

# **BUILDINGENERGY BOSTON**

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## **Modular Multifamily Passive House: Design, Build, and Verify**

**Stuart Lachs, Perkins Eastman**

**Tony Lisanti, Integral Building and Design**

**John Loercher, Northeast Projects / Pnius**

*Curated by Kurt Carlson and Ilka Cassidy*

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**Northeast Sustainable Energy Association (NESEA) | March 20, 2025**

**NORTHEAST SUSTAINABLE ENERGY ASSOCIATION (NESEA)**

**BUILDINGENERGY BOSTON**

**PERKINS —  
EASTMAN**

*Human by Design*

# **MODULAR MULTIFAMILY PASSIVE HOUSE: DESIGN, BUILD, AND VERIFY**



Photograph by Andrew Ruggie. Copyright Perkins Eastman

# DESIGN CONSIDERATIONS



# ORIGINAL SITE CONDITIONS



# FORMER LONGFELLOW SCHOOL – DEMOLISHED CIRCA 2007



# FORMER LONGFELLOW SCHOOL – DEMOLISHED CIRCA 2007



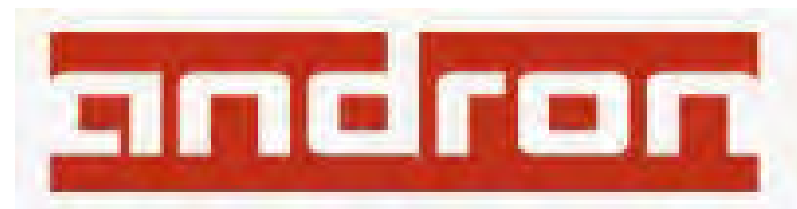
# SITE AS DELIVERED 2019



# THE PLAYERS



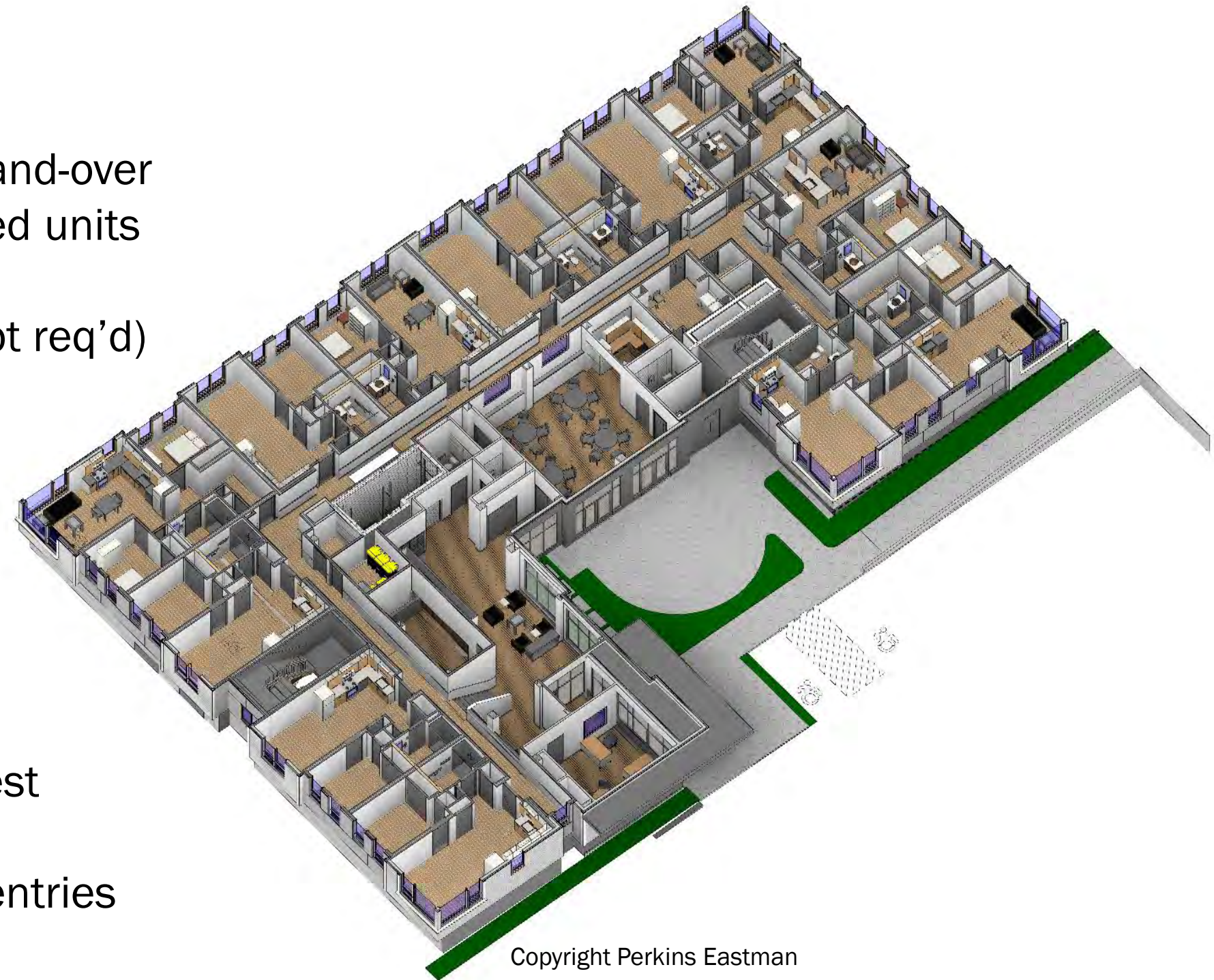
**PERKINS —  
EASTMAN**





# PROGRAM

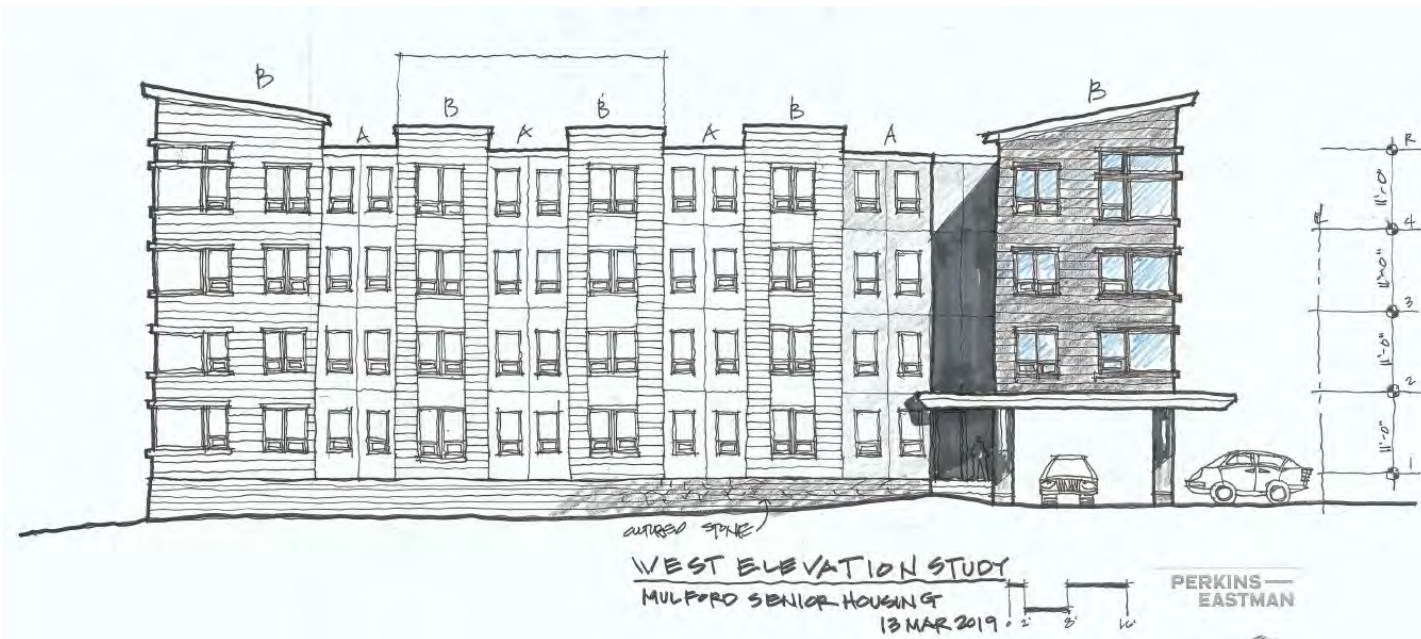
- 34,848 sf site (.8 acres)
- Sixty affordable rental apartments for 55-and-over
- Fully-adapted (Type B) and hearing-impaired units
- 60,000 Gross SF building area
- On-site resident parking (1/2 space per apt req'd)
- Community Room with Kitchen
- Two Business Rooms
- Fitness Room
- Landscaped Courtyard
- Landscaped Roof Deck
- Furnished Lobbies on Two Levels
- Central Laundry facilities
- In-unit stacking laundry available on request
- Building-wide WIFI
- Smart locks at entrances and apartment entries
- Resident storage
- Bicycle Storage
- Management Office



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# DESIGN STRATEGY

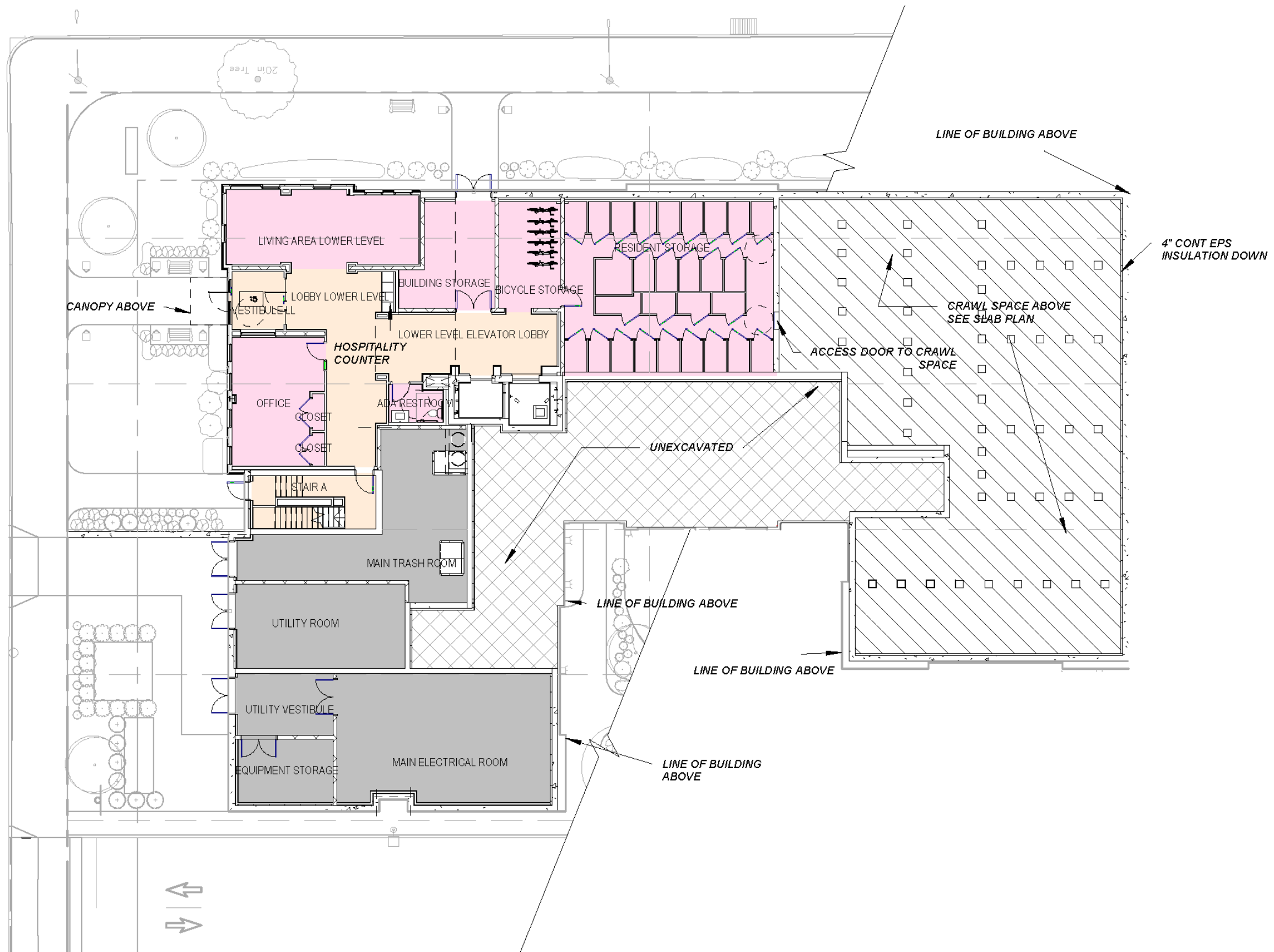
- Speaks to local vernacular of row-houses and two-family dwellings.
- Parapets create undulating roof line.
- Wall surface undulates to create a sense of depth.
- Provide spaces for gathering to create community.



