

# Passive House Multifamily Construction

Hook & Ladder – Minneapolis, Minnesota

Presented by Kim Bretheim, FAIA, LEED AP BD+C  
– Housing Studio Leader, LHB, Inc.



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

- Case study comparison
- Why Passive House for multifamily affordable housing?
- Review outcomes
- Compare “standard” and Passive House requirements
- Compare constructability and detailing



## HOLLAND NEIGHBORHOOD



## IMPROVEMENT ASSOCIATION

- Art
- Energy
- Innovation



After



Before





## PHIUS+ 2015 REQUIREMENTS

- High-performance building envelope
  - Thermal comfort
  - Moisture control
  - Durability
  - Thermal bridging
- Fresh air requirements
  - Direct bedroom supply
  - MERV 8 (MERV 12)
  - Limited exposure to combustion gas
- Balanced ventilation
- Renewable energy



## OCCUPANT BENEFITS

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



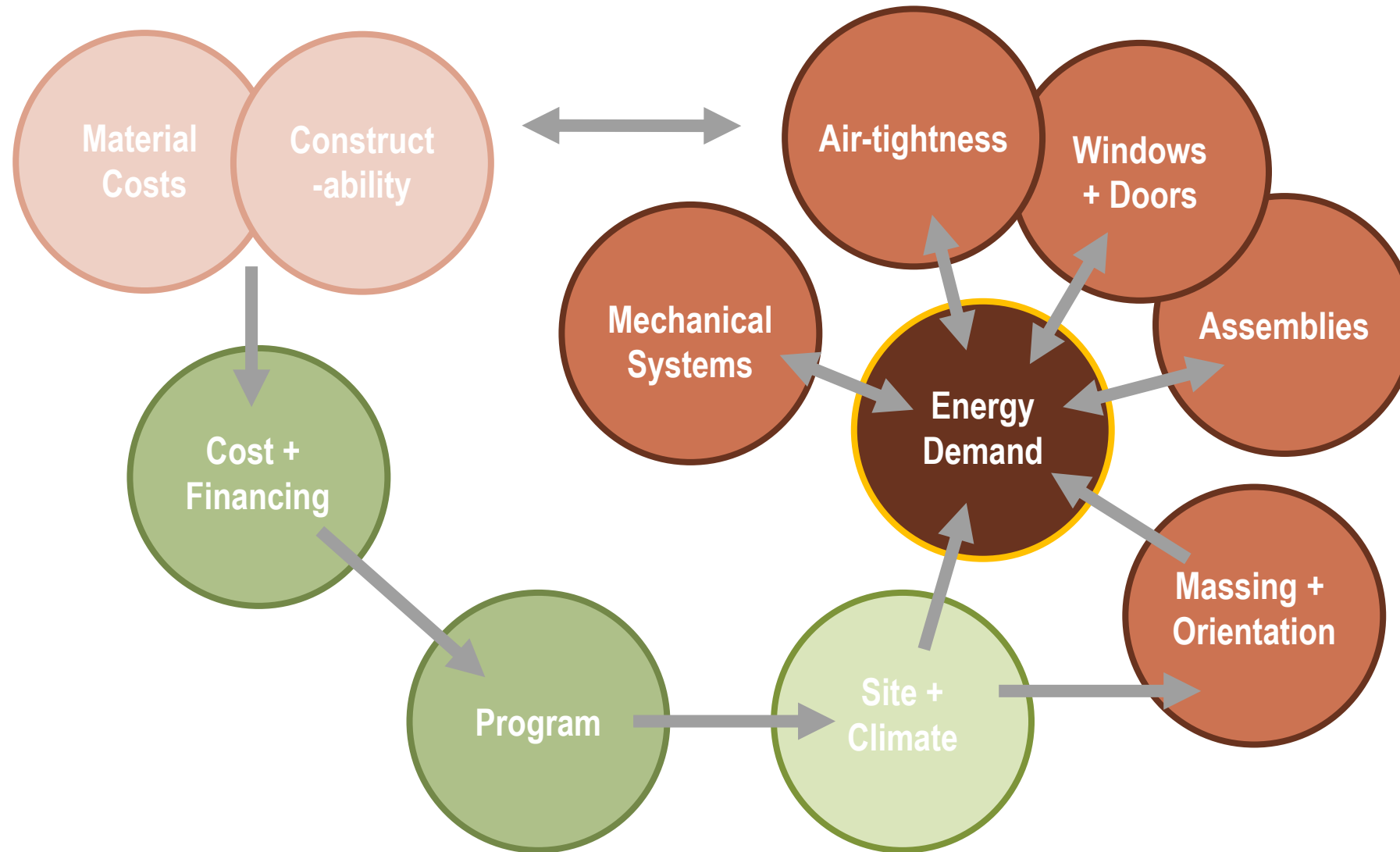
## COMMUNITY BENEFITS

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

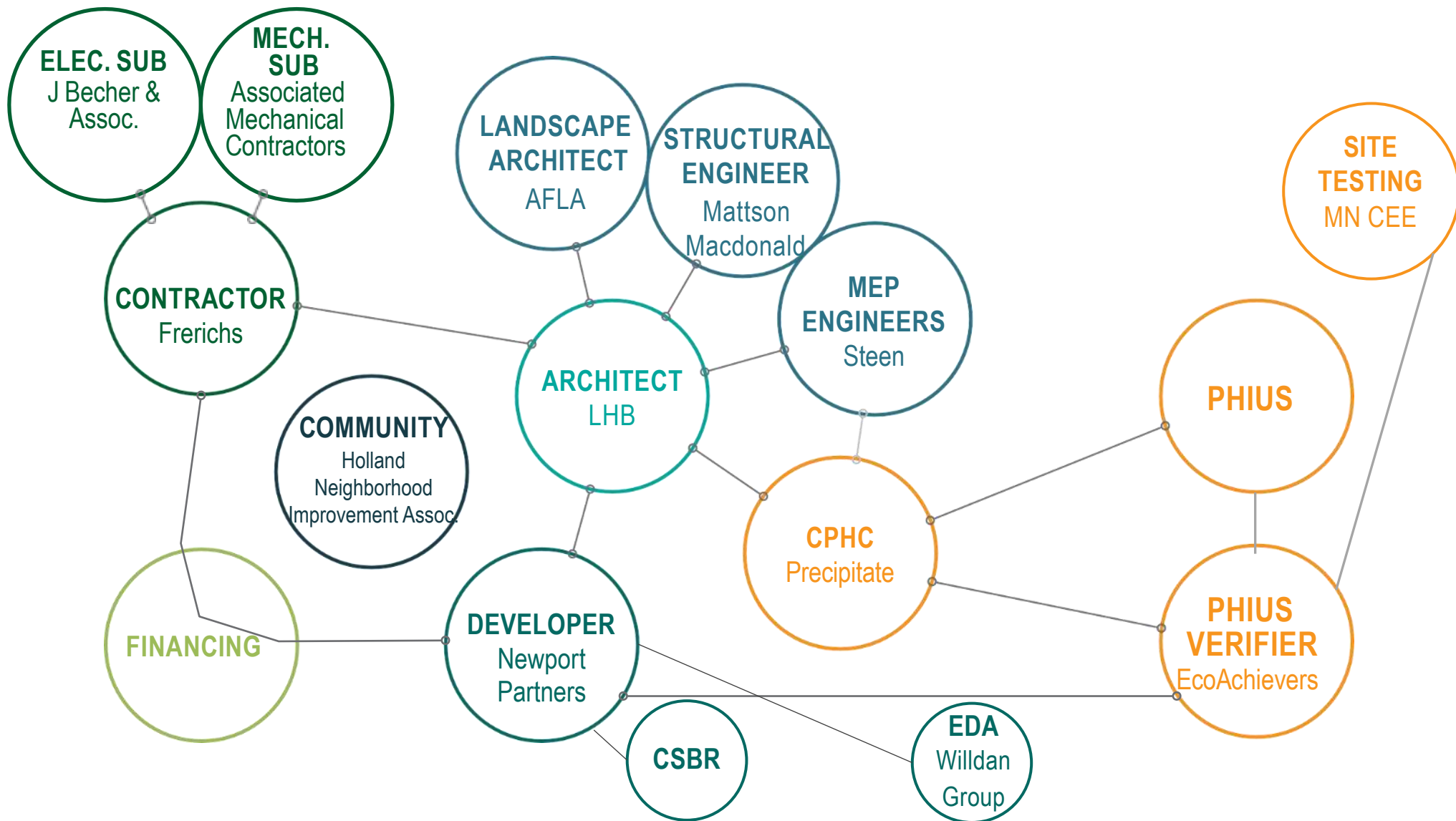


## OWNER BENEFITS

- Funding opportunities
- Reduced maintenance/operation costs
  - utilities
  - envelope durability (3rd party verified)
  - Reduced resident turnover



