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
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

**Diagram notes:**
- 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

<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>Design Standard Max</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/ft²</td>
<td>.038 cfm 50/ft²</td>
</tr>
<tr>
<td></td>
<td>.95 ACH&lt;sub&gt;50&lt;/sub&gt;</td>
<td>.3 ACH&lt;sub&gt;50&lt;/sub&gt;</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
## Why PHIUS for Multifamily Affordable Housing: Benefits

### 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

Material Costs

Construct -ability

Cost + Financing

Program

Site + Climate

Mechanical Systems

Air-tightness

Energy Demand

Windows + Doors

Assemblies

Massing + Orientation

Site + Climate
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 Hazucha, 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 and vapor retarder</td>
<td>Testing by PHIUS+ Rater (HERS rater allowed first time)</td>
</tr>
<tr>
<td>High Performance Windows/Doors</td>
<td>• Detailed on-site inspection</td>
</tr>
<tr>
<td>Balanced Ventilation (ERV)</td>
<td>– Slab + foundation insulation</td>
</tr>
<tr>
<td>Minimized Space Conditioning</td>
<td>– Insulation</td>
</tr>
<tr>
<td></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

**Building: 1 Standard**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Building: 1 Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal Protection</strong></td>
<td><strong>Building: 1 Standard</strong></td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>Energy Star Certified Homes, Version 3.1 rev.08</td>
</tr>
<tr>
<td></td>
<td>Maximum Assembly U value per ASHRAE 90.1-2010, appendix A</td>
</tr>
<tr>
<td></td>
<td>per MN Residential Energy Code C401.2.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Insulation level modeling</th>
<th>2012 IECC levels (table 402.1.3/1) and grade 1 installation per RESNET standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slabs on grade</td>
<td>Slab edge R5 + per 2009 IECC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wood Framed walls min.</th>
<th>(U-.051)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof minimum:</td>
<td>1) Above deck: R30 (u-.032)/.048</td>
</tr>
<tr>
<td></td>
<td>(Roof/Ceilings: 70-90)</td>
</tr>
<tr>
<td>Floors over unconditioned space (minimum)</td>
<td>U=.033 (per energy star 3.1)</td>
</tr>
</tbody>
</table>

**Building: 2 PHIUS**

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MN Commercial Energy Code</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ufactor and SHGC for northern zone</th>
<th>meet PHIUS for cold climate zone (#6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U factor</strong></td>
<td>-.27 -.30 U</td>
</tr>
<tr>
<td><strong>Air leakage</strong></td>
<td>.3 cfm 50/s.f. per Energy Star</td>
</tr>
<tr>
<td><strong>SHGC</strong></td>
<td>.32 - .42</td>
</tr>
<tr>
<td><strong>Models meeting standard/certification</strong></td>
<td>Pella Impervia – Natural Sun Low-E IG (.29 U, .5 shgc)</td>
</tr>
</tbody>
</table>

**Building: 2 PHIUS**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>MN Commercial Energy Code</td>
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</table>

| **U factor** | Overall Installed Window U-value: < 0.13 (Btu/h)/sf/F |
| **Center of Glass U-Values**: < 0.12 (Btu/h)/sf/F |
| **Air leakage** | .05cfm 50/ft2 (whole building) |
| **SHGC** | SHGC-South: > 0.50 SHGC-North, East, West: Any |
| **Models meeting standard/certification** | Pella 350 series (Advanced low-e argon triple pane – U=.17, shgc+.19) |
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
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

Standard

Passive House

Typical Apartment Magic Pak

Ventilation Ducts appear to be well sealed with mastic.

Common Area Furnace

VRF Unit

DOAS Unit with Heat Recovery
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

Standard

Passive House
Wall Assemblies

**STANDARD WALL ASSEMBLY**

- R-16
- U-0.053
- Metal Panel
- Weather Resistant Barrier (Type K)
- 36.5 Perm
- Exterior Wall Sheathing (Gypsum Deniglass)
- 25.1 Perm
- 2 x 8 Studs @ 16" O.C.
- 7 1/2" R-24 Batt Insulation
- Vapor Barrier: Cat. mkpoly
- 5/8" Gypsum Board

**PASSIVE HOUSE WALL ASSEMBLY**

- R-25
- U-0.357
- Metal Panel
- Weather Resistant Barrier (Polygard)
- 21 Perm
- Insulated Exterior Sheathing (Furterm Panels)
- 5/8" Plywood on 1/2" Polyisocyanurate (R-1.6)
- Perm+1 (polyiso only)
- 2 x 6 Studs @ 16" O.C. (Fire Twacx)
- 5 1/2" R-21 Batt Insulation