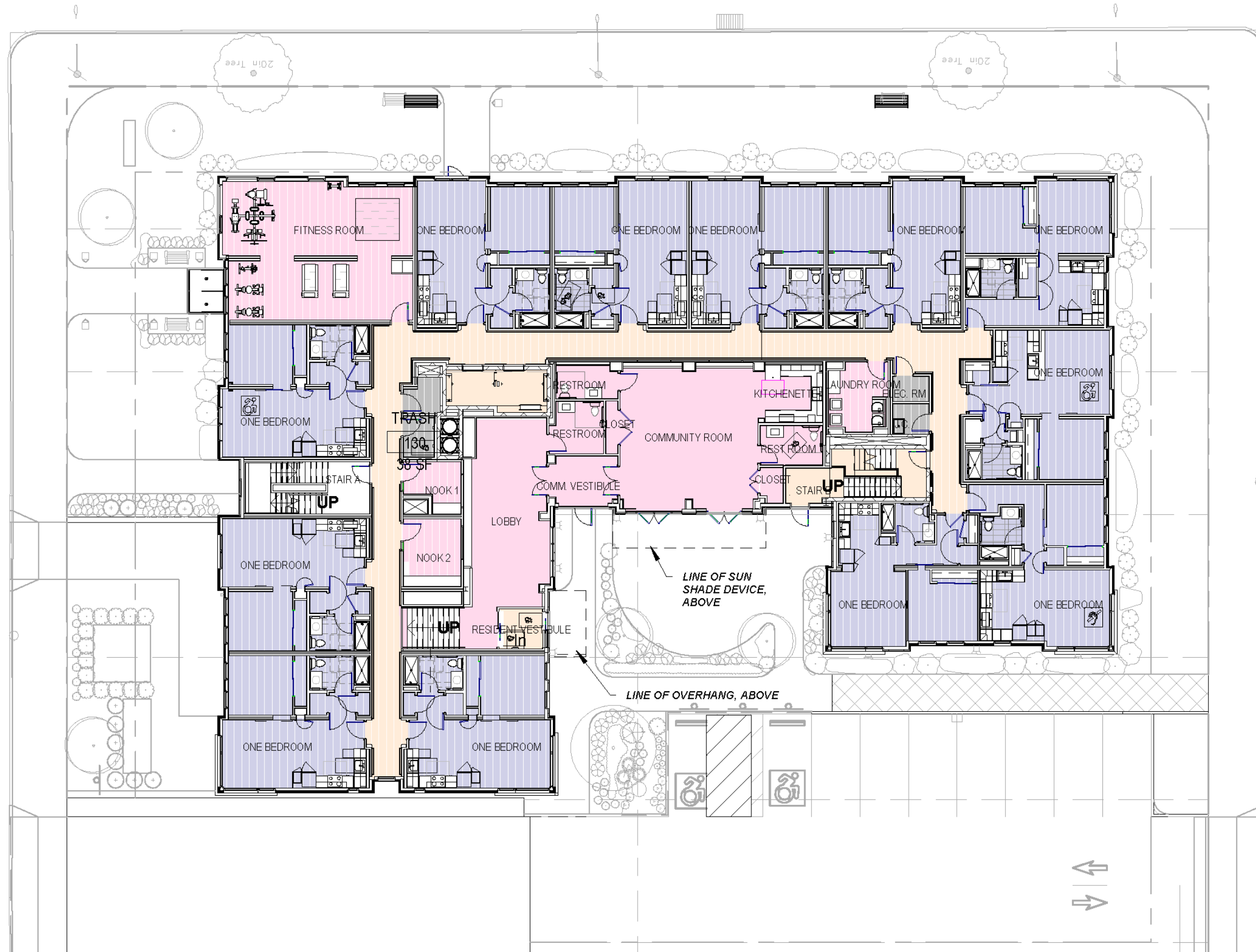
# SITE PLAN



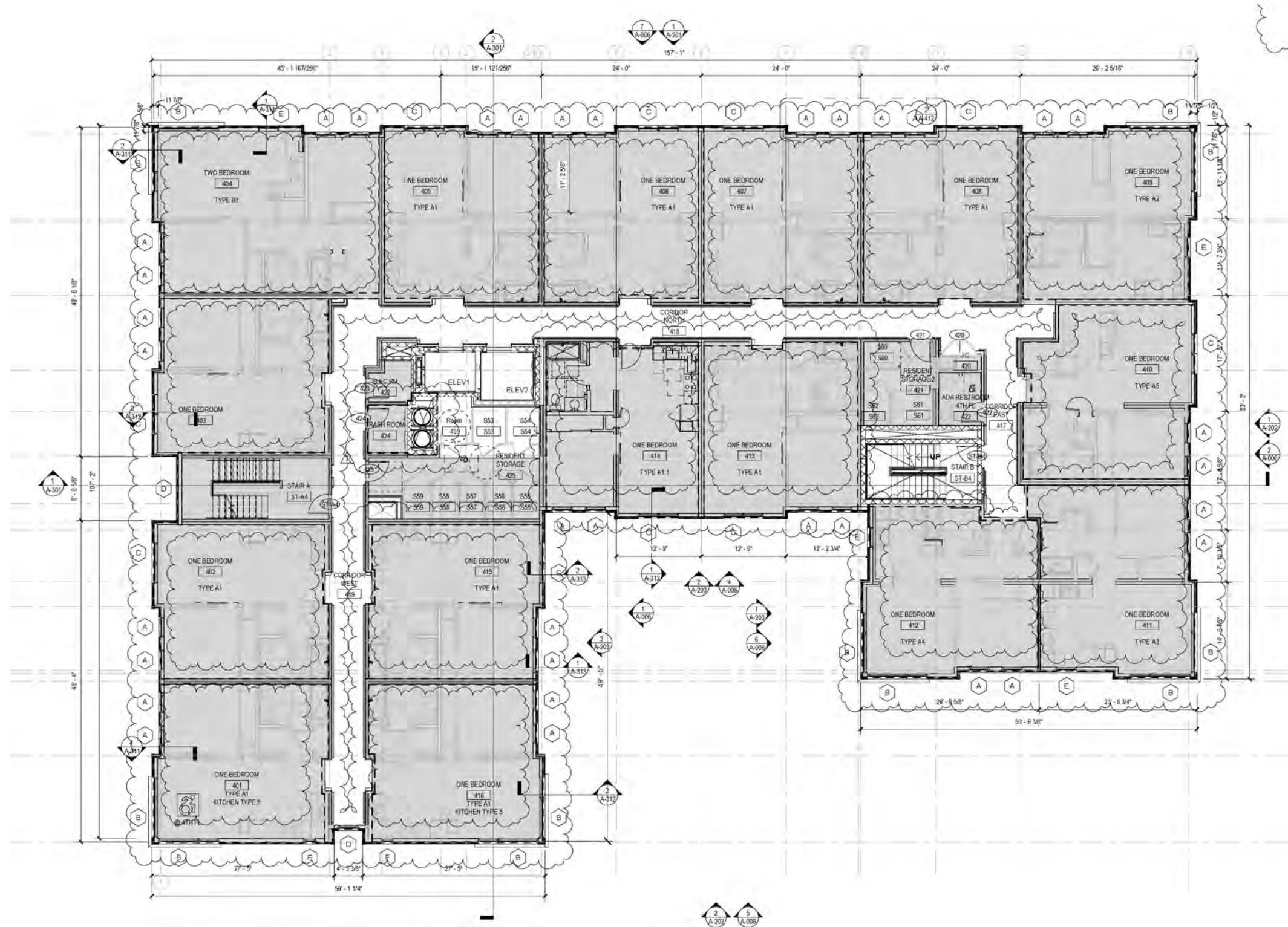
# BASEMENT



# FIRST FLOOR



# TYPICAL FLOOR



# PASSIVE HOUSE

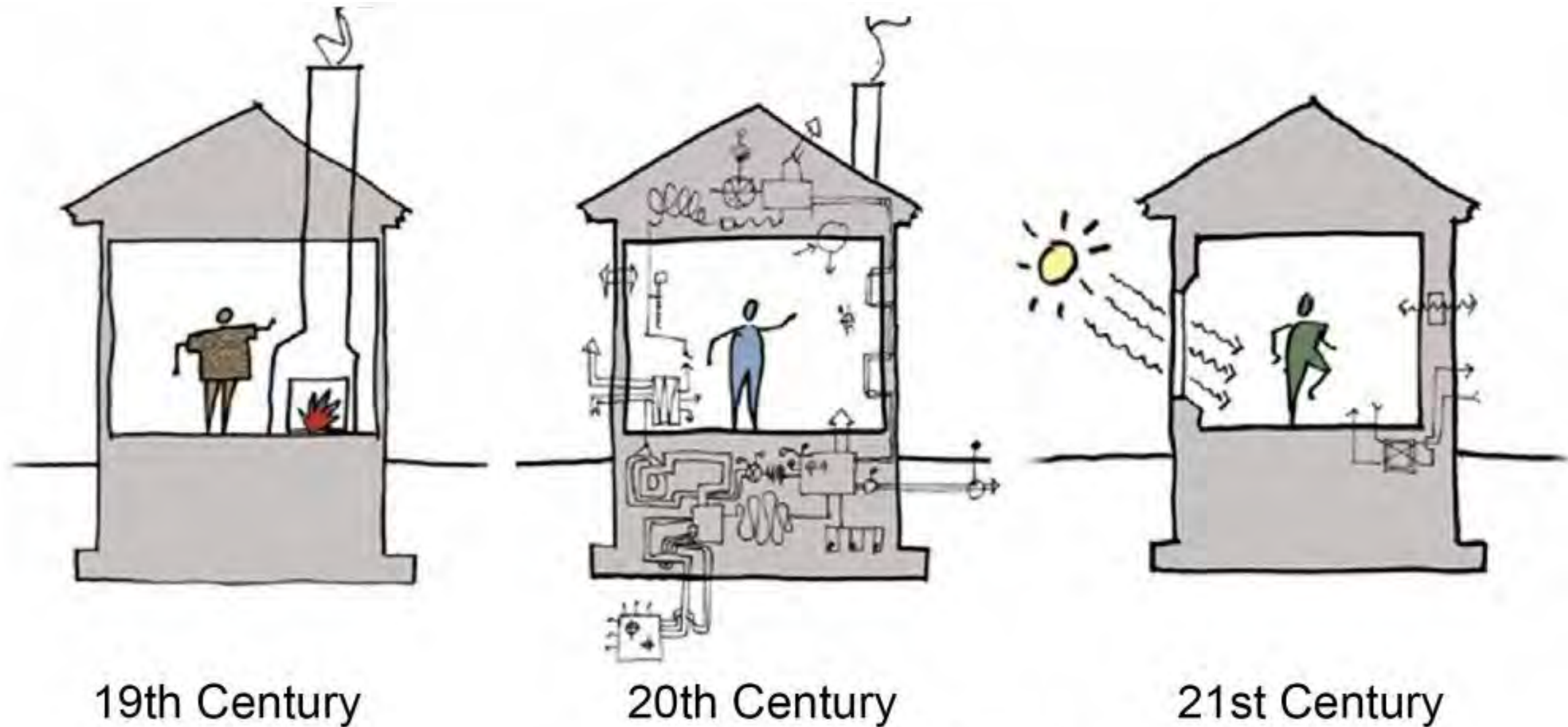
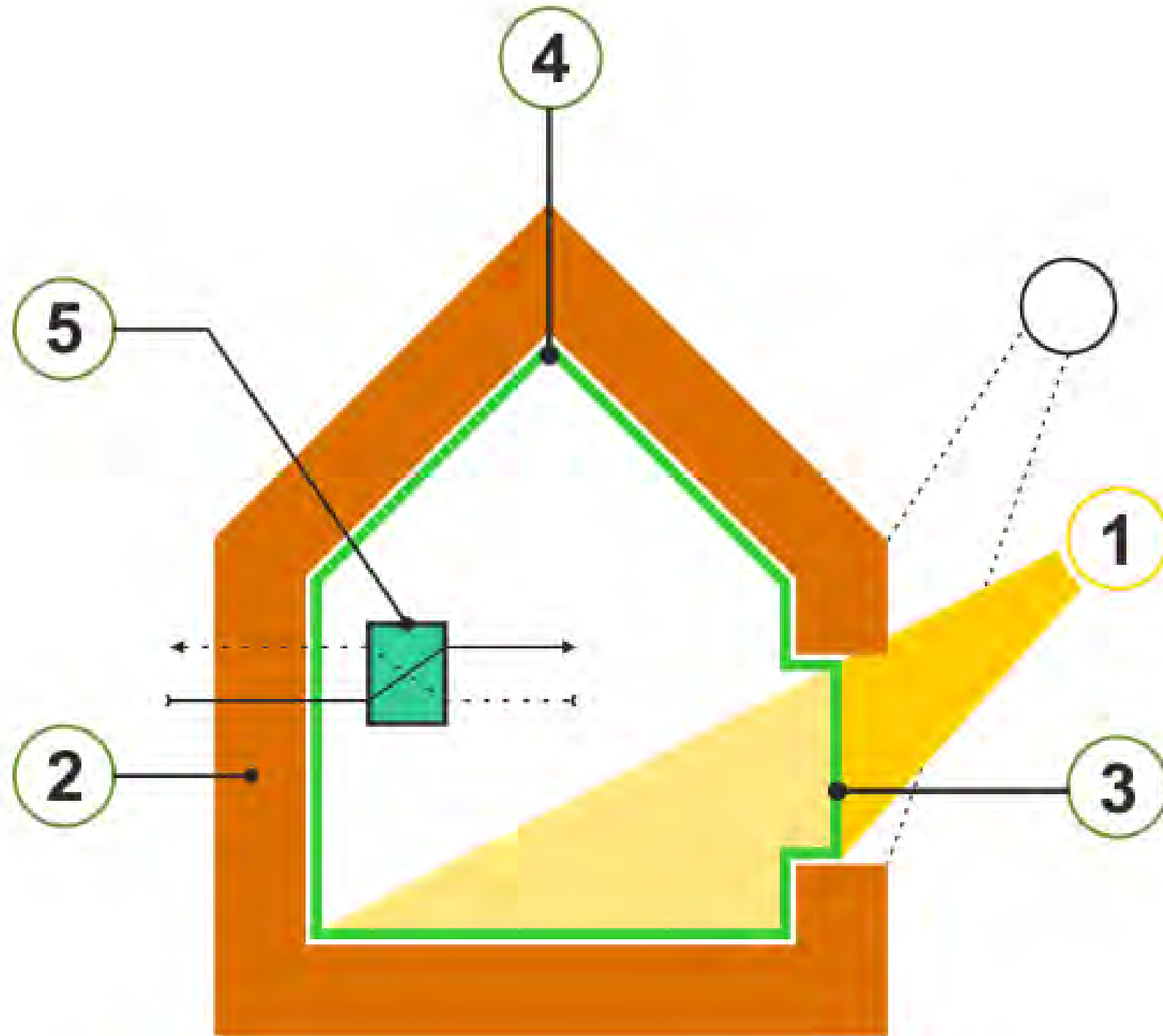


Image source: Albert, Righter and Tittmann Architects










# PASSIVE HOUSE DESIGN PRINCIPALS



- 1. Super Insulated Envelope**
- 2. Airtight Construction**
- 3. High-Performance Glazing**
- 4. Eliminate/Reduce Thermal Bridging**
- 5. Energy Recovery Ventilation**



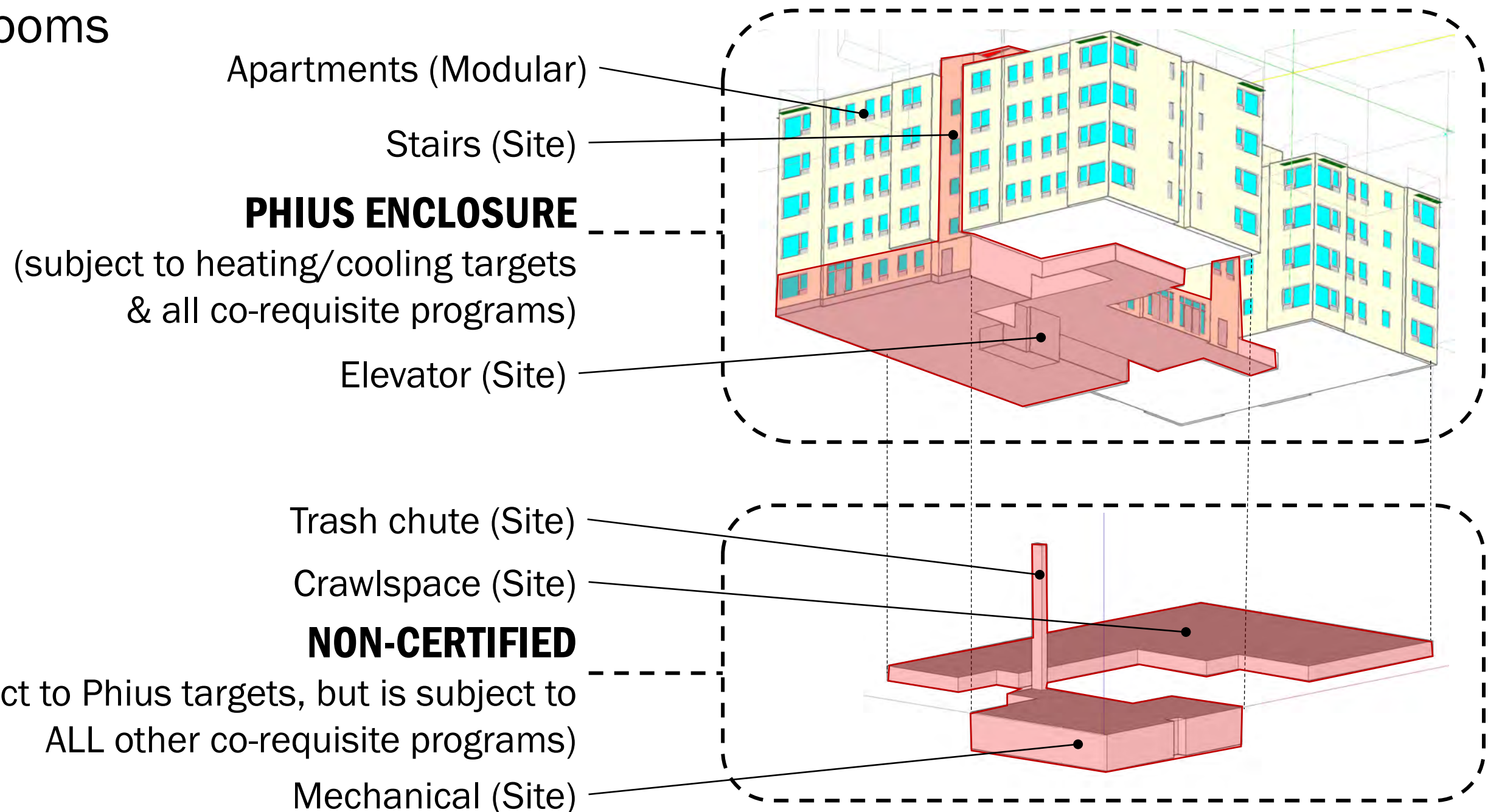
# CERTIFICATIONS

					Renewable Energy to Get to Zero
					Electrification Readiness
					Electric Vehicle Readiness
					Balanced Ventilation HRV/ERV
			SOLAR READY Depends on climate	SOLAR READY ALWAYS	SOLAR READY ALWAYS
			Eff. Comps. & H <sub>2</sub> O Distrib	Eff. Comps. & H <sub>2</sub> O Distrib	Eff. Comps. & H <sub>2</sub> O Distrib
			 EPA Indoor airPLUS VI	 EPA Indoor airPLUS VI	 EPA Indoor airPLUS VI
			Ducts in Condit. Space	Ducts in Condit. Space	Ducts in Condit. Space
	HVAC QI w/WHV	HVAC QI w/WHV	HVAC QI w/WHV	Micro-load HVAC QI	Micro-load HVAC QI
	Water Management	Water Management	Water Management	Water Management	Water Management
	Independent HERS Verification	Independent HERS Verification	Independent HERS Verification	Independent HERS Verification	Independent HERS Verification
IECC 2012 Enclosure	IECC 2012 Enclosure	IECC 2012 Enclosure	IECC 2015/18 Encl./ES Win.	Ultra-Efficient Enclosure	Ultra-Efficient Enclosure
HERS 70-80	HERS 60-70	HERS 50-60	HERS 35-45	HERS 30-40	HERS < 0
 <b>IECC 2012</b>	 <b>ENERGY STAR v3</b>	 <b>ENERGY STAR v3.1</b>	 <b>ZERH</b>	 <b>phius CORE</b>	 <b>phius ZERO</b>

