor with constant speed</td>
<td>1</td>
<td>17,454</td>
<td>-393</td>
<td>$2,421</td>
<td>$18,010</td>
</tr>
<tr>
<td>Apartments Common Areas Office Laundry Fitness</td>
<td>Glazing low solar gain, non-metal frame</td>
<td>3.0</td>
<td>-1,338</td>
<td>3,549</td>
<td>$1,962</td>
<td>$58,089</td>
</tr>
<tr>
<td>Garage</td>
<td>85% efficient gas furnace</td>
<td>0</td>
<td>0</td>
<td>2,307</td>
<td>$1,412</td>
<td>$191</td>
</tr>
<tr>
<td>Apartments, Garage - Enclosed, Laundry, Common Areas</td>
<td>Roof R 40</td>
<td>1</td>
<td>93</td>
<td>1,067</td>
<td>$675</td>
<td>$12,722</td>
</tr>
<tr>
<td>Apartments, Common Areas, Garage - Enclosed, Office, Laundry, Fitness</td>
<td>Wall R 16</td>
<td>0.7</td>
<td>333</td>
<td>919</td>
<td>$614</td>
<td>$1,457</td>
</tr>
</tbody>
</table>
## EDA Strategy Results: Passive House

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<th>kWh Savings</th>
<th>Gas Savings (Therm)</th>
<th>Energy Cost Savings</th>
<th>Inc. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC</td>
<td>Air-cooled VRF</td>
<td>-21.3</td>
<td>160,887</td>
<td>0</td>
<td>$19,902</td>
<td>$94,260</td>
</tr>
<tr>
<td>Apartments, Common Areas, Laundry</td>
<td>Glazing low solar gain triple pane, non-metal frame</td>
<td>9.5</td>
<td>87,235</td>
<td>0</td>
<td>$10,731</td>
<td>$182,022</td>
</tr>
<tr>
<td>DOAS</td>
<td>DOAS Total heat recovery</td>
<td>12</td>
<td>55,113</td>
<td>0</td>
<td>$6,768</td>
<td>$47,223</td>
</tr>
<tr>
<td>Apartments, Laundry, Garage - Enclosed, Common Areas, Bike storage / Trash</td>
<td>Lighting Power Reduction</td>
<td>4.4</td>
<td>33,493</td>
<td>0</td>
<td>$4,305</td>
<td>$7,872</td>
</tr>
<tr>
<td>Apartments</td>
<td>ENERGY STAR Appliances</td>
<td>5.7</td>
<td>24,056</td>
<td>311</td>
<td>$3,329</td>
<td>$20,060</td>
</tr>
<tr>
<td>Apartments, Common Areas, Laundry, Bike Storage / Trash</td>
<td>Wall R 24</td>
<td>2.0</td>
<td>24,335</td>
<td>0</td>
<td>$2,996</td>
<td>$31,221</td>
</tr>
<tr>
<td>Facility</td>
<td>50% reduced air infiltration</td>
<td>2.4</td>
<td>10,012</td>
<td>0</td>
<td>$1,242</td>
<td>$38,159</td>
</tr>
<tr>
<td>Apartments, Common Areas, Laundry</td>
<td>Roof R 60</td>
<td>0.8</td>
<td>9,547</td>
<td>0</td>
<td>$1,177</td>
<td>$18,070</td>
</tr>
<tr>
<td>Facility</td>
<td>Machine roomless elevator</td>
<td>0.8</td>
<td>4,397</td>
<td>0</td>
<td>$559</td>
<td>$14,695</td>
</tr>
<tr>
<td>DOAS</td>
<td>DOAS 30% improved heat pump cooling efficiency</td>
<td>4</td>
<td>2,198</td>
<td>0</td>
<td>$294</td>
<td>$31,783</td>
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</table>
This concludes The American Institute of Architects Continuing Education Systems Course

Kim Bretheim, FAIA, LEED AP BD+C
Housing Studio Leader
LHB, Inc.
Kim.Bretheim@LHBcorp.com