INTEGRATED DESIGN



## DEVELOPMENT TEAM RELATIONSHIPS

## **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

## **STRUCTURAL ENGINEERING: MATTSON MACDONALD YOUNG**

- Kirk Davis, Structural Engineer

## **MECHANICAL & ELECTRICAL ENGINEERING: STEEN ENGINEERING**

- John Hazucha, Mechanical Engineer
- Jake Melbostad, Electrical Engineer

## **CIVIL ENGINEERING : WENCK ASSOCIATES**

- Roshaan Grieme, Civil Engineer

## **LANDSCAPE ARCHITECTS: AUNE FERNANDEZ LANDSCAPE ARCHITECTURE**

- Jason Aune, Landscape Architect

## **GENERAL 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

PROJECT TEAM

## PASSIVE HOUSE PRINCIPLES

### Minimize Thermal Loss/Gain

- Continuous Insulation
- Minimize thermal bridging

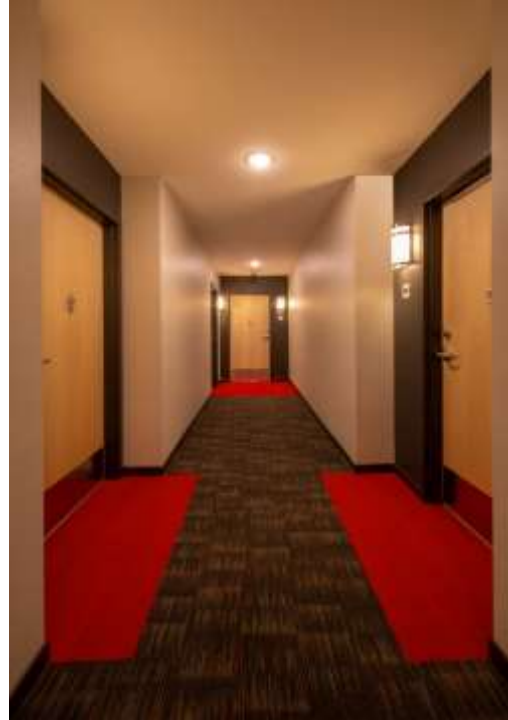
### Air-Tight Construction

- Proper location and durability of air barrier and vapor retarder

### High Performance Windows/Doors

### Balanced Ventilation (ERV)

### Minimized Space Conditioning



## PHIUS CERTIFICATION

Certified Passive House Consultant

WUFI Passive Energy + Hygrothermal Modeling

Pre-certification Design Review by PHIUS

Testing by PHIUS+ Rater (HERS rater allowed first time)

- Detailed on-site inspection
  - Slab + foundation insulation
  - Insulation
  - Air barrier details
- Blower door test
- HVAC + DHW commissioning





### Building 1: Standard Construction Type VB

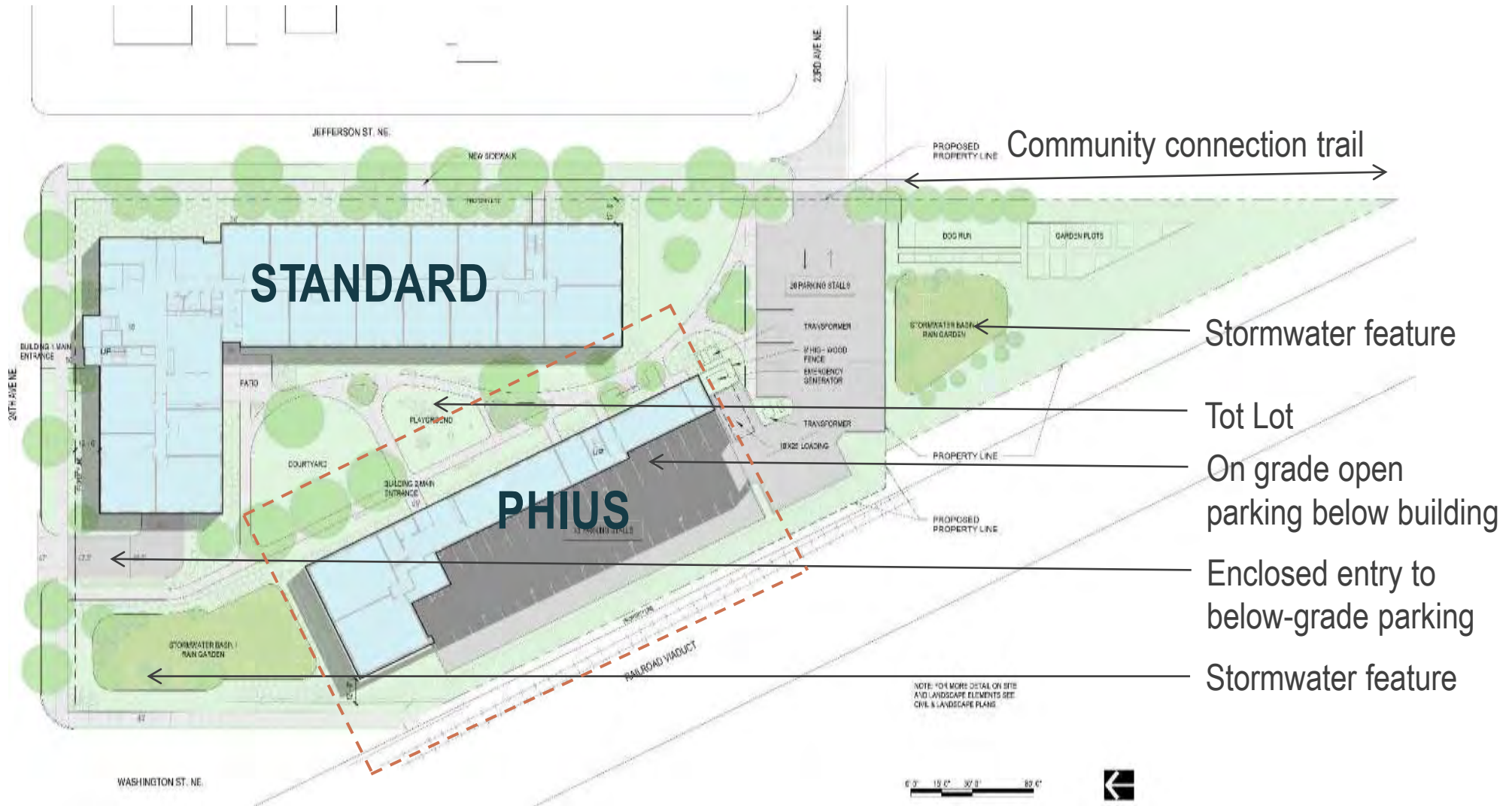
- 59 Units (32-1BR, 16-2BR, 11-3BR)
- 3-story wood frame over 1 level precast
- 46,595 net rentable SF
- 59,553 GSF finished
- 19,768 GSF enclosed parking below

### Building 2: Passive House Construction Type VA

- 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

# PROJECT STATISTICS



## STANDARD BUILDING

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

## PHIUS

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

PROJECT SITE







SECOND & THIRD FLOORS





## FOURTH & FIFTH FLOORS



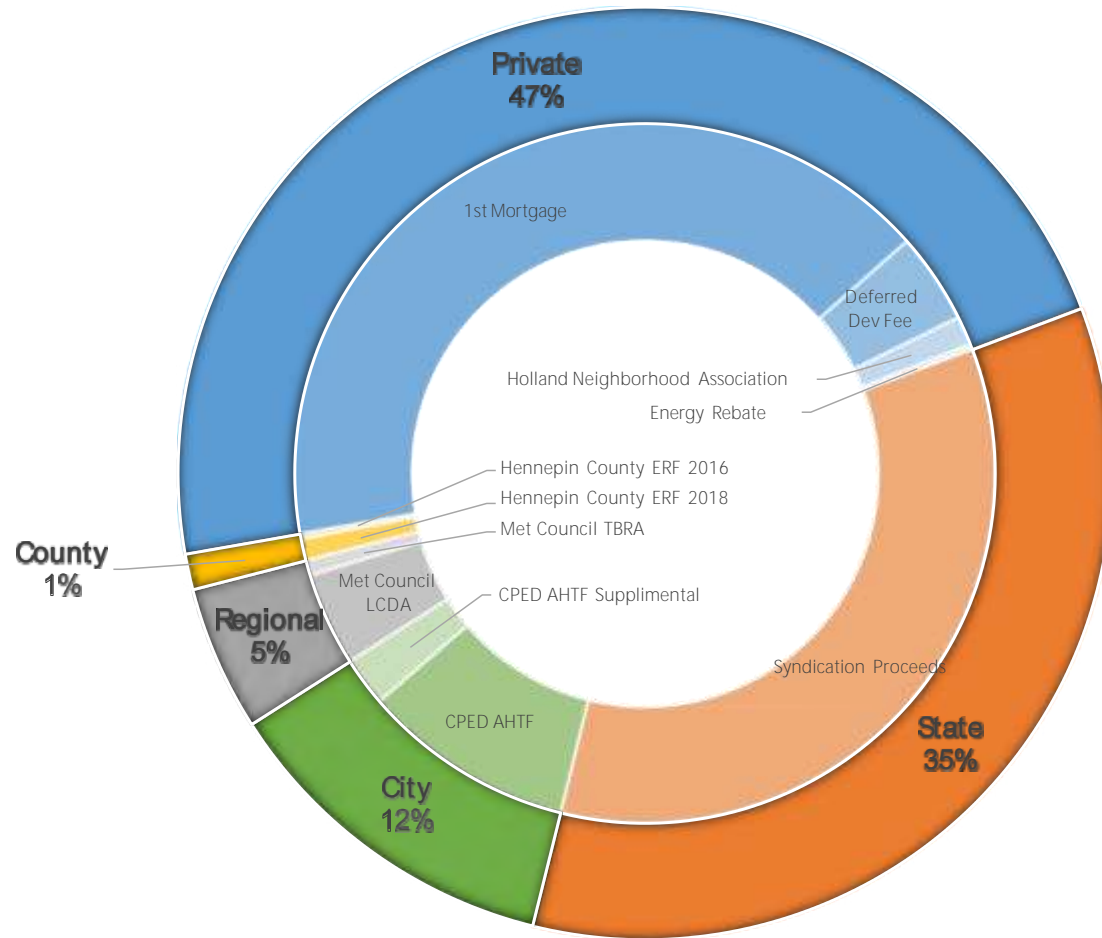


<i>ENERGY USE INTENSITY (EUI = kBtu/sf/yr)</i>		
	Standard Building (with enclosed parking)	Passive House Building (without enclosed parking)
EUI Baseline	75.4	66.7
EUI Goal	62.3	40
EUI Predicted	56.7	23.75