# ENVELOPE: DEFINING PHIUS BOUNDARIES

- Site-built elements vs Modular
- Stair wells
- Elevator shafts
- Utility Rooms

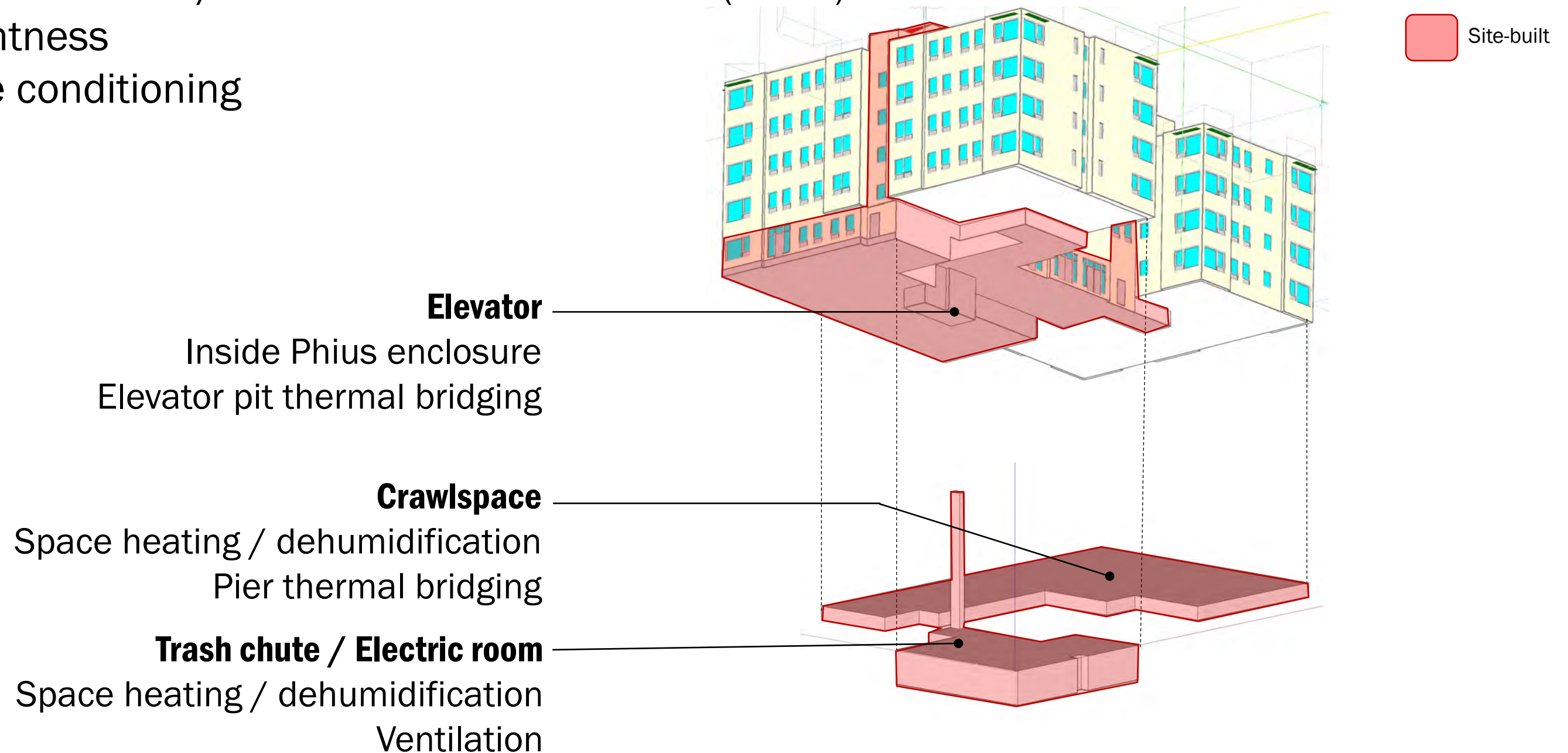
 Site-built



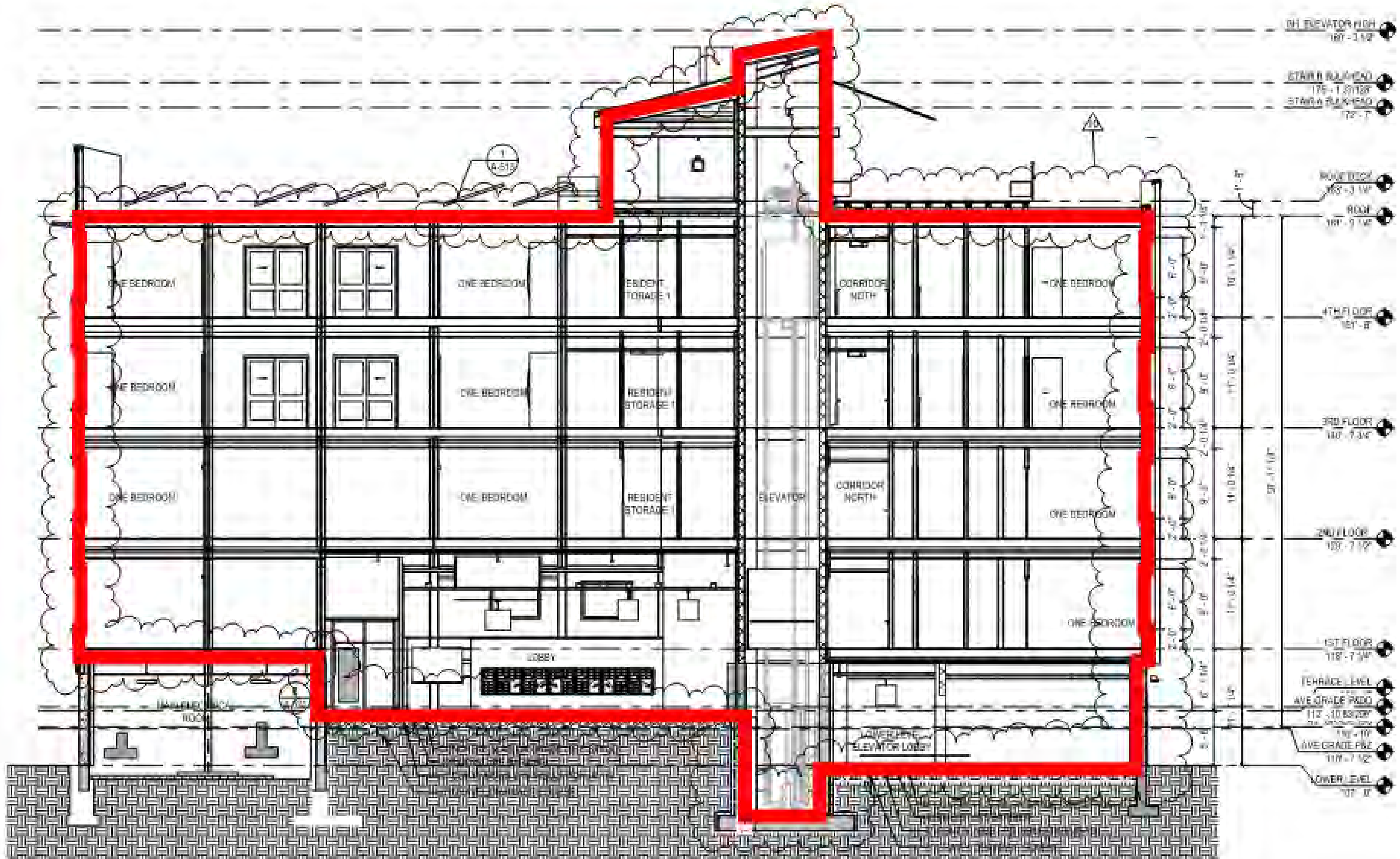
# 'OUT-OF-ENVELOPE' SPACES ARE NOT OFF THE HOOK...

## EPA Indoor AirPlus

- Foundation Wall / Slab: Code min. insulation (or R5)
- Airtightness
- Space conditioning

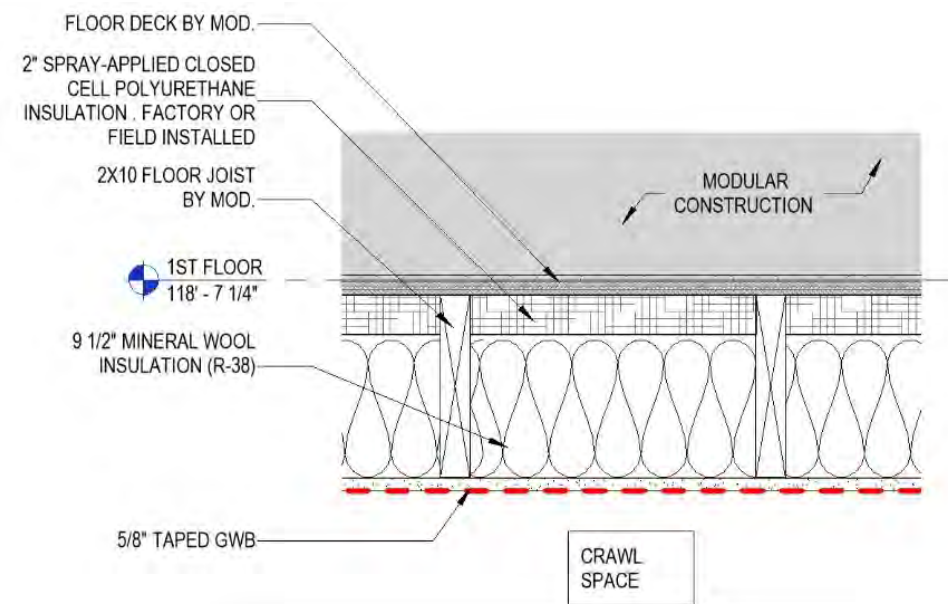
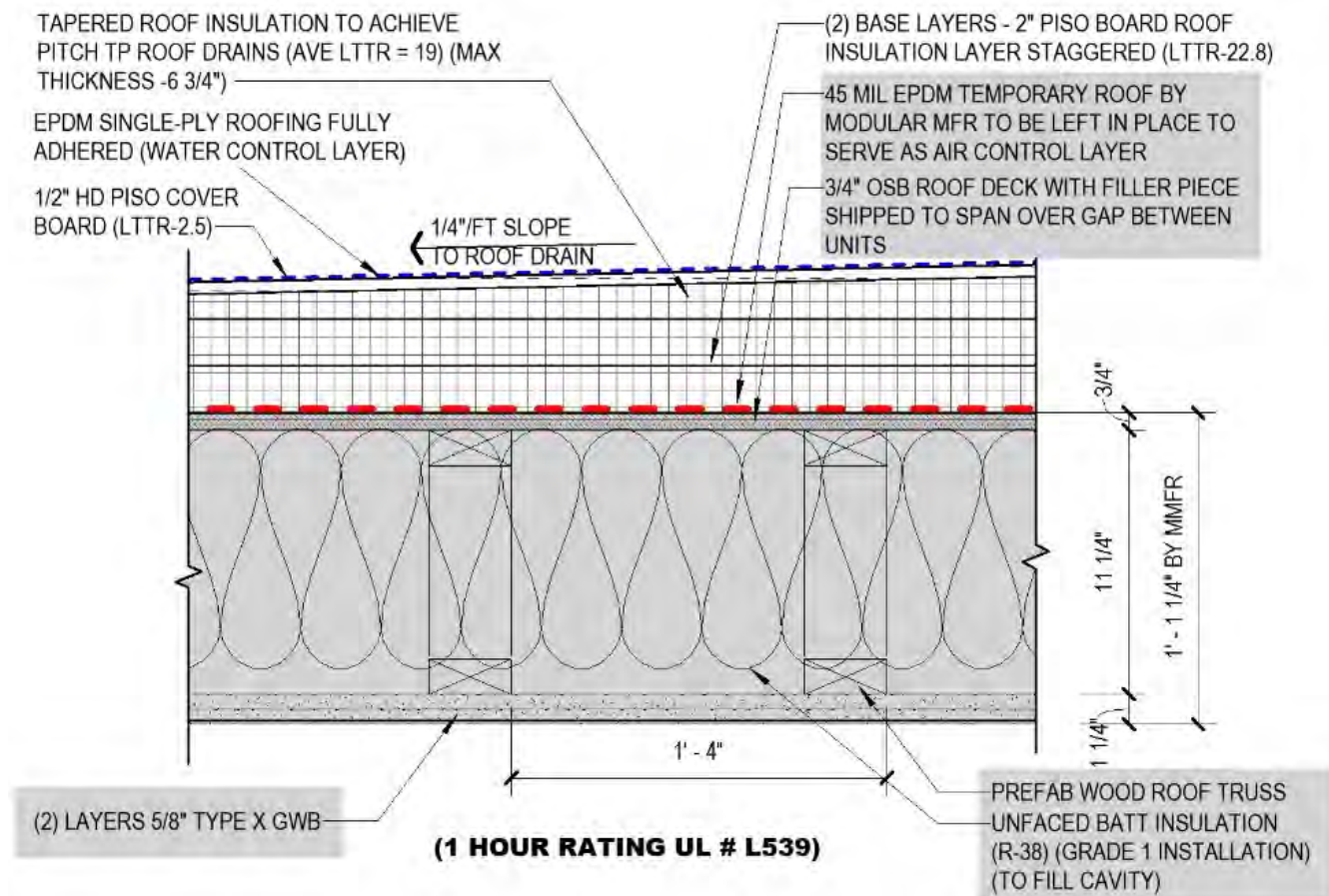
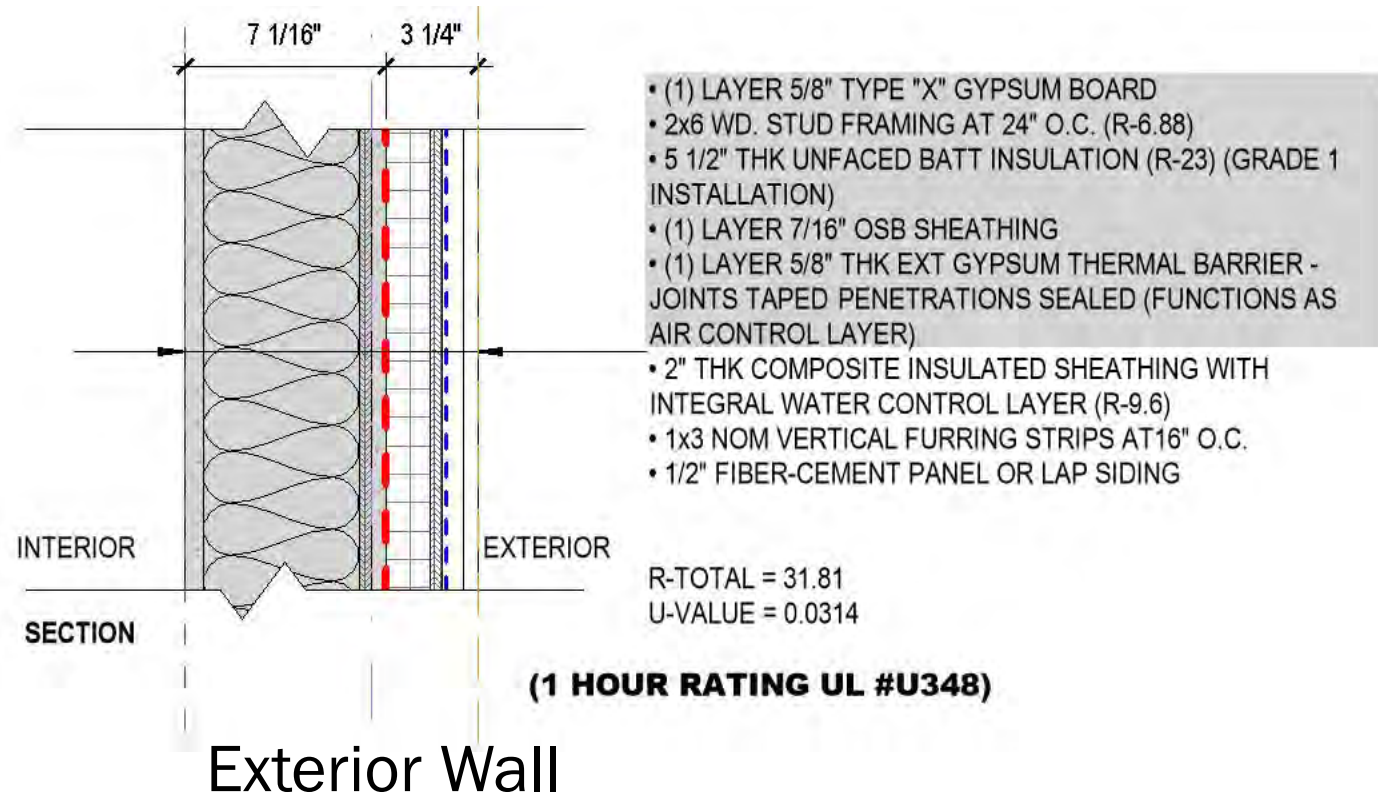