Tyvek Drainwrap

Polygard
Floor to Wall Connection

**STANDARD**
FLOOR TO WALL CONNECTION

- Exterior Finish (varies)
- Weather Resistant Barrier (Tyvek Membrane)
- 36 Piano
- Vapor Retarder, 0.5 mil Poly
- Sealsant
- Floor Sheathing
- 1/8" Gyproc
- 1/4" Acoustic Matt
- Truss
- Closed Cell Low Expansion Spray Foam Insulation (R-24 MIN)
- Ceiling Vapor Retarder, 0.5 mil Poly
- Sealsant
- Vapor Retarder, 0.5 mil Poly

**PASSIVE HOUSE**
FLOOR TO WALL CONNECTION

- Exterior Finish (varies)
- Fluid Applied Air Barrier (1/1 Perme)
- Insulated Exterior Sheathing (Xtratherm Panels)
- Wood Stud Wall with Batt Insulation
- Continuous Sealsant
- Taped Joint, Fluid Applied
- Spray Foam
- Floor Sheathing
- 1/4" Joint with Continuous Seal
- 1/8" Gyproc
- 1/4" Acoustic Matt
- S/S Screws
- Interior Sheathing (Vapor Barrier)
- Gypsum Board
- Truss Hanger
- Blown-in Insulation

- Ceiling Vapor Retarder (0.5 mil Poly)
- Typical Window Head Framing
- Gypsum Board Furring on Metal Studding
- Gypsum Board on Resilient Channels
Wall Details: Roof at Exterior Wall – Non-Bearing
Wall Details at Garage

Standard

Passive House
Wall Details: Base of Wall

Standard

Passive House
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

*Source: Verification Reports prepared by Willdan*

<table>
<thead>
<tr>
<th>Building 1: Standard</th>
<th>Building 2: PHIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Energy Cost Savings</td>
<td>30%</td>
</tr>
<tr>
<td>Percent Electric Demand Savings</td>
<td>25%</td>
</tr>
<tr>
<td>Percent Electric Consumption Savings</td>
<td>28%</td>
</tr>
<tr>
<td>Percent Gas Consumption Savings</td>
<td>40%</td>
</tr>
<tr>
<td>Total Incremental First Cost</td>
<td>$150,315</td>
</tr>
<tr>
<td>Total Incentive</td>
<td>$31,806</td>
</tr>
<tr>
<td>Simple Payback with Incentive</td>
<td>3.1</td>
</tr>
<tr>
<td>Energy Use Intensity (EUI) (modeled) Baseline: 79.6 KBtu/ft²/yr As Built: 51.6 KBtu/ft²/yr</td>
<td>53% from Standard baseline</td>
</tr>
<tr>
<td>Energy Use Intensity (EUI) (modeled) Baseline: 62.8 KBtu/ft²/yr As Built: 37.7 KBtu/ft²/yr</td>
<td>27% better than Standard as built</td>
</tr>
<tr>
<td>% Savings</td>
<td>35%</td>
</tr>
<tr>
<td>Space Asset Area</td>
<td>Strategy Description</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>------------------------------------------------------------</td>
</tr>
<tr>
<td>Office, Garage - Enclosed, Fitness, Apartments</td>
<td>Lighting power reductions</td>
</tr>
<tr>
<td>Apartments</td>
<td>ENERGY STAR APPLIANCES</td>
</tr>
<tr>
<td>Facility</td>
<td>Machine roomless elevator</td>
</tr>
<tr>
<td>Magic Pak</td>
<td>Increased DX cooling efficiency</td>
</tr>
<tr>
<td>Magic Pak</td>
<td>Electronically commutated motor with constant speed</td>
</tr>
<tr>
<td>Apartments Common Areas, Office, Laundry, Fitness</td>
<td>Glazing low solar gain, non-metal frame</td>
</tr>
<tr>
<td>Garage</td>
<td>85% efficient gas furnace</td>
</tr>
<tr>
<td>Apartments, Garage - Enclosed, Laundry, Common Areas</td>
<td>Roof R 40</td>
</tr>
<tr>
<td>Apartments, Common Areas, Garage - Enclosed, Office, Laundry, Fitness</td>
<td>Wall R 16</td>
</tr>
</tbody>
</table>
### EDA Strategy Results: Passive House

<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>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>
</tr>
</tbody>
</table>
This concludes The American Institute of Architects Continuing Education Systems Course

Kim Bretheim, FAIA, LEED AP BD+C
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Kim.Bretheim@LHBcorp.com