Standard Building HERS Rating: 61 Target, 51 Actual

AIR TIGHTNESS (Blower Door Air Leakage Tests) Code Maximum: 3 ACH <sub>50</sub>		
	Standard Building (with enclosed parking)	Passive House Building (without enclosed parking)
Design Standard Max	Energy Star Max = .3 cfm 50/ft	PHIUS = .05 cfm 50/ft
	.15 cfm 50/ft <sup>2</sup>	.038 cfm 50/ft <sup>2</sup>
	.95 ACH <sub>50</sub>	.3 ACH <sub>50</sub>

OUTCOME



## TOTAL COST (Excluding site)

### PHIUS BUILDING

\$10,020,951 = \$149.20/GSF w/ parking  
\$163.53 GSF w/o parking

### STANDARD BUILDING

\$9,547,675 = \$120.37/GSF w/ parking  
\$140.41/GSF w/o parking

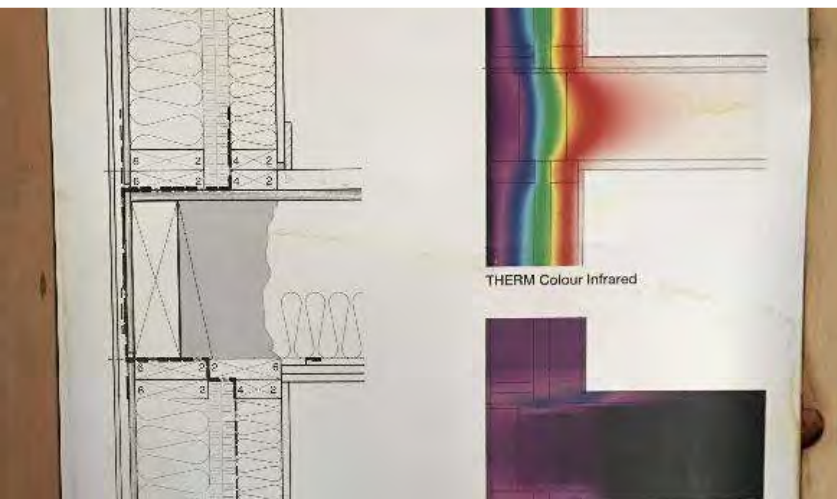


	Building: 1 Standard	Building: 2 PHIUS
<b>Standard</b>	Energy Star Certified Homes, Version 3.1 rev.08 Maximum Assembly U value per ASHRAE 90.1-2010, appendix A per MN Residential Energy Code C401.2.	PHIUS Energy Star Multifamily High Rise. Version 1.7 MN Commercial Energy Code
<b>Insulation level modeling</b>	2012 IECC levels (table 402.1.3/1) and grade 1 installation per RESNET standards	Meet or exceed 2012 IECC insulation levels (ASHRAE 90.1-2010)
<b>Slabs on grade</b>	Slab edge R5 + per 2009 IECC	below slab insulation: whole slab R20-28
<b>Wood Framed walls min.</b>	(U-.051)	continuous exterior insulation +R5 (Walls: 39-51)
<b>Roof minimum:</b>	1) Above deck: R30 (u-.032)/.048	(Roof/Ceilings: 70-90)
<b>Floors over unconditioned space (minimum)</b>	U=.033 (per energy star 3.1)	U=.026 blown insulation in framing plank

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

Thermal and Moisture Protection / Window Openings

DESIGN PERFORMANCE STANDARDS



PRECEDENT : VANCOUVER – ENVELOPE & CONSTRUCTABILITY



- 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



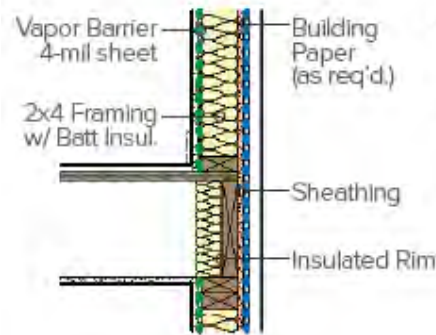
TAKEAWAYS FOR COST CONTAINMENT AND QUALITY CONTROL

### TRADITIONAL WALL / RIM

Pre-1980

Platform Framed

Building EUI:  
60+ kBtu/sf

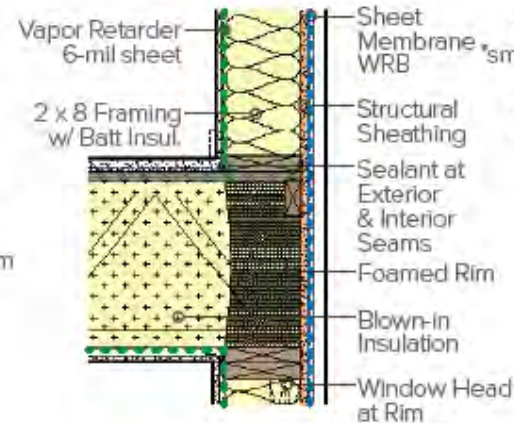


### TYPICAL WALL / RIM

Current

Platform Framed

Targeted Building EUI: 40  
kBtu/sf outcome

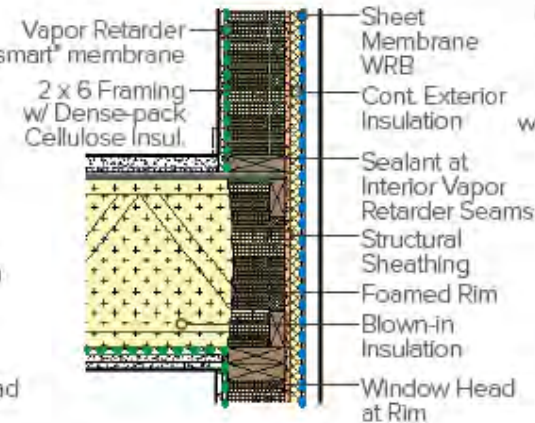


### ENHANCED WALL / RIM

Current

Platform Framed

Targeted Building EUI: 30  
kBtu/sf outcome

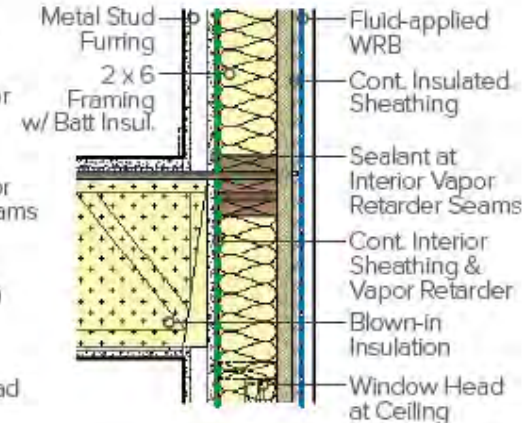


### INNOVATIVE WALL / RIM

'Next-Gen'

Balloon Framed

Targeted Building EUI: 20  
kBtu/sf outcome



## GOALS

- Minimalized thermal bridging
- Increased air tightness
- Managed vapor plane
- Managed drainage plane