# ENVELOPE: IDENTIFY BOUNDARY IN DOCUMENTS

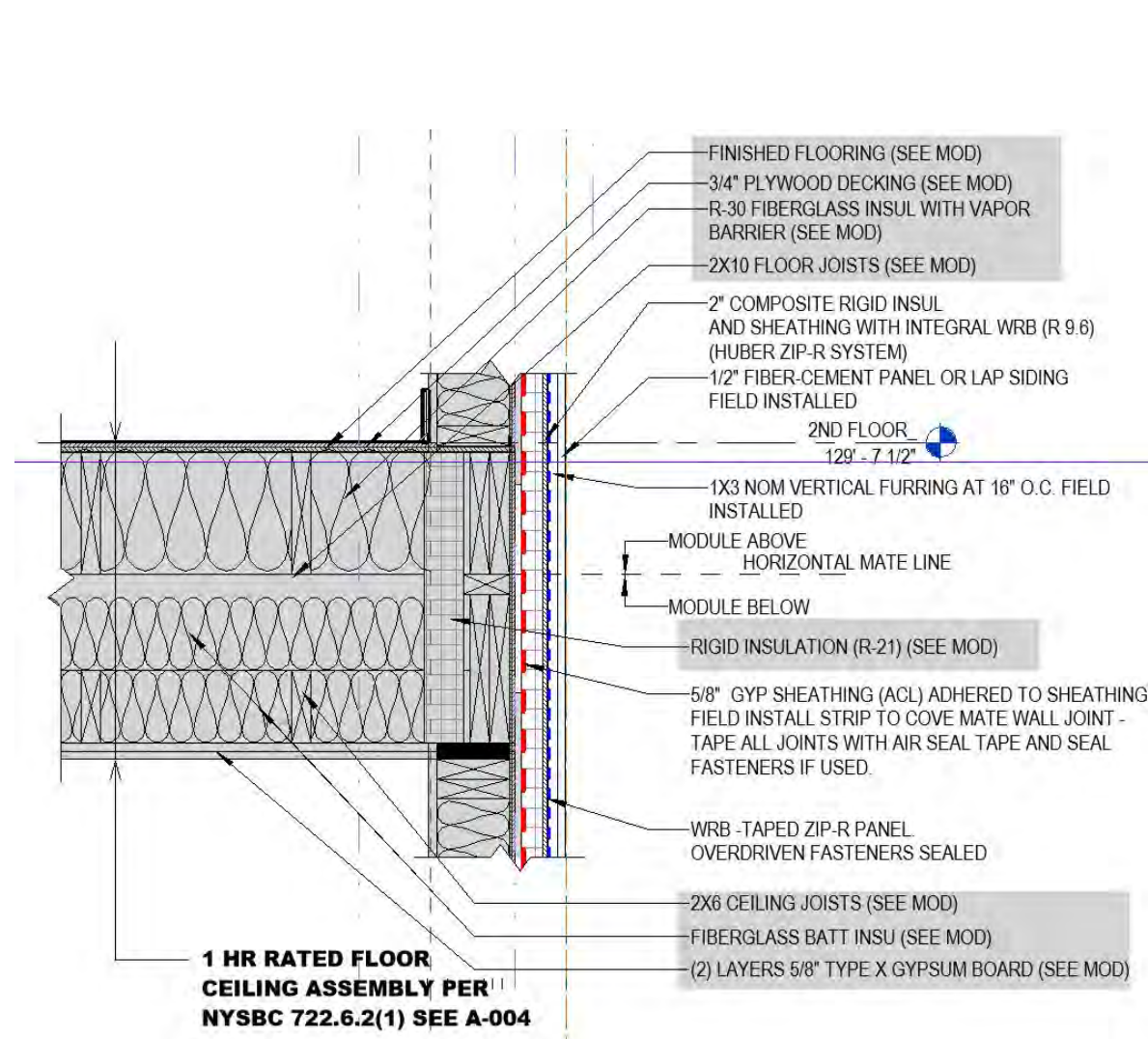


2 NORTH-SOUTH CROSS SECTION  
187'-1 1/2"

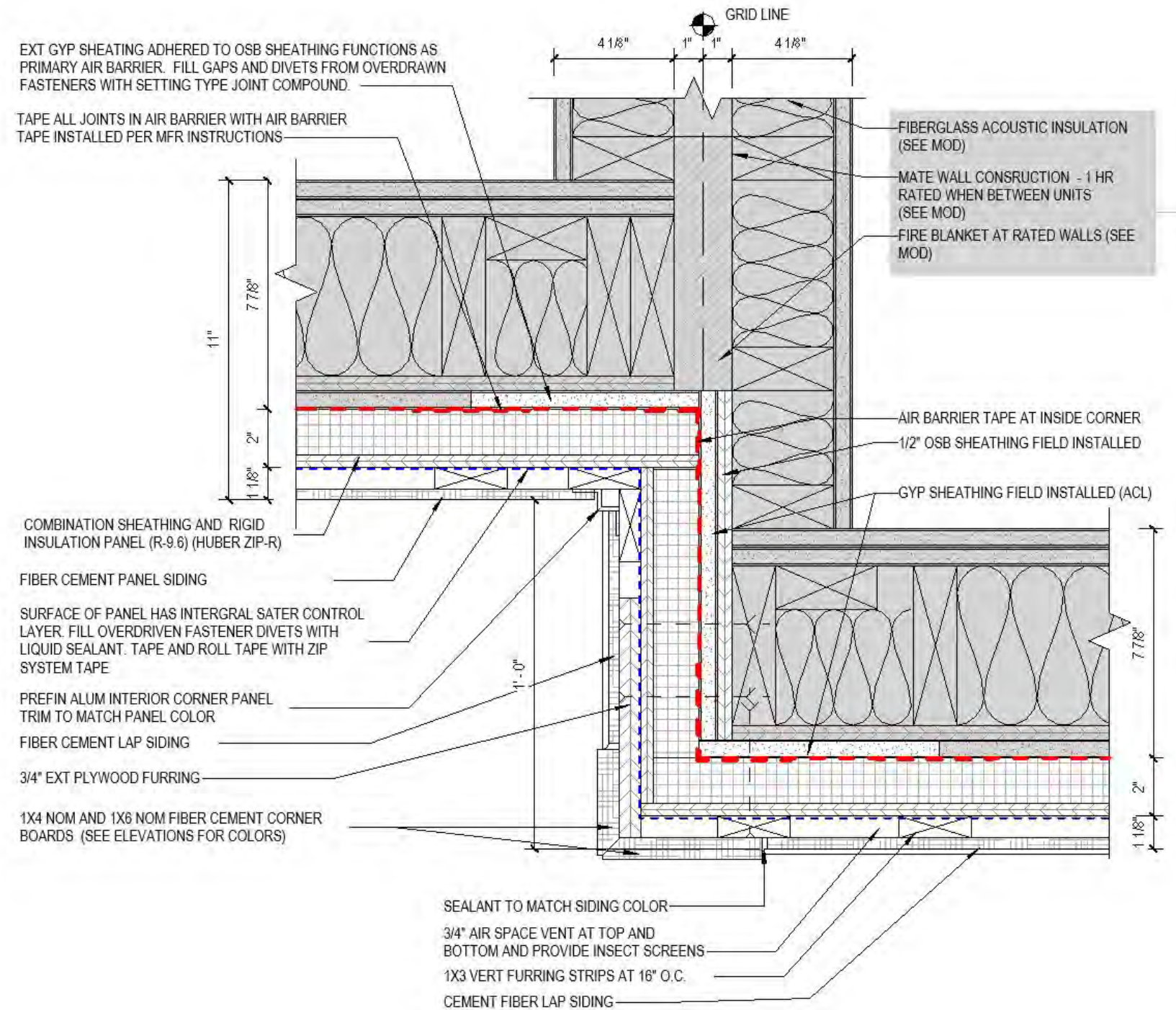
# ENVELOPE: IDENTIFY BOUNDARY IN DOCUMENTS



# AIR-TIGHT CONSTRUCTION: DETAIL CONDITIONS WHERE BOXES JOIN



Vertical Mate



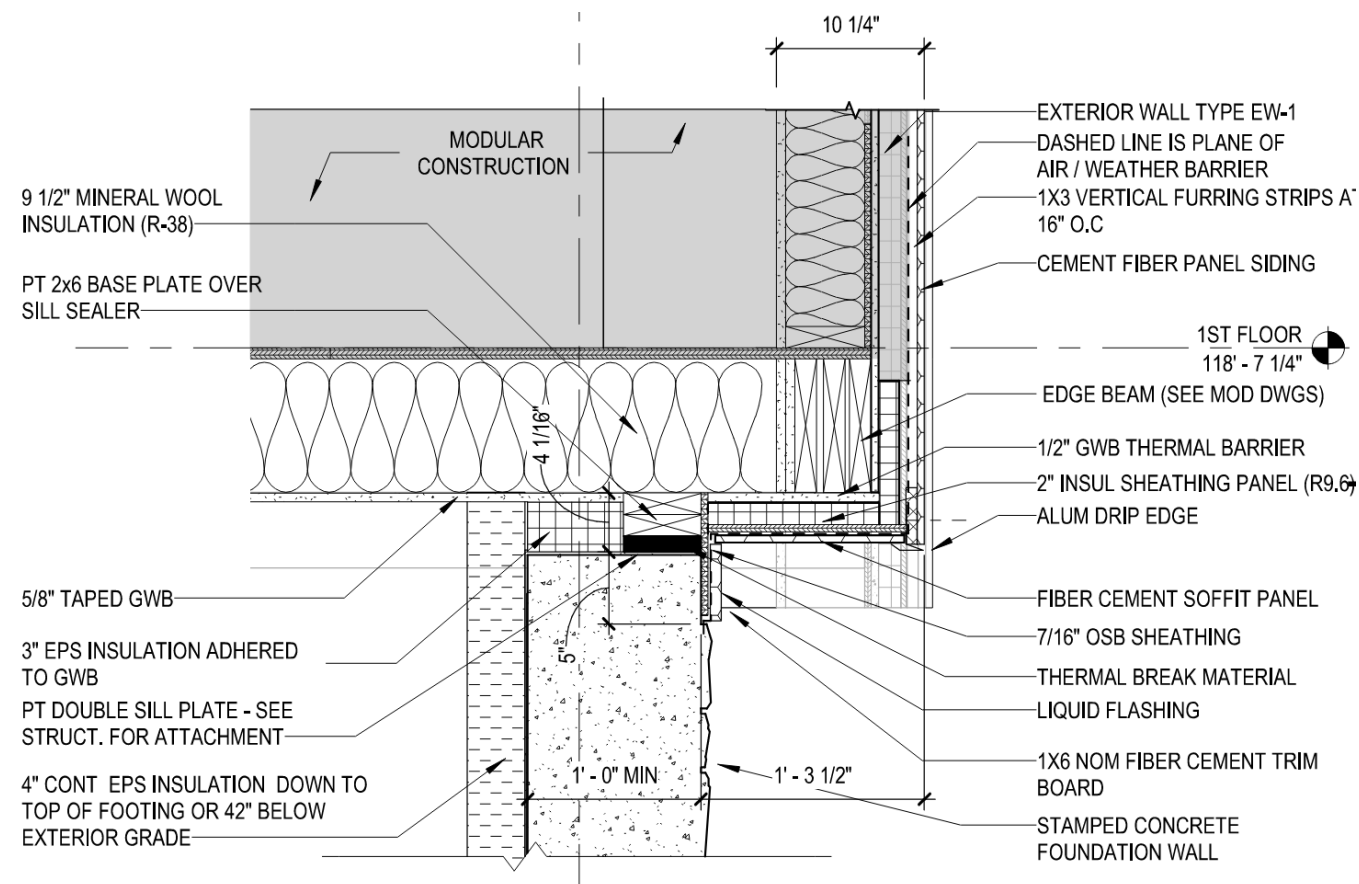
Horizontal Mate

# PHIUS MOISTURE CONTROL GUIDELINES: 'FLUFFY FLOORS'

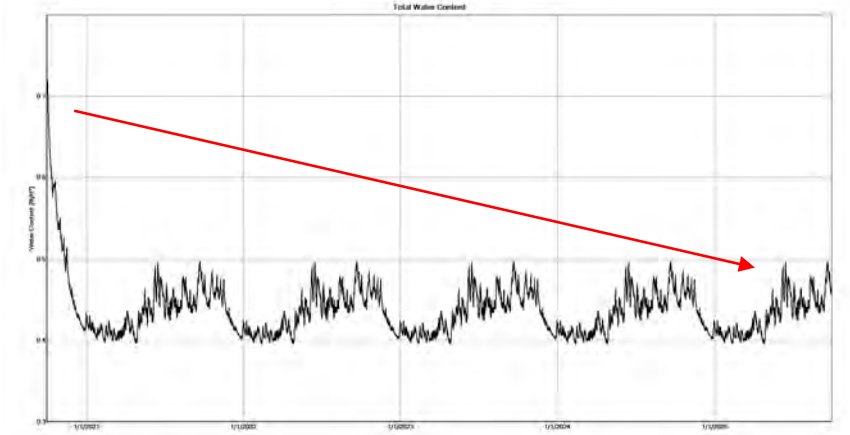
## B-4.1 Floors with Vapor Permeable Insulation

If subject to bulk water events from above, subject to meet both requirements:

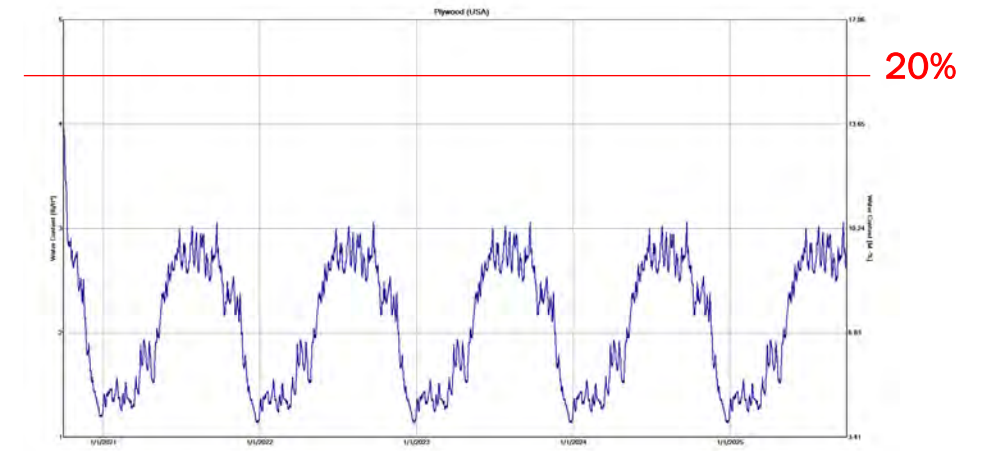
1. Provide water resistant layer above air permeable insulation
2. Limit insulation to 2.5" or pass hygrothermal performance test



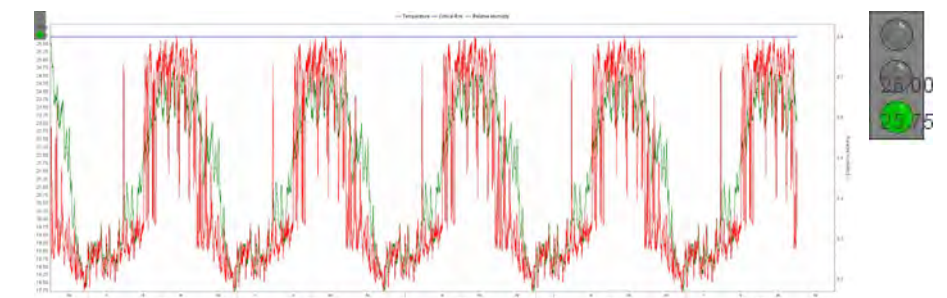
5-year dryout



MC% in condensing layer

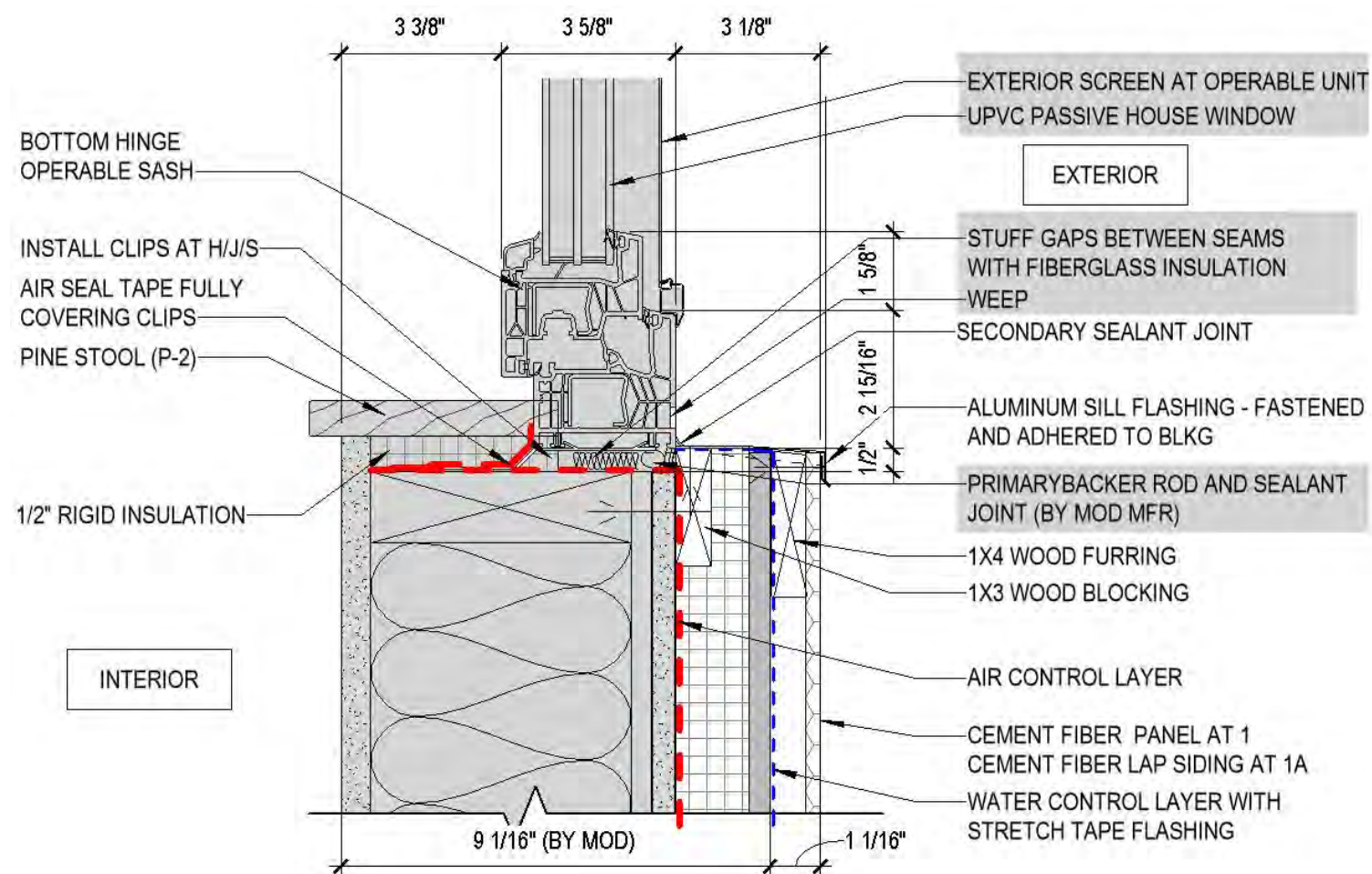


Mold growth (VTT)



# HIGH-PERFORMING GLAZING: WINDOWS

- Steel reinforced - UPVC frames.
- American made triple-pane glass by Guardian.
- Thermal transmittance = 0.1482 to 0.1729 Btu/h per square foot °F
- Frame profiles imported from Europe, but fabricated in Ramsey, NJ using robotic equipment.
- Can feed the modular factory during assembly – reduces need for storage.



Outdoors	
GLASS 1	Guardian Clear Glass (North America) #1 Thickness = 5/32" (4mm)
	#2 SunGuard® SN 68 (North America)
GAP 1	10% Air, 90% Argon, 9/16" (14.3mm)
GLASS 2	Guardian Clear Glass (North America) #3 Thickness = 5/32" (4mm)
	#4 SunGuard® SN 68 (North America)
GAP 2	10% Air, 90% Argon, 9/16" (14.3mm)
GLASS 3	Guardian Clear Glass (North America) #5 Thickness = 5/32" (4mm)
	#6
Total Unit (Nominal) = 1 19/32 in	
Slope = 90°	
Window Height = 1 meter	
Estimated Nominal Glazing Weight: 5.89 lb/ft²	

Indoors

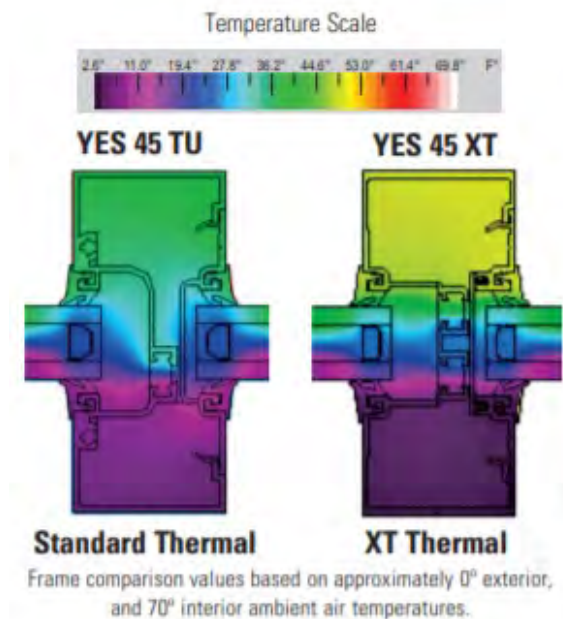
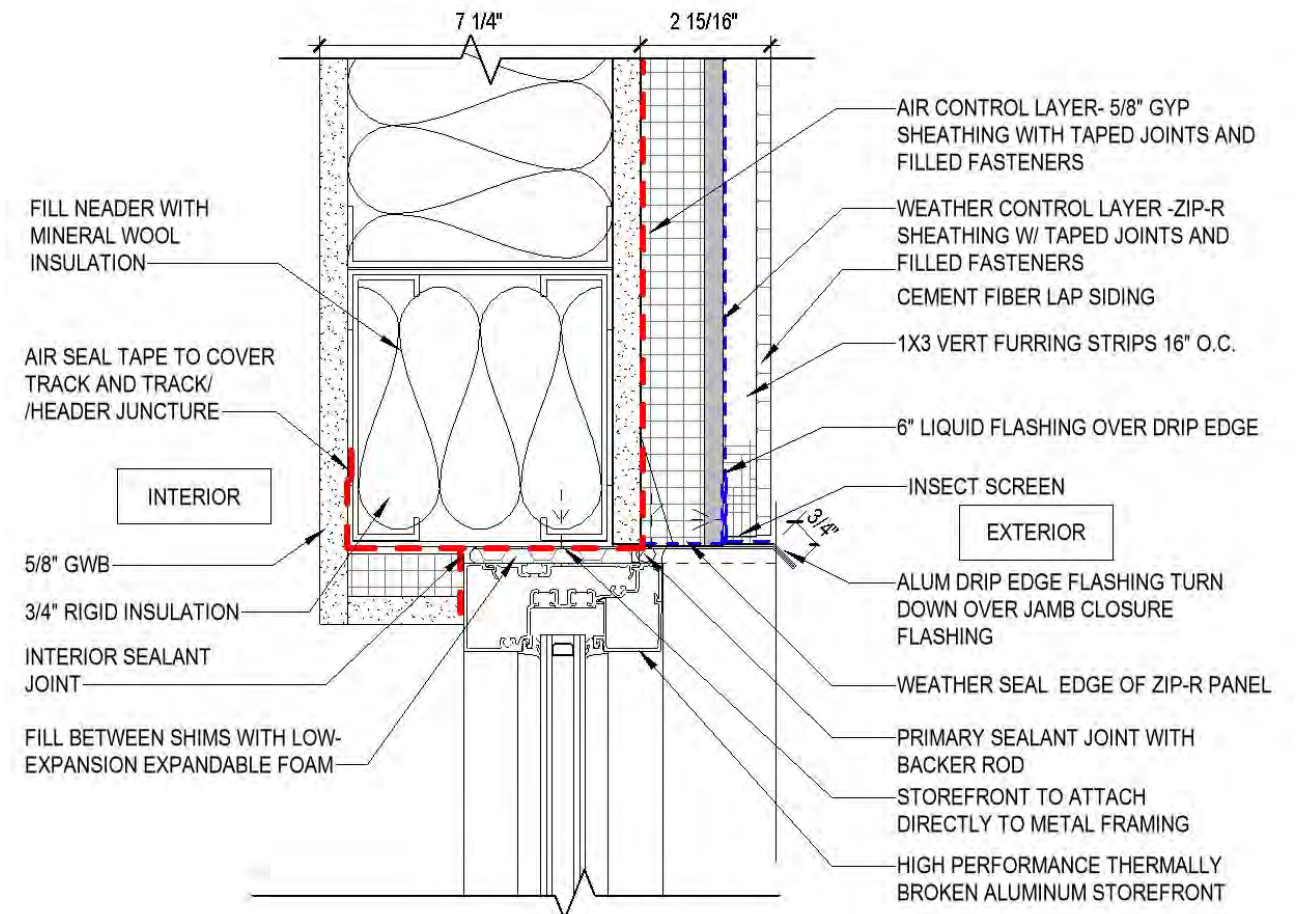
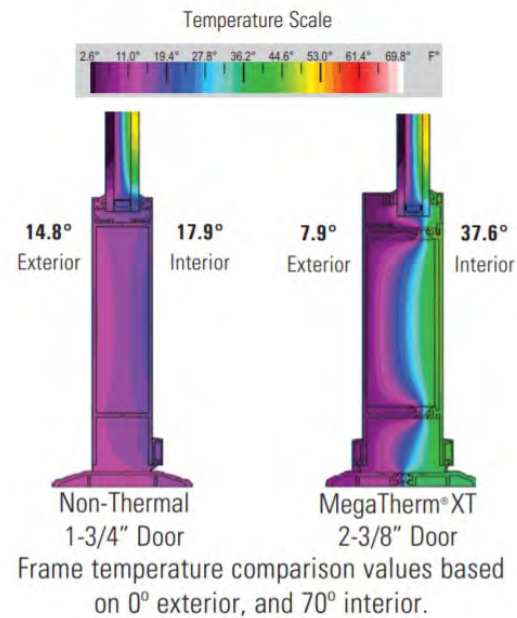
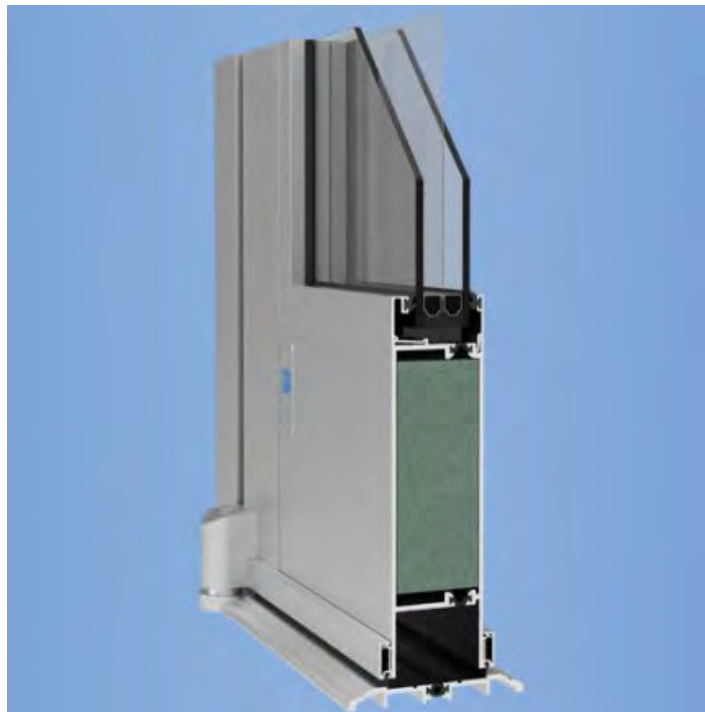




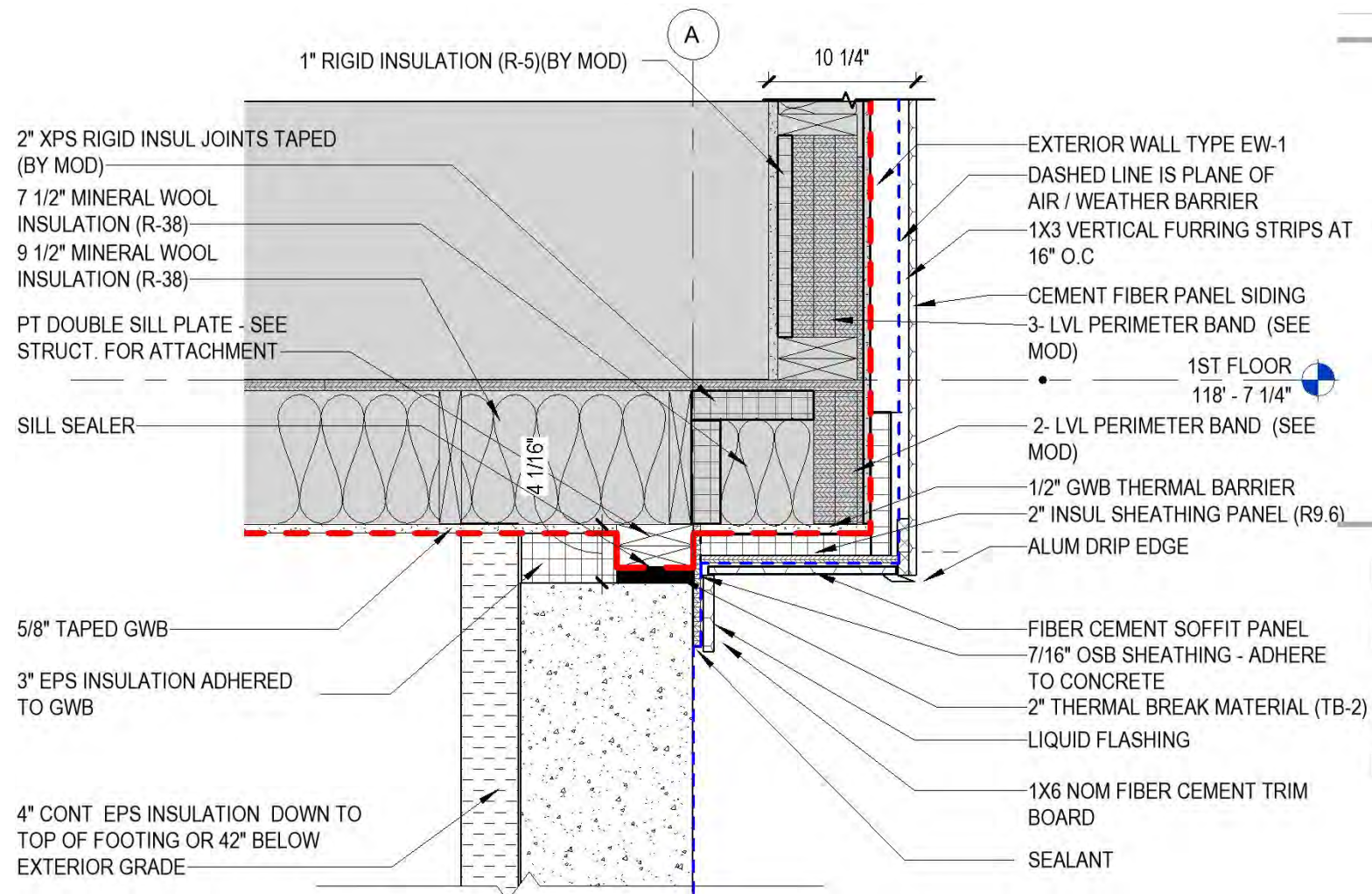
# THERMAL BRIDGING: STOREFRONT

## Terrace Level Amenity Areas

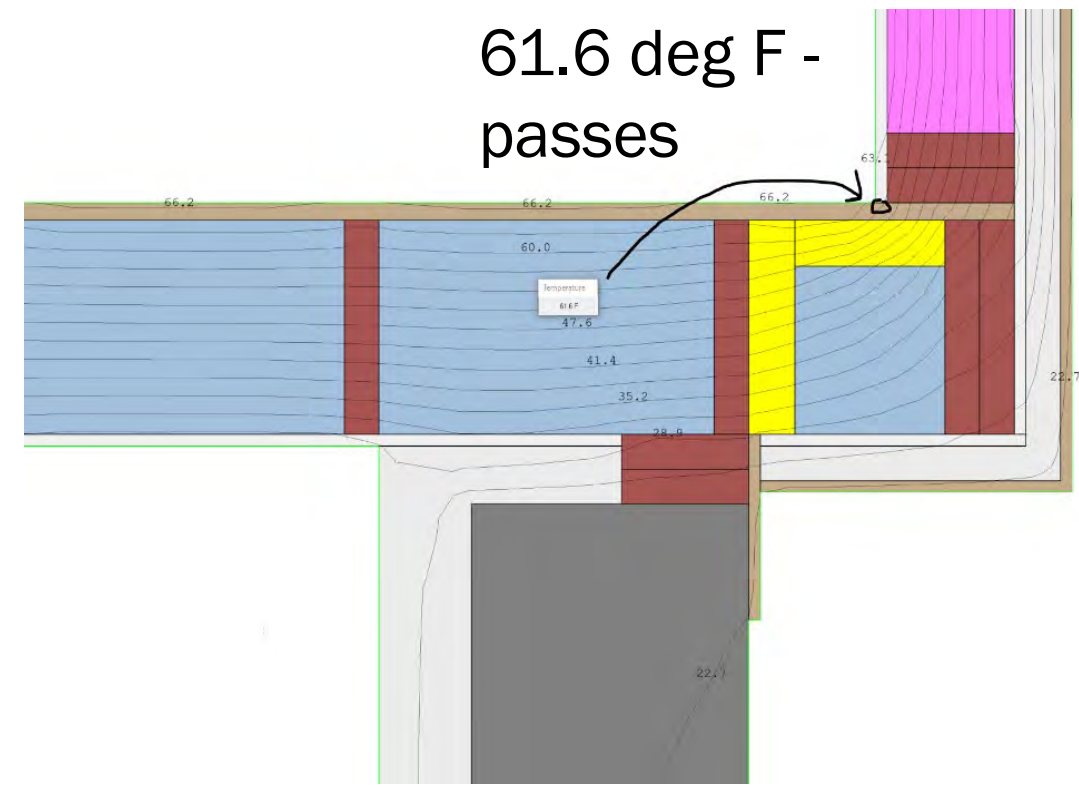
- Snap in pressure fit sealing – lower on-site labor cost
- Thermally Broken Framing and Sill Profiles
- Double-pane insulated glass with Low-E argon filled
- Entrances have thermally-broken panel faces, frames and thresholds; double sweep and self rising pivot hinges