INTEGRATION OF  
BUILDING COMPONENTS

ROLE OF WALL / ENVELOPE

CONTINUITY & INTEGRITY  
OF MOISTURE PLANES

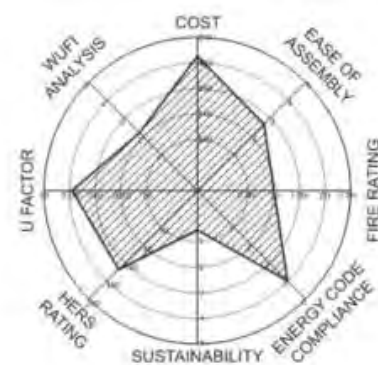
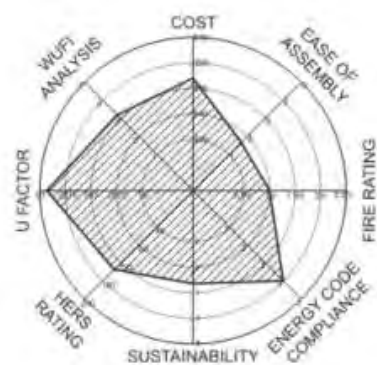
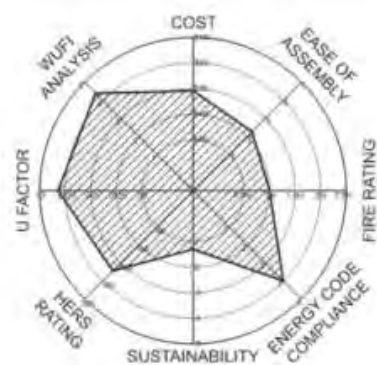
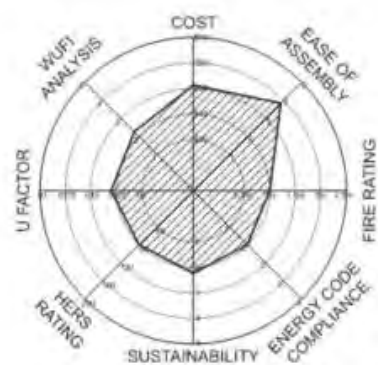
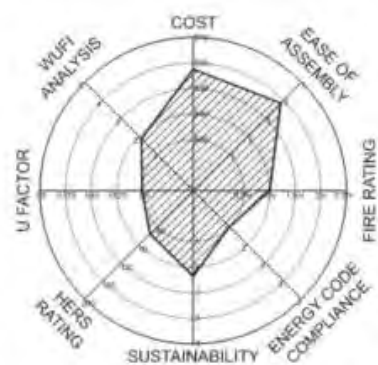
ENERGY CODE  
COMPLIANCE

EVALUATION OF PERFORMANCE

WHOLE-BUILDING &  
COMPONENT MODELING

# ASSEMBLY COMPARISON : CLIMATE ZONE 6 & 7





### STANDARD 2X6 WALL

5/8" Type X Gyp. Board  
 6 mil. polyethylene Sheet  
 -Smart MemBrain Vapor Retarder  
 2x6 Stud Layer  
 R-21 Batt Insulation  
 -Blown in cellulose  
 -Blown in blanket  
 -3" close cell foam  
 5/8" Plywood Sheathing  
 OSB  
 -Gypsum Board  
 Tyvek drain wrap (WRB)  
 Exterior Cladding (varies)

Vapor Retarder

### STANDARD 2X8 WALL

5/8" Type X Gyp. Board  
 6 mil. polyethylene Sheet  
 -Smart MemBrain Vapor Retarder  
 2x8 Stud Layer  
 R-25 Batt Insulation  
 -Blown in cellulose  
 -Blown in blanket  
 -3" close cell foam  
 5/8" Plywood Sheathing  
 OSB  
 -Gypsum Board  
 Tyvek drain wrap (WRB)  
 Exterior Cladding (varies)

Vapor Retarder

### PASSIVE HOUSE WALL

5/8" Type X Gyp. Board  
 Metal Framing Layer  
 OSB Vapor Retarder  
 2x6 Stud Layer  
 R-21 Batt Insulation  
 -Blown in cellulose  
 -Blown in blanket  
 -3" close cell foam  
 Hunter Panel Xci NB  
 (R-9.8)  
 Liquid Applied WRB  
 -3M Sheet WRB  
 -Tyvek drain wrap  
 Exterior Cladding (varies)

Vapor Retarder

### THE PERFECT WALL

5/8" Type X Gyp. Board  
 2x Stud Layer  
 5/8" OSB Sheathing and Vapor Retarder  
 Tyvek drain wrap (WRB)  
 4" Rigid Insulation  
 -Polysio  
 -Mineral wool  
 -XPS  
 Exterior Cladding (varies)

Vapor Retarder

### AWESOME WALL

5/8" Type X Gyp. Board  
 2x6 Stud Layer  
 2" Close Cell Spray Foam  
 Hunter Panel Xci NB  
 (R-12.9)  
 Tyvek drain wrap (WRB)  
 Exterior Cladding (varies)

Vapor Retarder

Base Cost: \$/SF

Base Cost: \$/SF

Base Cost: \$/SF

Base Cost: \$/SF

Base Cost: \$/SF

Carbon Footprint:

Carbon Footprint:

Carbon Footprint:

Carbon Footprint:

Carbon Footprint:

.060 U Factor

.051 U Factor

.035 U Factor

.033 U Factor

.038 U Factor

HERS Rating:

HERS Rating:

HERS Rating:

HERS Rating:

HERS Rating:

WUFI Analysis:

WUFI Analysis:

WUFI Analysis:

WUFI Analysis:

WUFI Analysis:

Fire Rating:

Fire Rating:

Fire Rating:

Fire Rating:

Fire Rating:

Energy Code:

Energy Code:

Energy Code:

Energy Code:

Energy Code:

**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 w/ standard
- DHW - Gas with VRF Preheat
- Solar - 40 kW system on rooftop  
(located on Standard Building due to orientation)

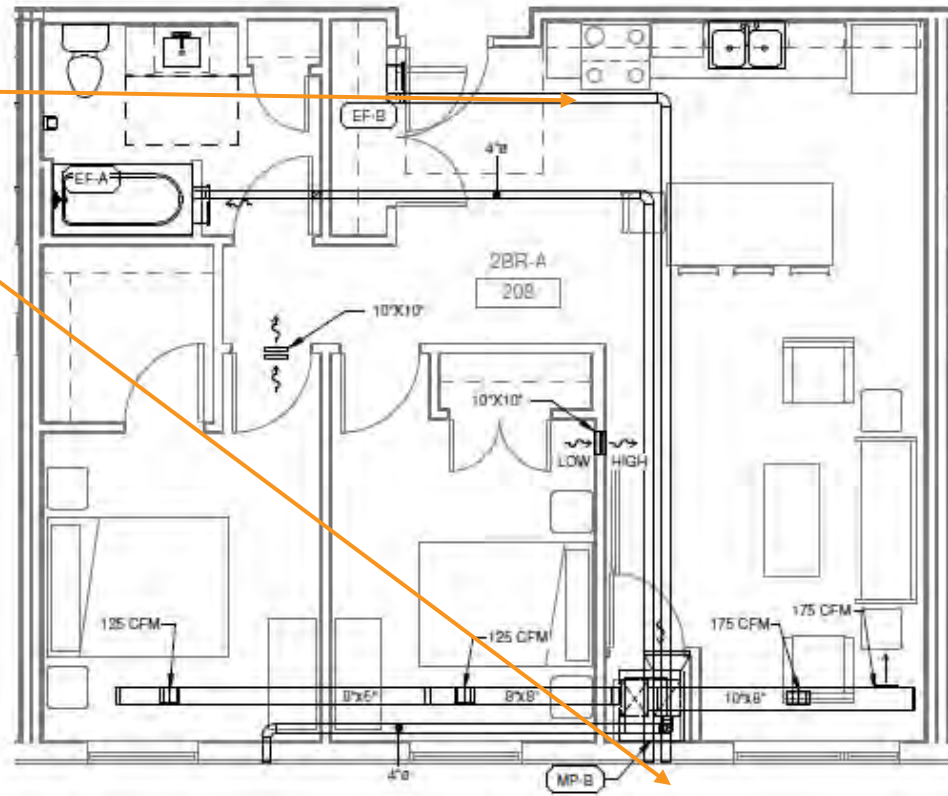
**ENVELOPE**

- 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

## Standard

Direct  
Exhaust

Magic Pak

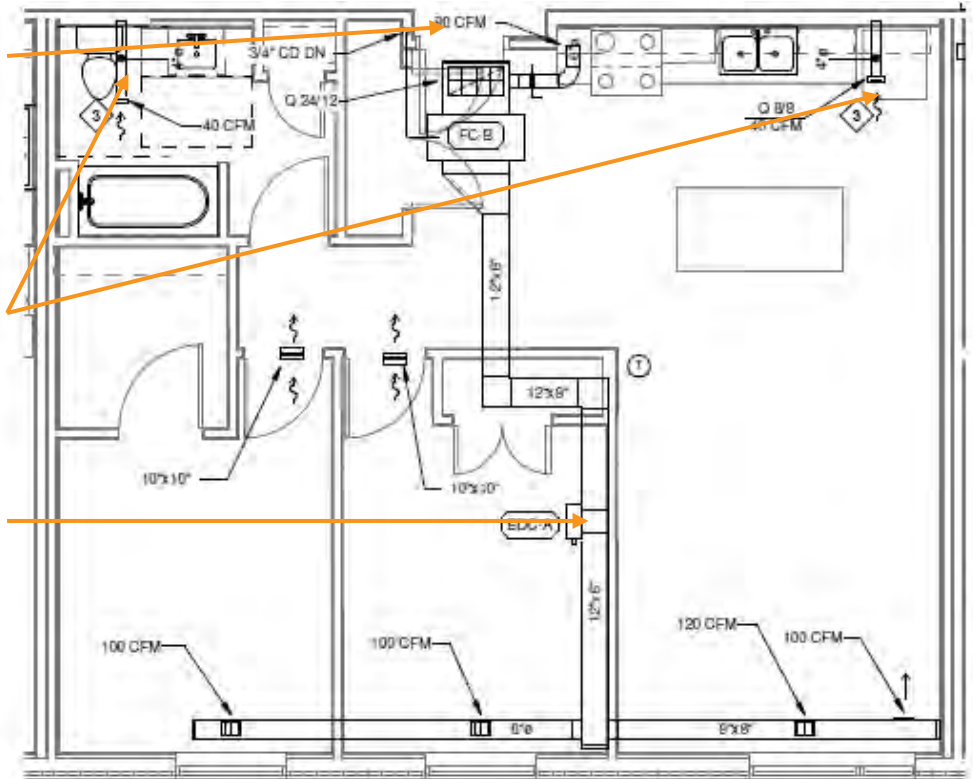


## Passive House

Fan Coil

DOAS  
System

Electric Duct  
(Backup  
heaters)



CONTINUOUS FRESH AIR SUPPLY : DIRECT TO BEDROOMS



Standard



Common Area Furnace



Typical Apartment Magic Pak

Passive House



Ventilation Ducts appear to be well sealed with mastic.