# THERMAL BRIDGING: MODULAR



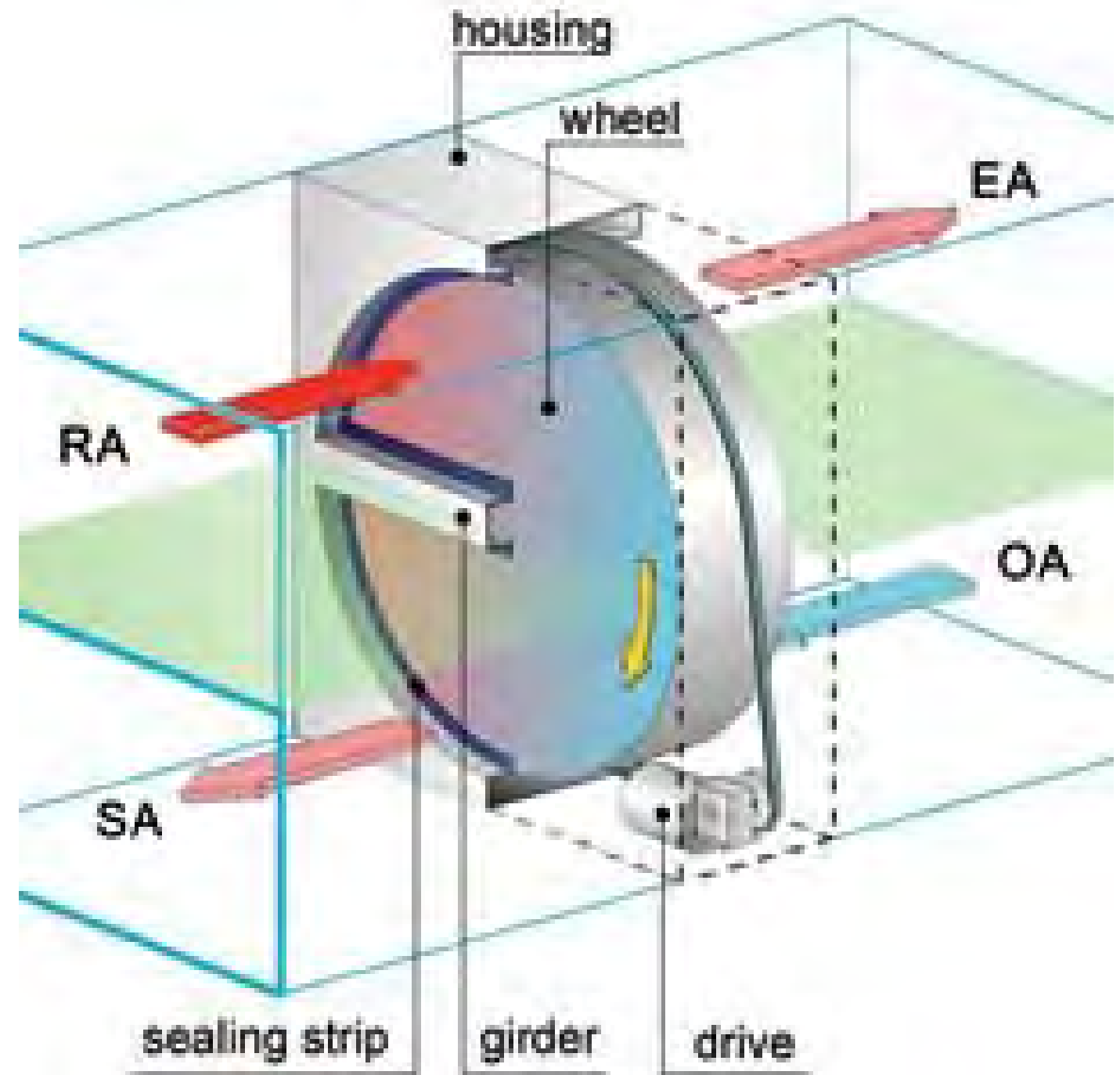
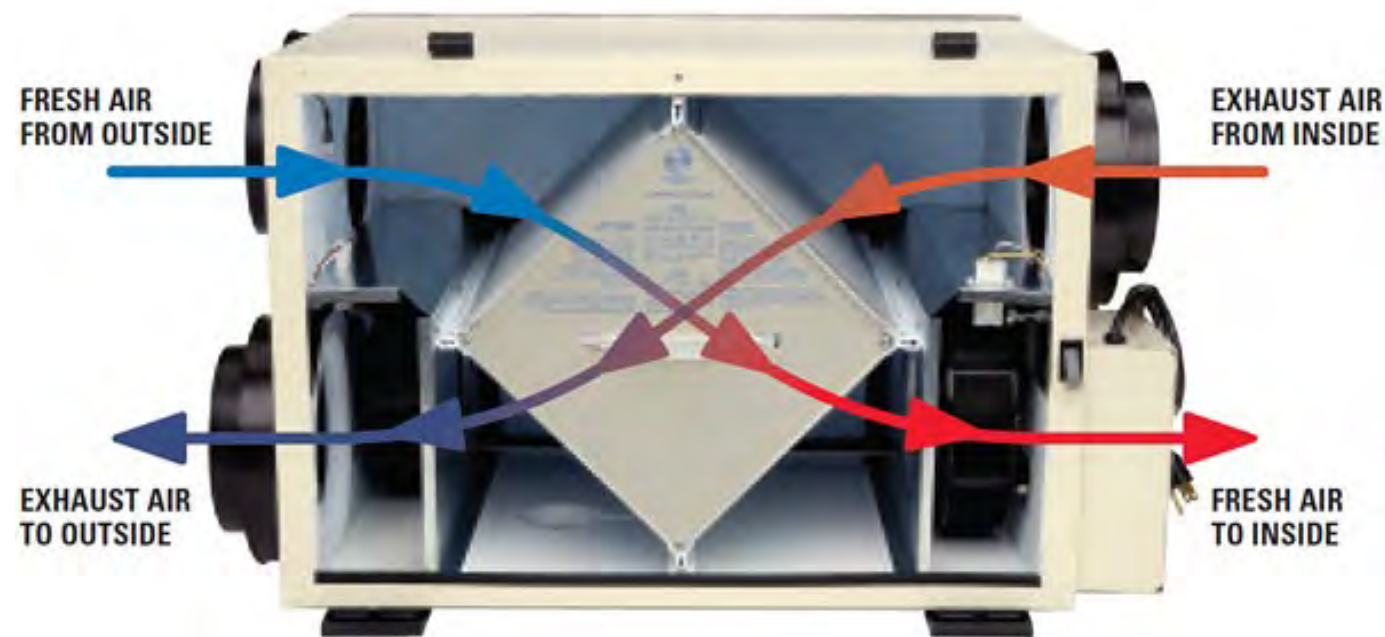
Modular Overhang



Condensation Risk analysis

# ENERGY RECOVERY VENTILATION

- Centralized Rooftop Units with Enthalpy Wheel
- Operates 24/7
- Exhausts Kitchen and bathroom
- Supplies to Living Room and Bedrooms
- MERV 13 filtration
- No inter-mixing of air between units – alleviates COVID concern.



# ENERGY RECOVERY VENTILATION



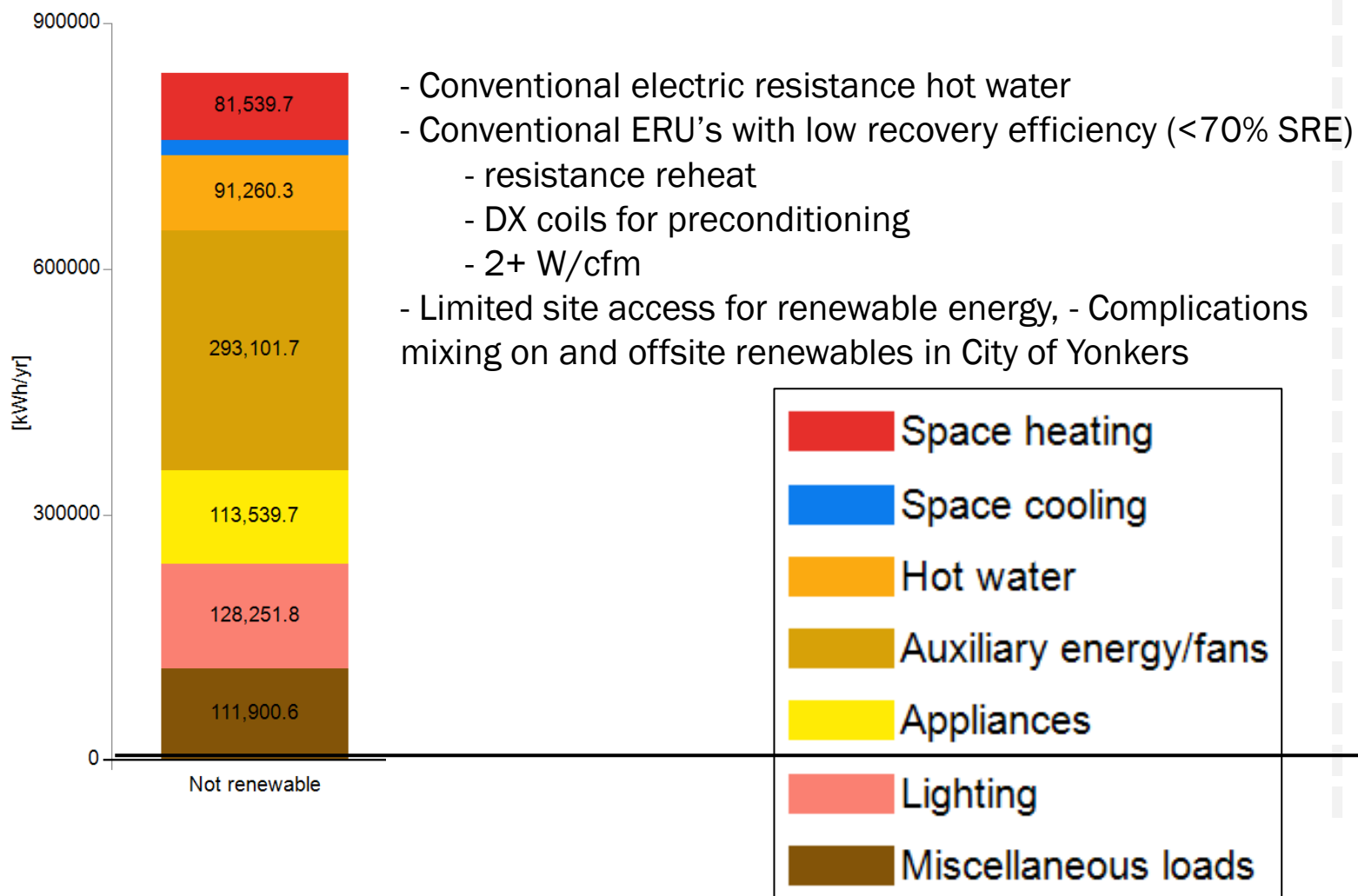
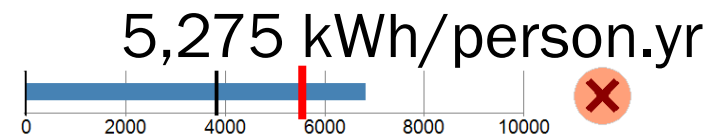
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# OTHER PASSIVE HOUSE CONSIDERATIONS: ELECTRIC HEAT-PUMP HOT WATER

## ORIGINAL FOSSIL-FUEL FREE DESIGN

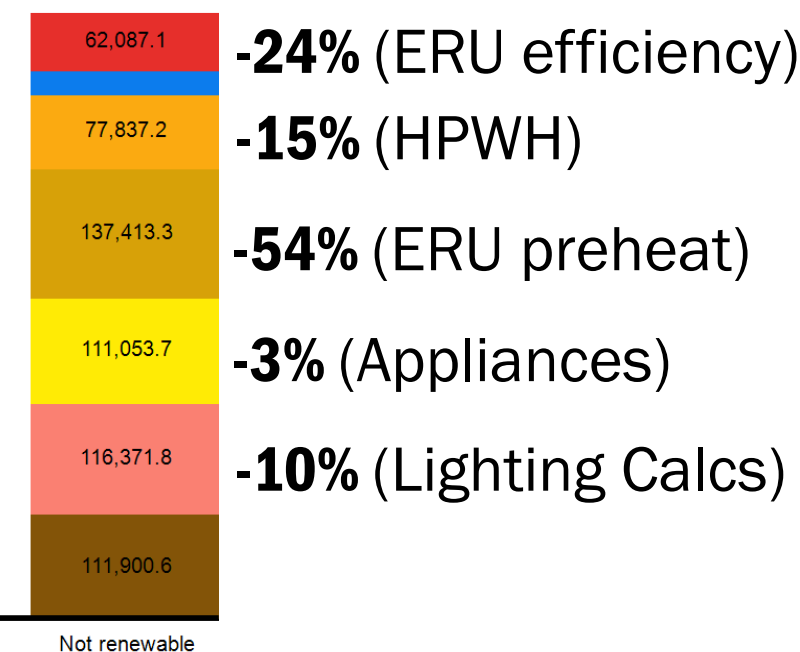
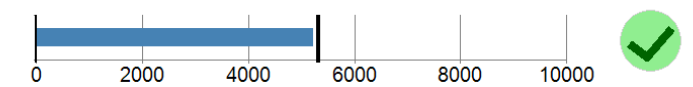
### Source energy

total: 838,942.02 kWh/yr  
 specific: 6,821 kWh/Person yr  
 target: 3,840 kWh/Person yr  
 total: 2,862,306.46 kBtu/yr  
 specific: 53.26 kBtu/ft²yr



## OPTIMIZED FOSSIL-FUEL FREE DESIGN

total: 642,193.41 kWh/yr  
 specific: 5,221 kWh/Person yr  
 target: 5,325 kWh/Person yr  
 total: 2,191,038.58 kBtu/yr  
 specific: 39.63 kBtu/ft²yr



- Heat Pump Hot Water design
- High efficiency ERU  
 - .74 W/cfm (measured)
- Refined appliance specifications
- Custom LPD calculations



# OTHER PASSIVE HOUSE CONSIDERATIONS: ELECTRIC HEAT-PUMP HOT WATER

- Hot Water becomes major electrical load
- Exterior Heat pumps greatly improve efficiency from electric resistance water heaters.
- Estimated \$20,000/year electrical savings.
- Required to achieve phius/NYSERDA Tier 3.
- New technology at a commercial scale.
- Domestic source – Washington State



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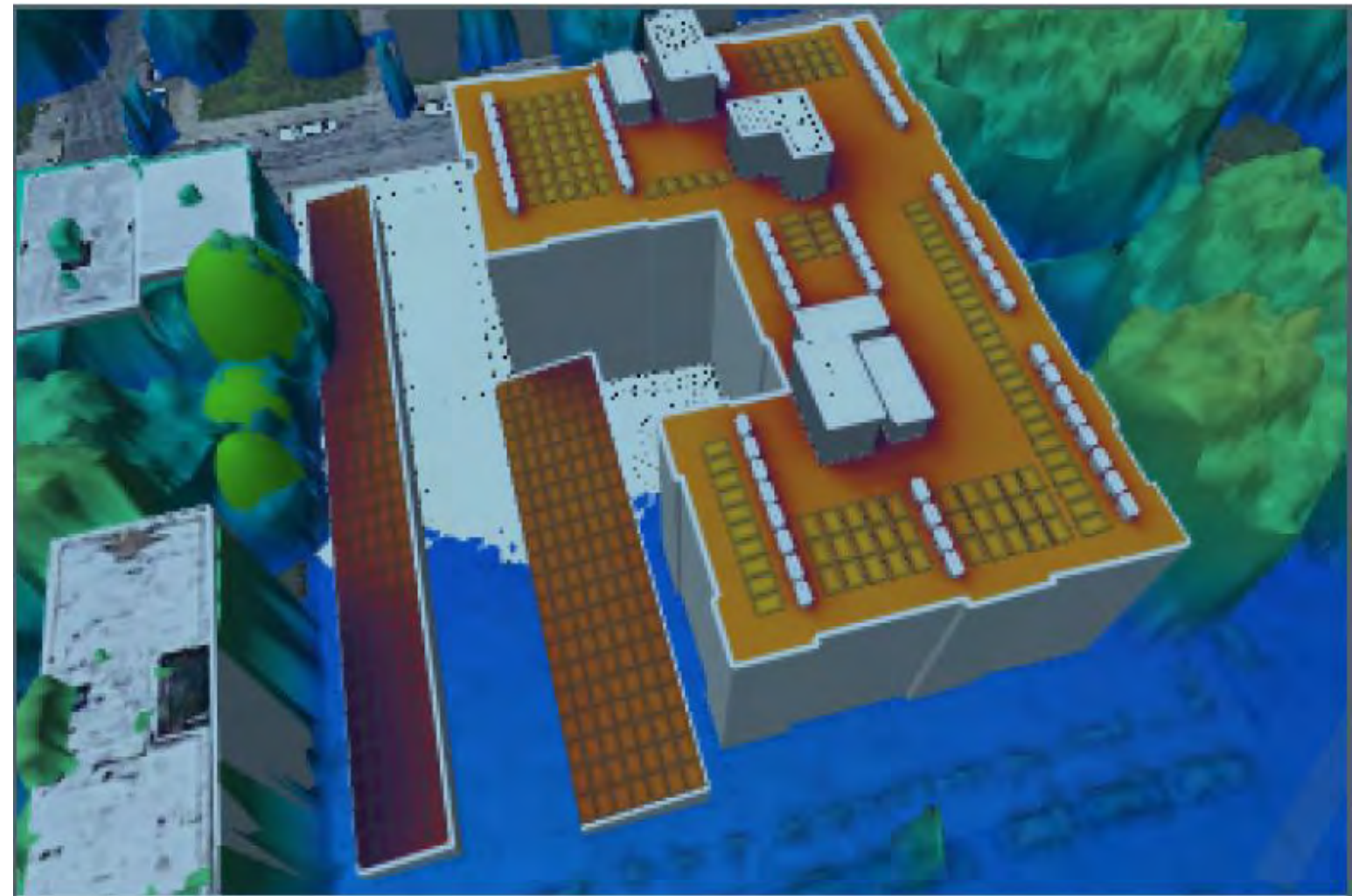
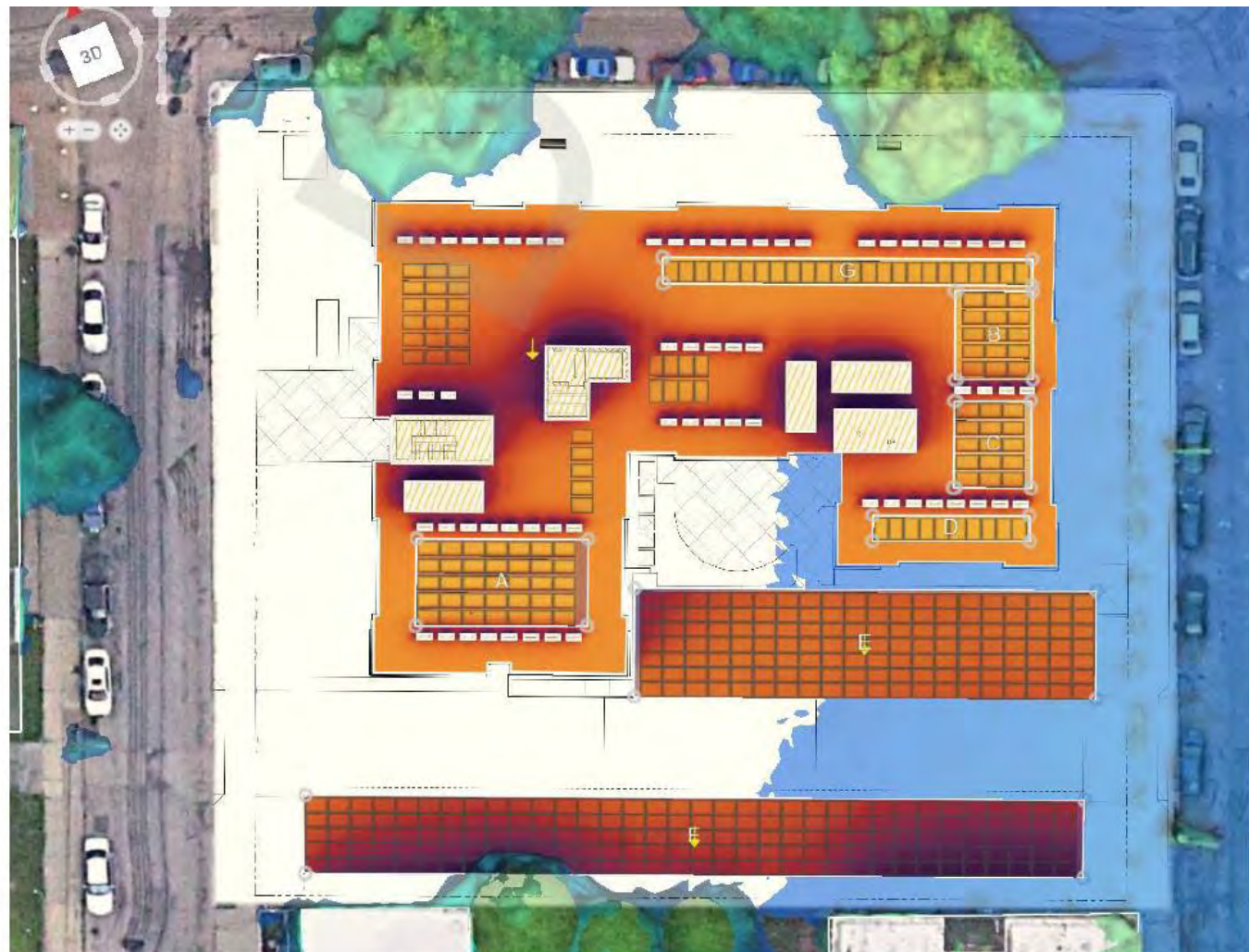
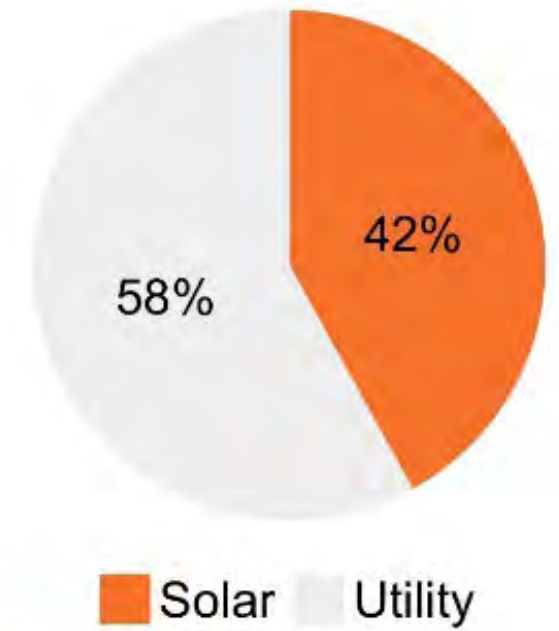
# APARTMENT MECHANICAL SYSTEM: SPLIT SYSTEM HEAT PUMP

- All electric - two per unit
- One-to one connection
- Field installed
- No ductwork



# SOLAR (PHOTOVOLTAIC)

- Roof and parking canopies considered
- System Size: 140.8 kW
- Yearly Production 137,127kWh – 42% of annual load
- 440 Modules
- Required for Passive House certification - 24,000 kWh/ year.
- Considered, but deferred for future installation when ROI is more reasonable



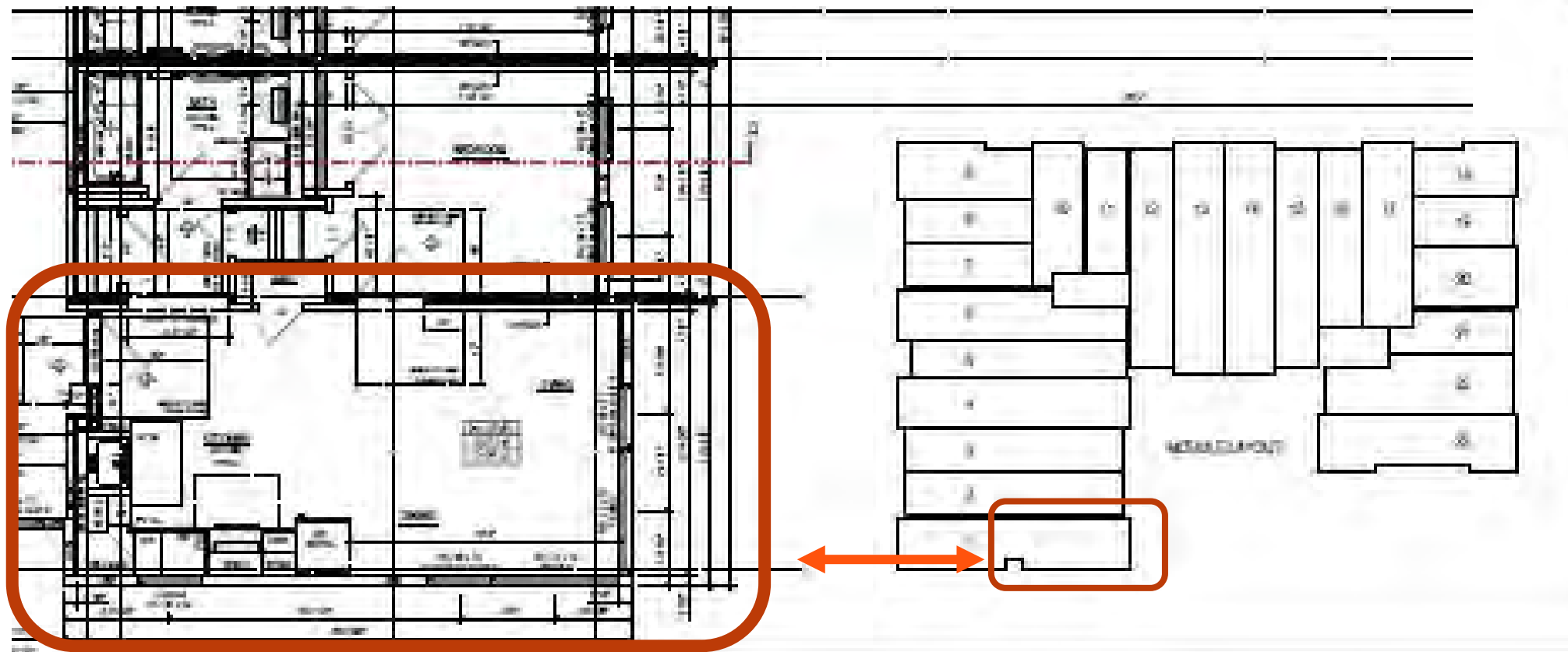
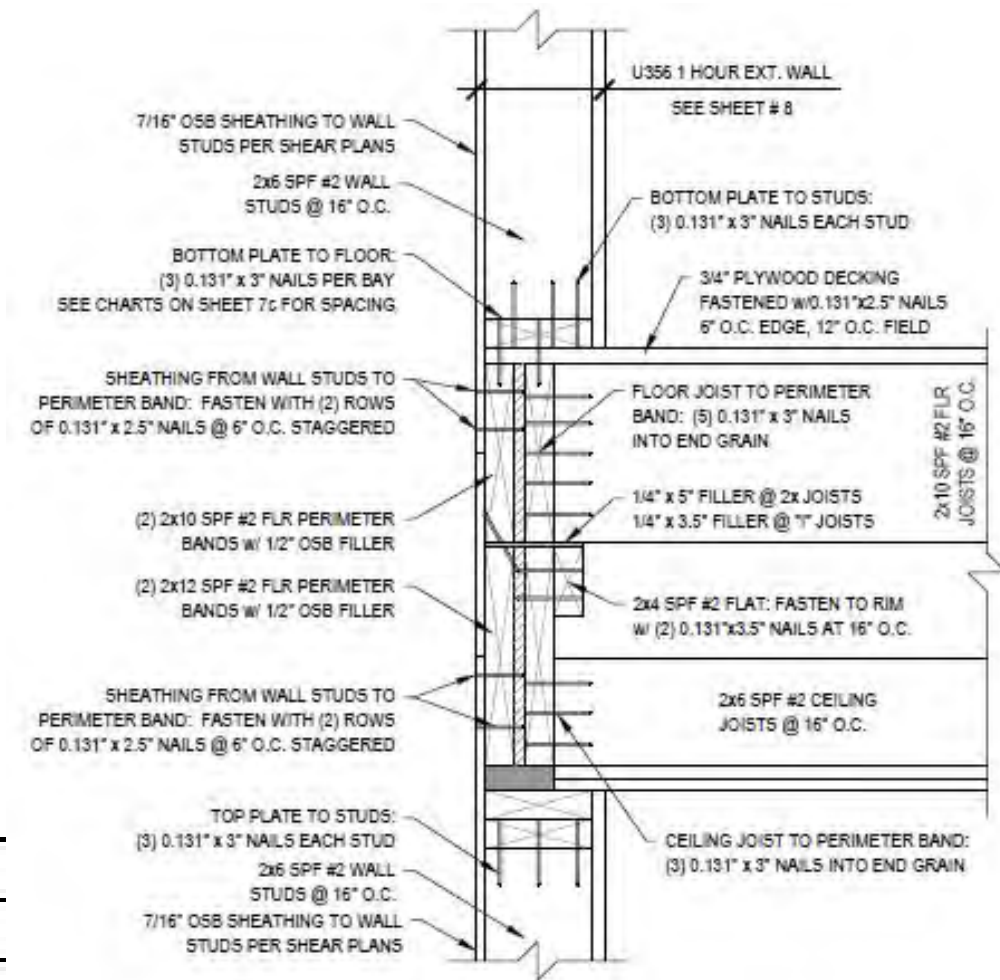
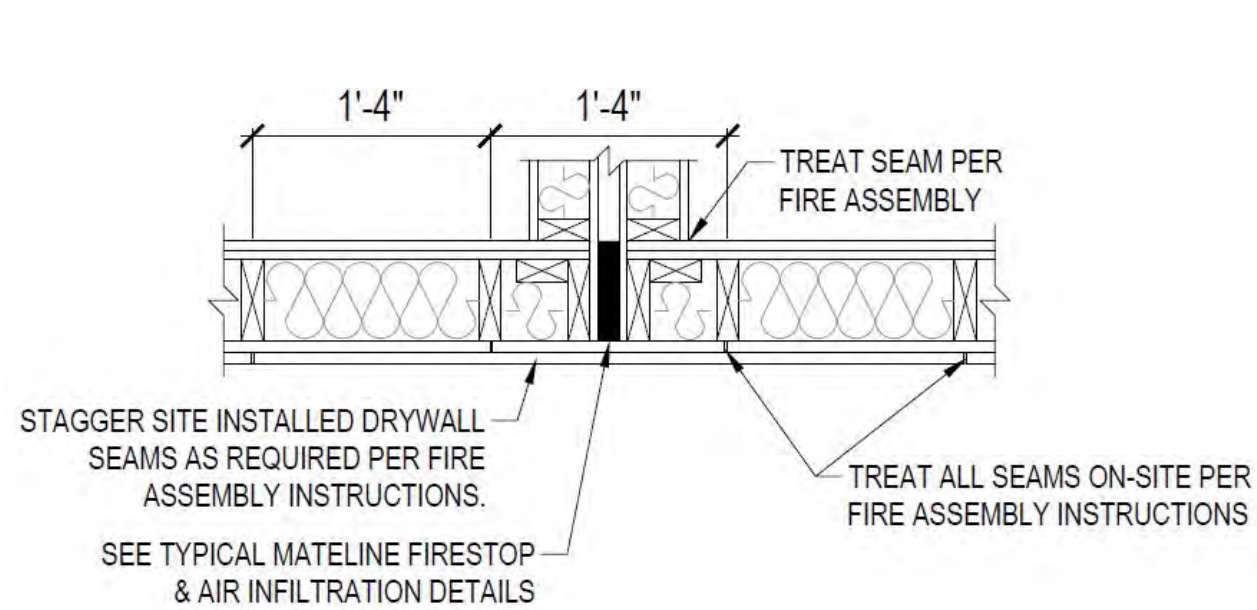


# MODULAR





# MODULAR CONSTRUCTION

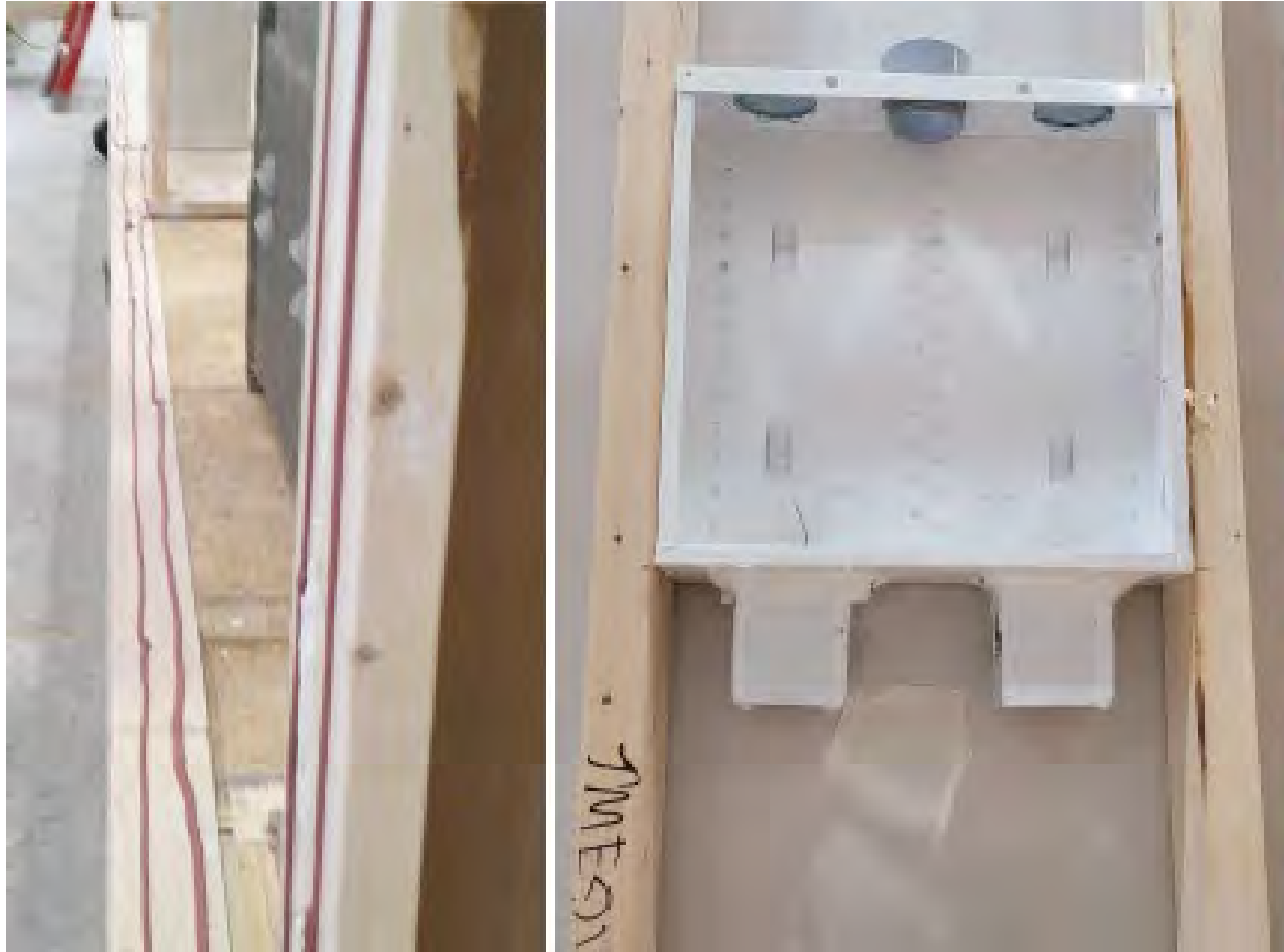


# MODULAR: FACTORY FABRICATION



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# MODULAR: FACTORY FABRICATION



# MODULAR: FACTORY FABRICATION



# MODULAR: FACTORY FABRICATION



# MODULAR: FACTORY FABRICATION



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# MODULAR: FACTORY FABRICATION

## plus Field Verification

- In factory inspections Division of work- Factory vs. Site:

6. Mate wall gaps were taped for the testing with the exception of the mate line at the floor level as we could not access it and which will provide similar challenges onsite.