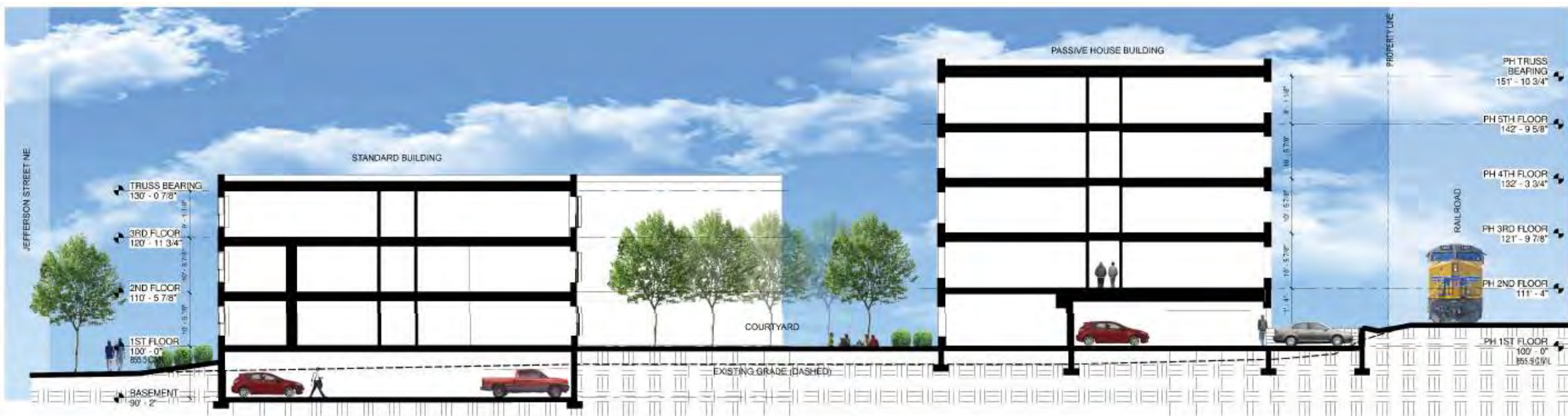
VRF Unit



DOAS Unit with Heat Recovery

CONTINUOUS FRESH AIR SUPPLY





### Standard Building

Roof R-Value = 49

Wall R-Value = 22

Window U-factor = .29

SHGC = .40

### Passive House

Roof R-Value = 62.3

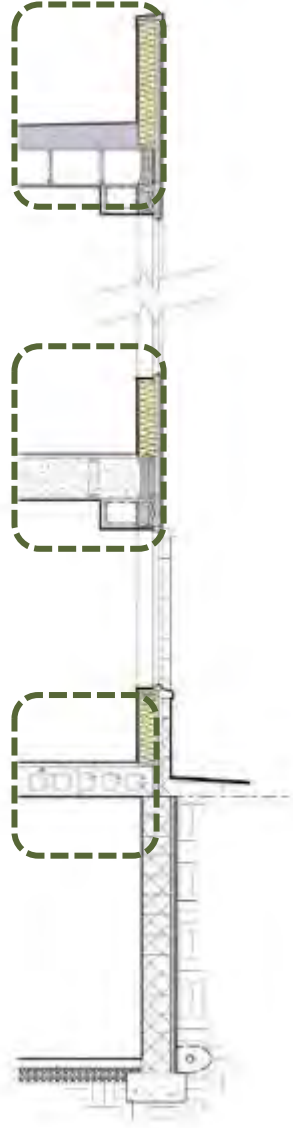
Wall R-Value = 29.7

Window U-factor = .15

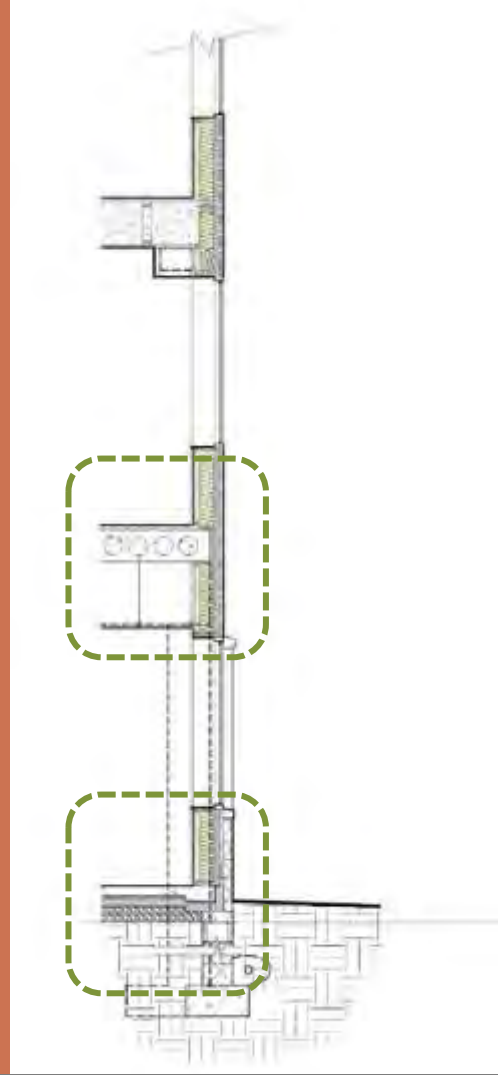
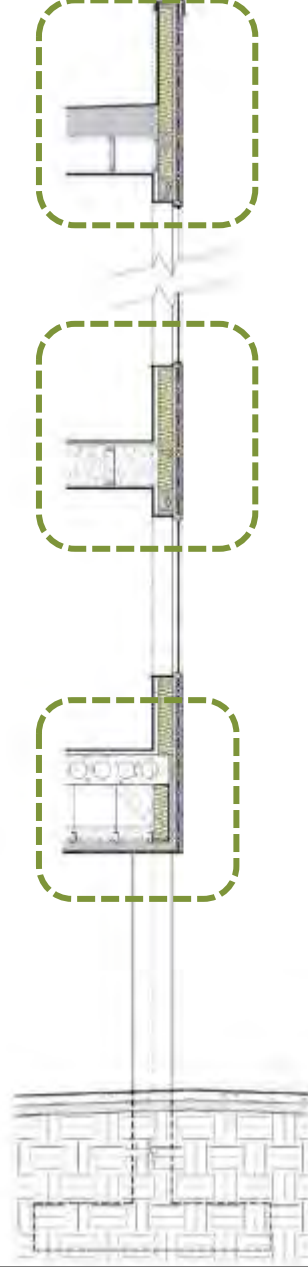
SHGC = .27

# BUILDING ASSEMBLIES

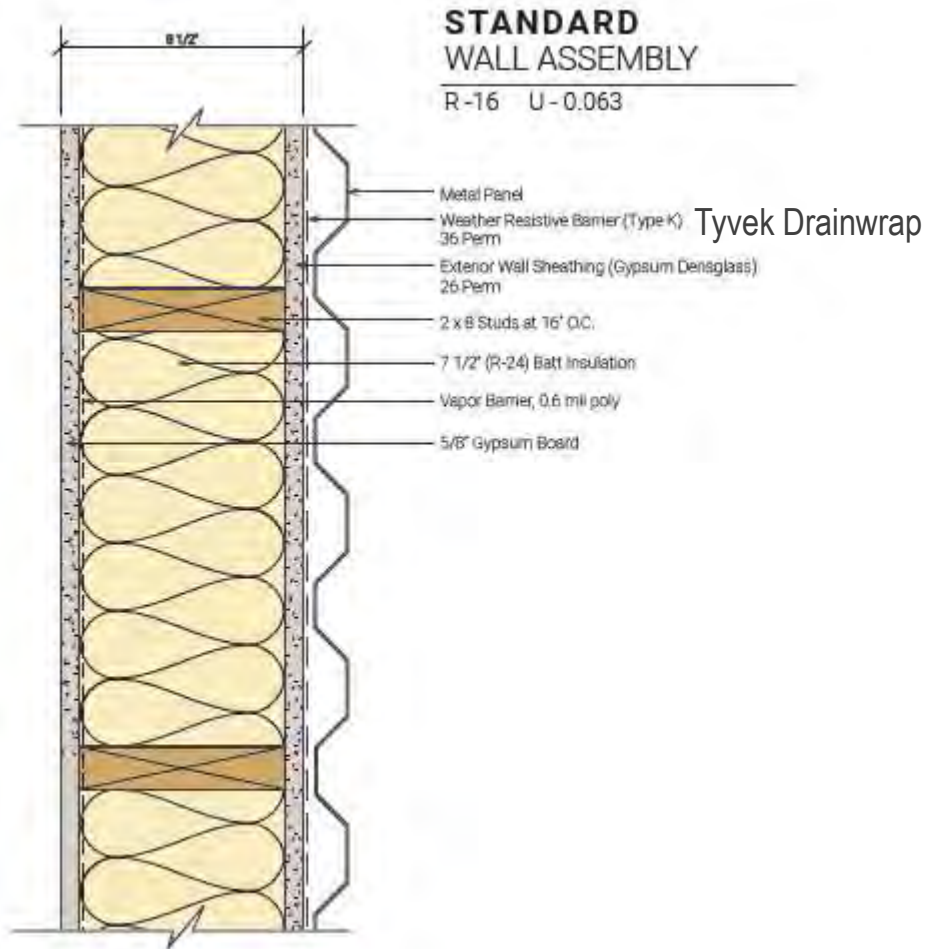
Standard



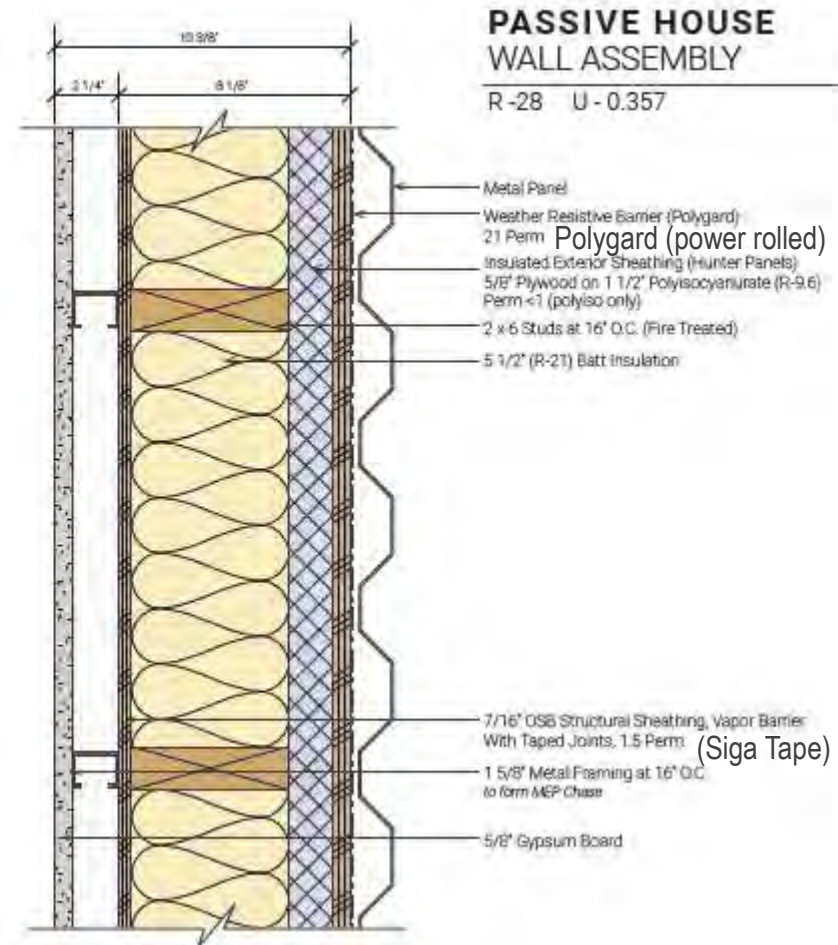
Passive House



## WALL SECTIONS



Standard

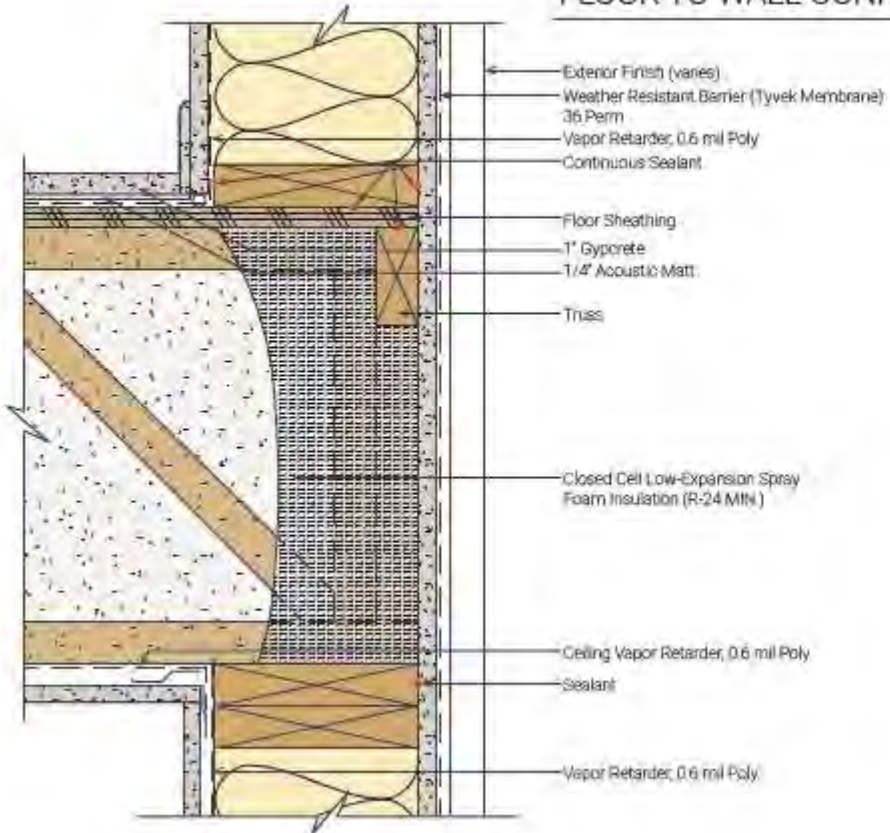


Passive House

## WALL ASSEMBLIES

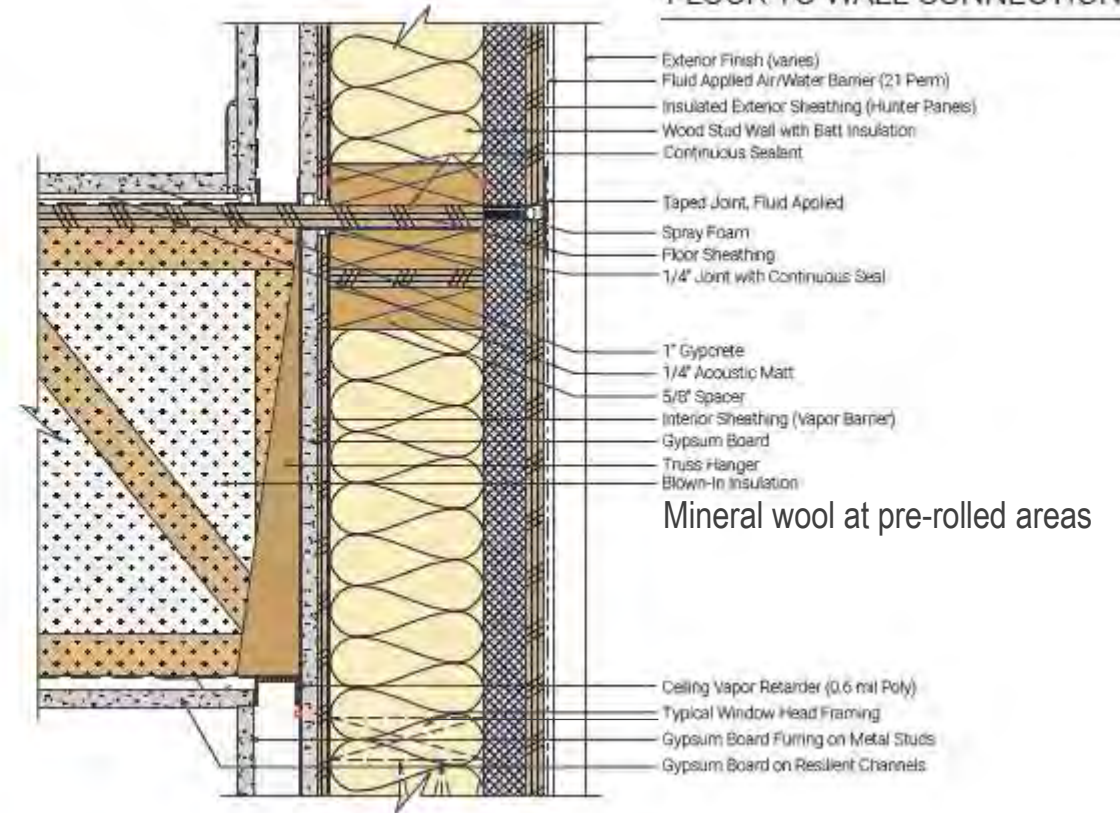


## STANDARD FLOOR TO WALL CONNECTION



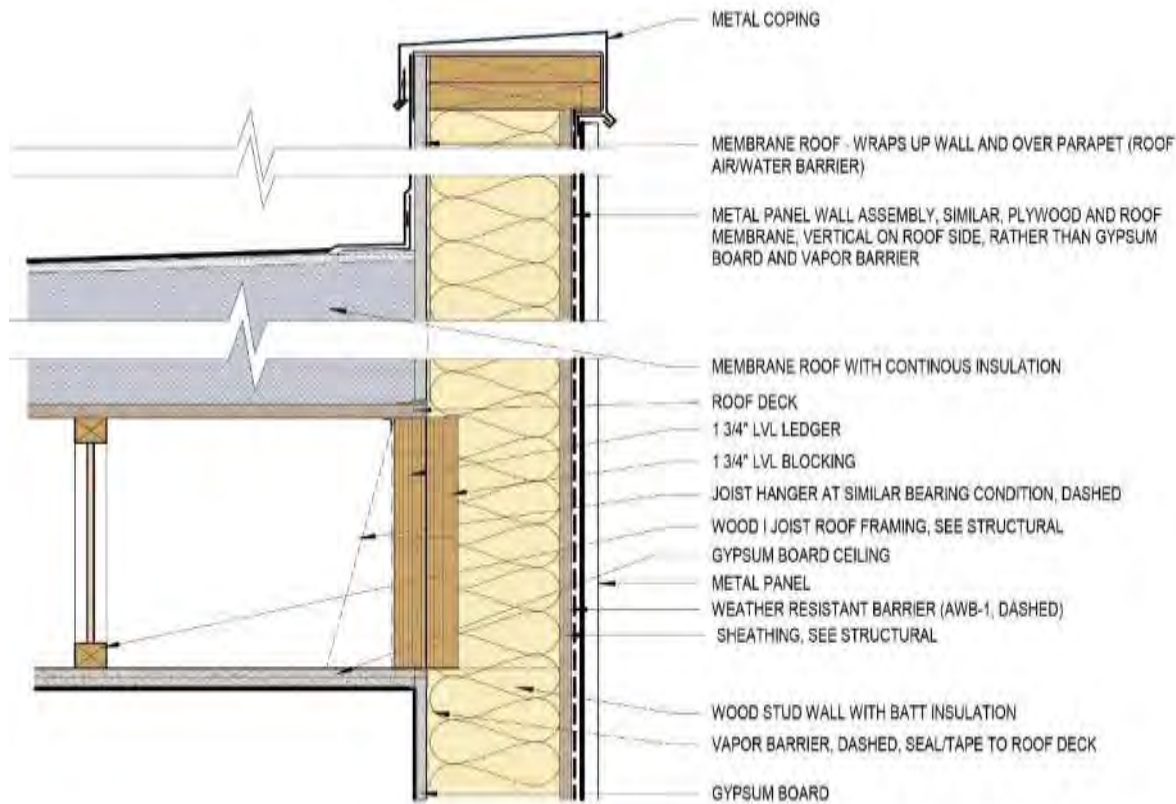
Standard

## PASSIVE HOUSE FLOOR TO WALL CONNECTION

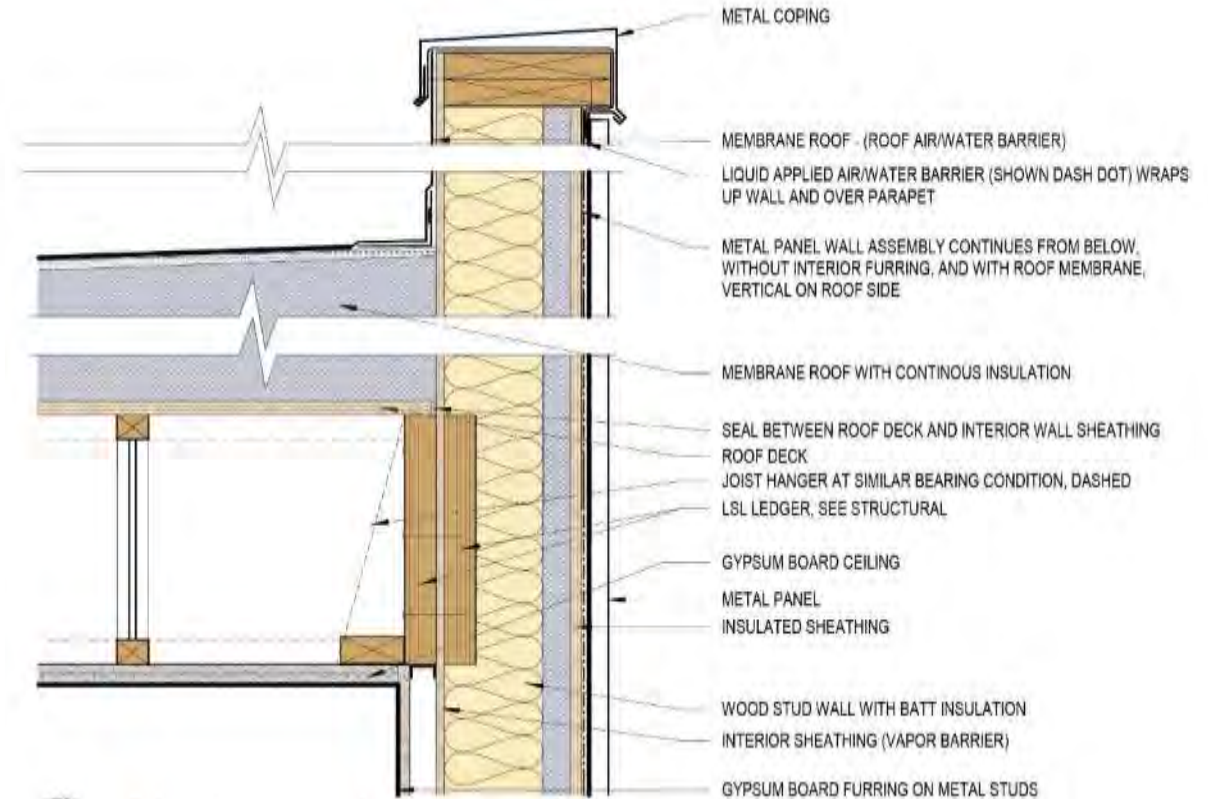


Passive House

# FLOOR TO WALL CONNECTION



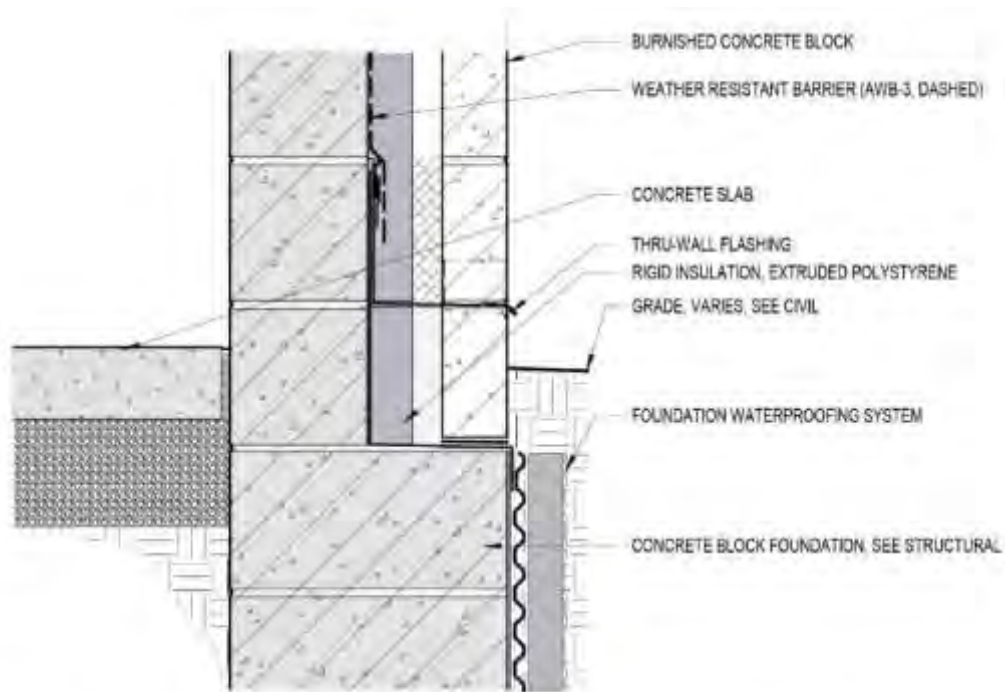
Standard



Passive House

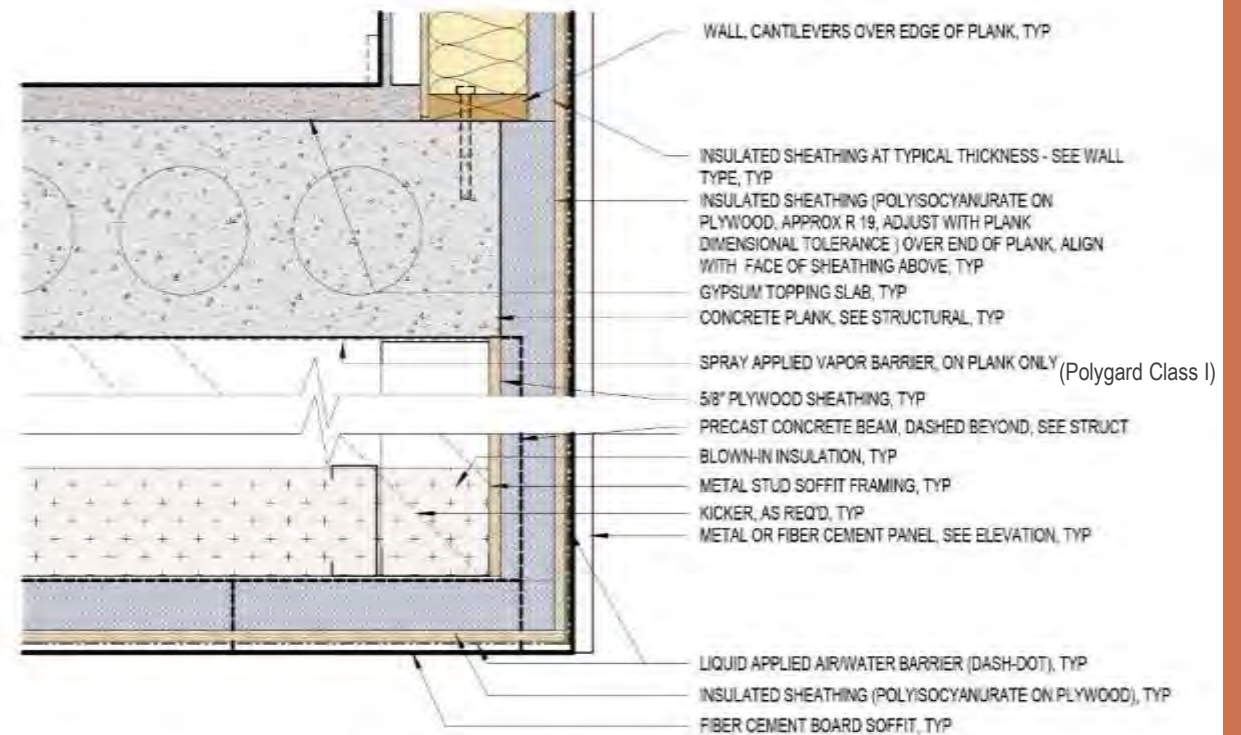
## WALL DETAILS : ROOF AT EXTERIOR WALL – NON BEARING





**10 STANDARD - BASE OF WALL @ GARAGE SLAB**  
 1 1/2" = 1'-0"

Standard

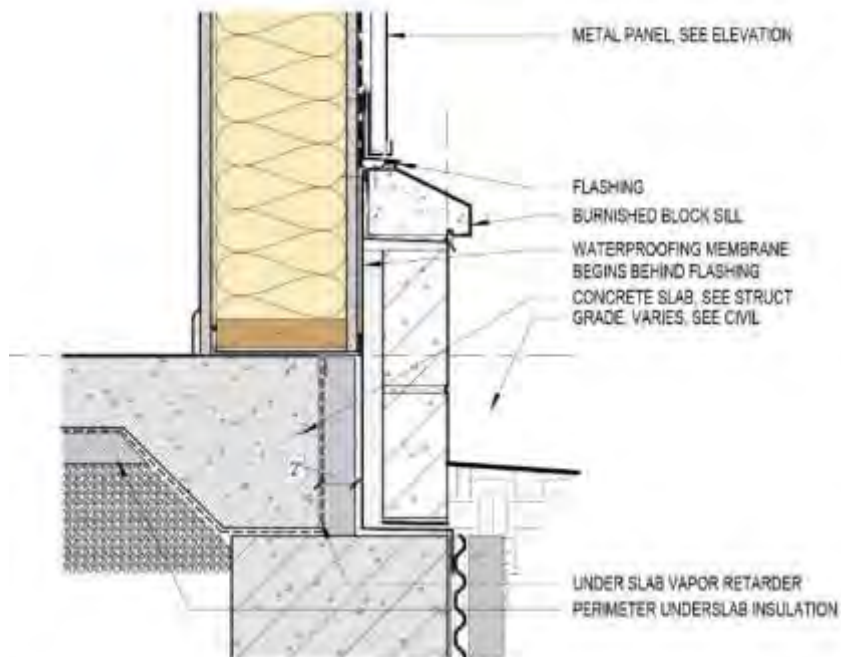


**9 SECOND FLOOR ABOVE OPEN GARAGE- NON-BEARING**  
 1 1/2" = 1'-0"

Passive House

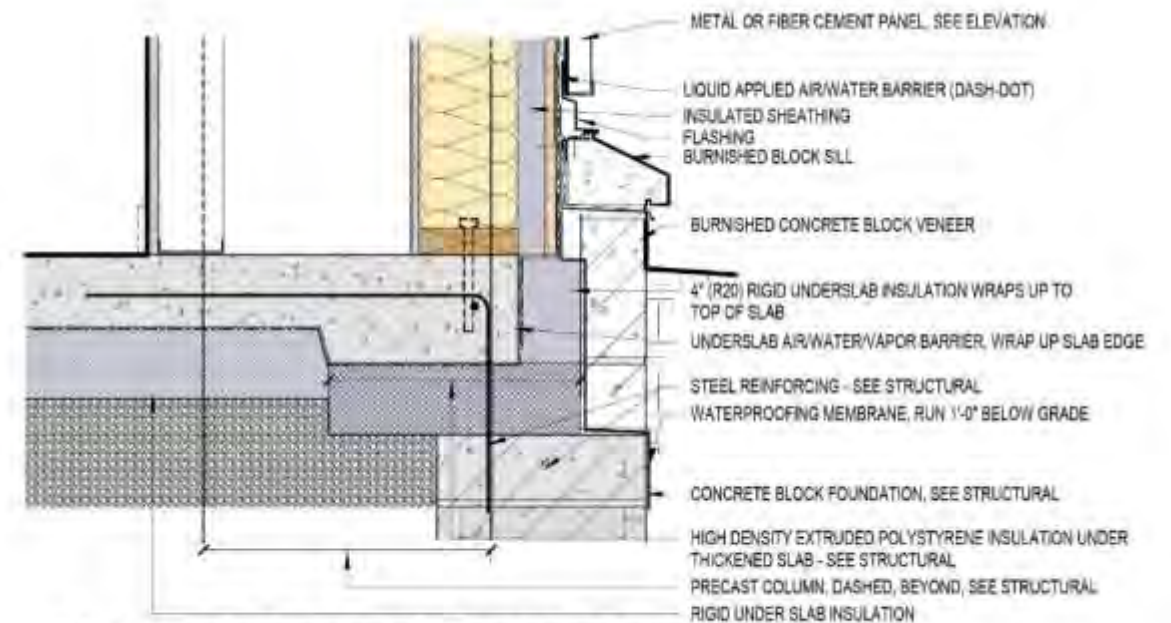
WALL DETAILS AT GARAGE





**11 STANDARD - BASE OF WALL @ VESTIBULE**  
1 1/2" = 1'-0"

Standard



**8 BASE OF WALL UNDER ENTRY CANOPY**  
1 1/2" = 1'-0"

Passive House

WALL DETAILS : BASE OF WALL



Standard: Platform Framing



Passive House – Balloon Framing

FRAMING





PASSIVE HOUSE BALLOON FRAMING





Standard



Passive House

## WINDOW OPENINGS



Standard - openings



Passive House – no openings

INSULATION CAVITY





Standard



Passive House

## WINDOW OPENINGS





Standard



Passive House

GYPSUM BOARD



Standard – Platform



Passive - Balloon

FRAMING





WEATHER BARRIER





Standard – Sheet



Passive House – Fluid Applied

WEATHER BARRIER



PASSIVE HOUSE FLUID APPLIED VAPOR BARRIER





Standard – Rain Screen



Passive House – Rain Screen

CLADDING





Standard Building



Passive House

EXTERIOR WALL PENETRATIONS



PASSIVE HOUSE PARKING GARAGE CEILING



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



Source: Final Blower Door Test Results prepared by  
Eco Achievers

**BLOWER DOOR TEST RESULTS : PASSIVE HOUSE**



	Building 1: Standard	Building 2: PHIUS
Percent Energy Cost Savings	30%	40%
Percent Electric Demand Savings	25%	19%
Percent Electric Consumption Savings	28%	41%
Percent Gas Consumption Savings	40%	40%
Total Incremental First Cost	\$150,315	\$495,724
Total Incentive	\$31,806	\$30,319
Simple Payback with Incentive	3.1	8.6
Energy Use Intensity (EUI) (modeled)	Baseline: 79.6 KBtu/ft²/yr As Built: 51.6 KBtu/ft²/yr	Baseline: 62.8 KBtu/ft²/yr As Built: 37.7 KBtu/ft²/yr
% Savings	35%	40%

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

Source: Verification Reports prepared by Willdan

EDA: MODELING & REBATE INCENTIVES

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

EDA STRATEGY RESULTS : STANDARD BUILDING

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

EDA STRATEGY RESULTS : PASSIVE HOUSE









18















# > QUESTIONS?

---

**Kim Bretheim, FAIA, LEED AP BD+C**  
**Housing Studio Leader, LHB, Inc.**

[Kim.Bretheim@LHBcorp.com](mailto:Kim.Bretheim@LHBcorp.com)