As you can see in photo above there are strips of R13 batt at the perimeter of all mate lines and at each cross-over opening. It is my understanding that this is part of the fire-code and that batts were used in place of Albi Clad (rock wool board) due to dimensional restrictions. Either, alone, will allow air to cross the mate lines. This is not a problem at your ceiling and vertical wall mates but is a problem at your floor mates as you will not have access to these as boxes are swung together. The test numbers shown in this report reflect only the R13 in the floor mate line, so if all else can be replicated onsite you could still achieve passing numbers with just batt in this floor mate line. Despite getting good numbers there was still a significant amount of air moving thru the floor mate line. We discussed adding a traditional gasket above the R13 at the floor level but there was still concern about horizontal dimensions expanding too much. My concern is when setting the boxes, they use a wedging technique which will likely further compromise the floor level R13 strip vs. how we just pushed them together in the plant. There are ways to reinforce this area using expanding foam, copious amounts of caulk, zip tape, but will somewhat depend on the site/set situation and how the floor joists line up with the ceiling joists in box below. Need to be prepared to tackle this onsite with multiple means, but once you can see the site situation it can be figured out quickly.



# MODULAR: FACTORY FABRICATION

## plus Field Verification

- In factory inspections Division of work- Factory vs. Site:



# MODULAR: FACTORY FABRICATION

## plus Field Verification

- In factory inspections Division of work- Factory vs. Site:



# MODULAR CONSTRUCTION

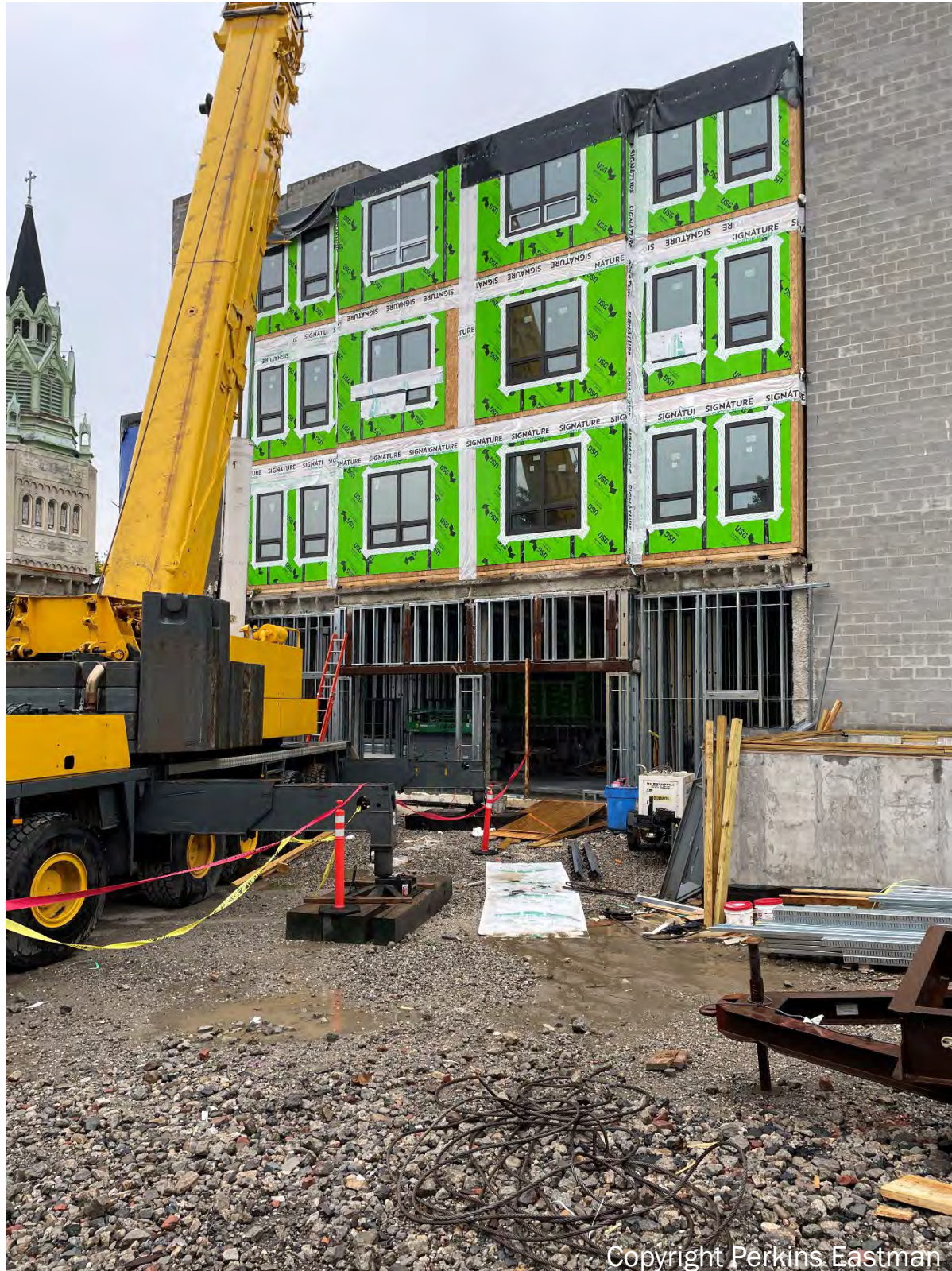
- Wood Frame Boxes sized for transport – 16 ft x 60 ft
- Windows, millwork, finished bathrooms prime painted walls and ceilings shipped with units.
- 2” gap horizontally and 3” gap vertically required for erection. Must be air-sealed on-site.



# MODULES ARRIVE ON SITE WITH KITCHEN CABINETS INSTALLED



# MODULAR CONSTRUCTION PROGRESS PHOTOS



# MODULAR CONSTRUCTION PROGRESS PHOTOS



# MODULAR CONSTRUCTION PROGRESS PHOTOS

1

Exposed marriage joints prior to sealing and concealment behind fireproof sheathing (green)



2

Typical marriage joint w/air sealing tape over foamed joints



3

Typical belly band at podium with Airtight Tape being applied



4

Completed air barrier (prior to ZIP-R cladding / insulation / weather barrier install)





# MODULAR CONSTRUCTION PROGRESS PHOTOS



Copyright Perkins Eastman

# MODULAR CONSTRUCTION PROGRESS PHOTOS



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# FIELD VERIFICATION



# FIELD VERIFICATION: BLOWER DOOR TEST PLAN

FINAL TESTING: WHOLE BUILDING AIR TIGHTNESS TARGET = 3654 CFM @ -50PA



**Main Office:**  
231 Main St., Suite 103  
PO Box 96, New Paltz, NY 12561  
(845) 255-0418

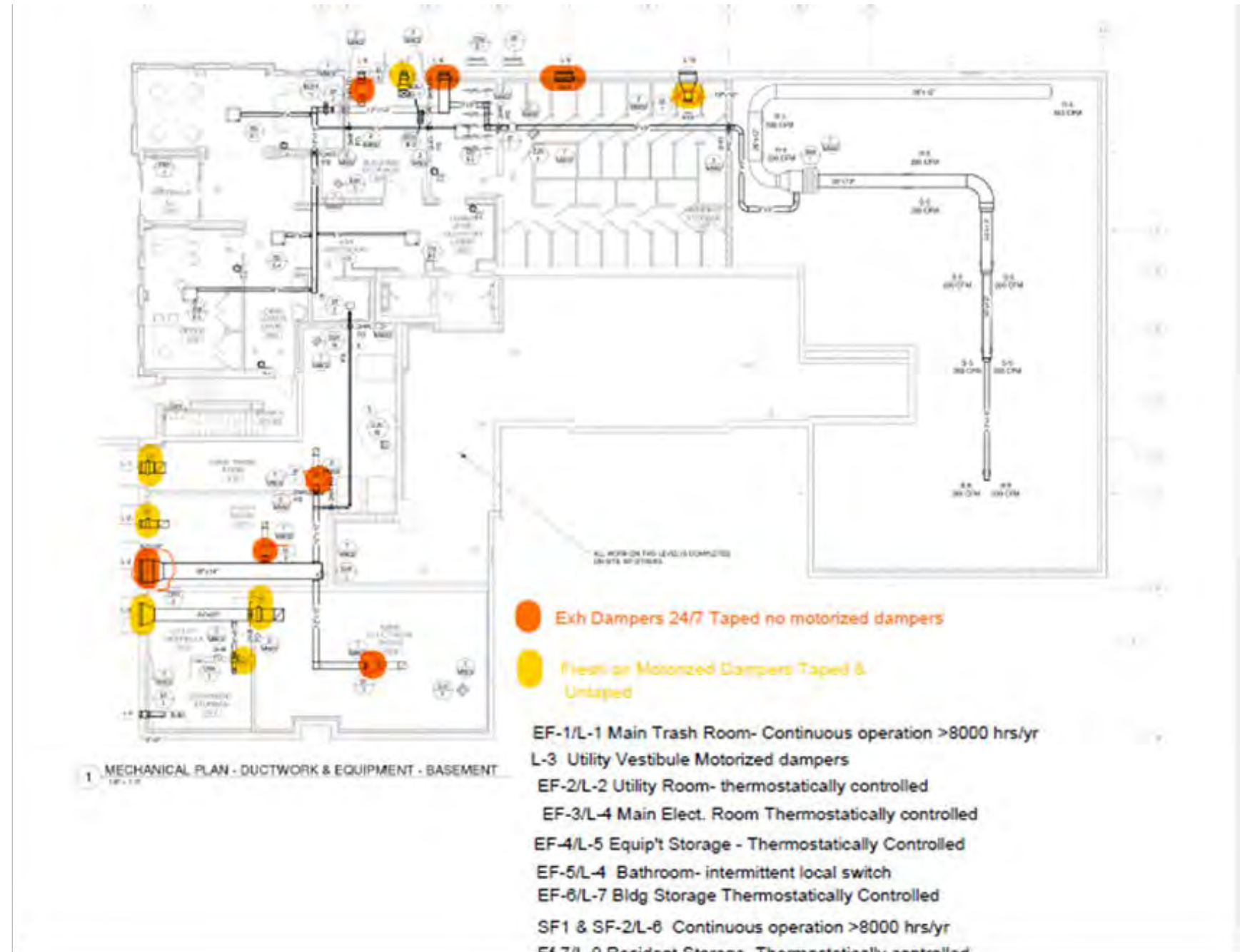
**Lower Hudson Valley:**  
15 N. Mill St., Suite 218  
Nyack, NY 10960  
(845) 535-3035

## PHIUS+ 2021 Whole-Building Testing Plan

LaMora Senior Living  
The Mulford Corporation  
23 Mulberry Street  
Yonkers, NY 10701



Prepared by:  
Anthony V. Lisanti CEM, CPHC  
Phius Rater/Verifier  
Integral Building + Design, Inc.  
April 12, 2023



# FIELD VERIFICATION: BLOWER DOOR TESTING




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# FIELD VERIFICATION: BLOWER DOOR TESTING & RESULTS



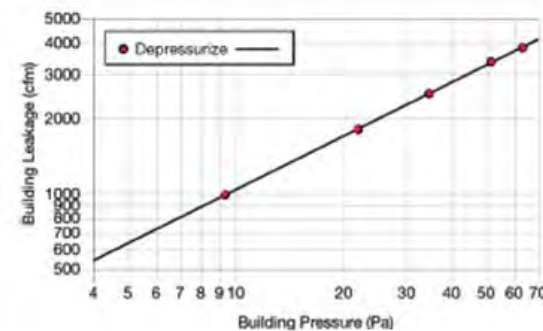
**Envelope Leakage Test** 

<b>Testing Company:</b>	<b>Technician:</b>
Name: Integral Building + Design	Name: Anthony Lisanti CEM, CPHC
Address: 15 N. Mill Street Suite 218 Nyack, NY 10960 Phone: 845 535 3035	Credentials: CEM CPHC Phius Rater/Verifier QAD Email: tony@integralbuilding.com

<b>Building Information:</b>	<b>Customer Information:</b>
Project ID: LaMora Whole Bldg Final	Name: LaMora /Mulford/MHACY
Address: 23 Mulberry St Yonkers, NY 10701	Address: 23 Mulberry St Yonkers, NY
Year Built: 2024	
Geo-Tag Data: Latitude: 40.937088 Longitude: -73.882623 Timestamp: 2024-03-27 10:29:14	

<b>Measured Leakage:</b>	0.05 CFM50/ft <sup>2</sup> (Env. Area)
<b>Leakage Target:</b>	0.06 CFM50/ft <sup>2</sup> (Env. Area)
<b>Compliance with Leakage Target:</b>	Pass

Test ID: Depressurization Taped Whole Bldg Test 6-6-24	
Purpose of Test: RESNET Multi-Pt Env. Leakage	
Measured CFM50: 3,257.4 (+/- 1.2%)	Effective Leakage Area: 153.4 in <sup>2</sup>
Building Volume: 443,142.0 ft <sup>3</sup>	Enclosure Surface Area: 60,903.0 ft <sup>2</sup>
Coefficient (C): 201.8 (+/- 4.6%)	Exponent (n): 0.711 (+/- 0.013)
Correlation Coefficient: 0.99995	
Test Standard: RESNET 380 Multi-Point	Test Mode: Depressurize
Test Characteristics: Indoor Temp: 73 °F	Outdoor Temp: 73 °F
Altitude: 121.0 ft	Time Average Period: 10 seconds
Test Date and Time: 2024-06-06 09:43:45	



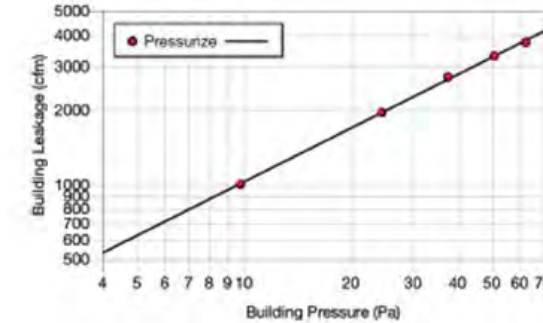
**Envelope Leakage Test** 

<b>Testing Company:</b>	<b>Technician:</b>
Name: Integral Building + Design	Name: Anthony Lisanti CEM, CPHC
Address: 15 N. Mill Street Suite 218 Nyack, NY 10960 Phone: 845 535 3035	Credentials: CEM CPHC Phius Rater/Verifier QAD Email: tony@integralbuilding.com

<b>Building Information:</b>	<b>Customer Information:</b>
Project ID: LaMora Whole Bldg Final	Name: LaMora /Mulford/MHACY
Address: 23 Mulberry St Yonkers, NY 10701	Address: 23 Mulberry St Yonkers, NY
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<b>Measured Leakage:</b>	0.05 CFM50/ft <sup>2</sup> (Env. Area)
<b>Leakage Target:</b>	0.06 CFM50/ft <sup>2</sup> (Env. Area)
<b>Compliance with Leakage Target:</b>	Pass

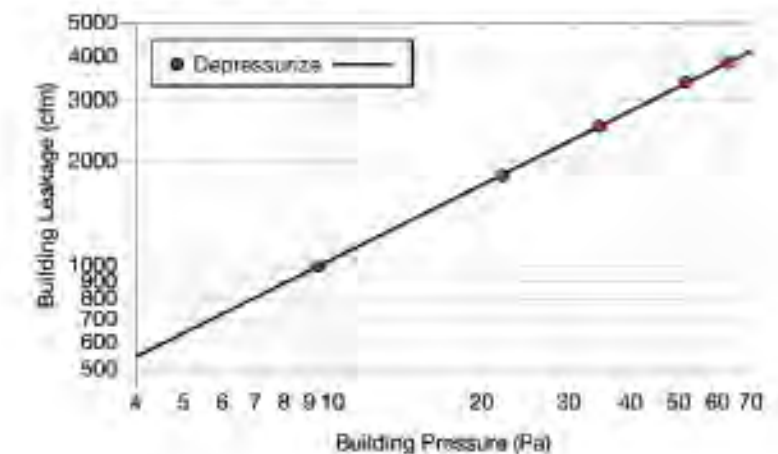
Test ID: Pressurization Taped Whole Bldg 6-6-24	
Purpose of Test: RESNET Multi-Pt Env. Leakage	
Measured CFM50: 3,256.5 (+/- 3.1%)	Effective Leakage Area: 150.7 in <sup>2</sup>
Building Volume: 443,142.0 ft <sup>3</sup>	Enclosure Surface Area: 60,903.0 ft <sup>2</sup>
Coefficient (C): 198.2 (+/- 13.5%)	Exponent (n): 0.718 (+/- 0.039)
Correlation Coefficient: 0.99957	
Test Standard: RESNET 380 Multi-Point	Test Mode: Pressurize
Test Characteristics: Indoor Temp: 73 °F	Outdoor Temp: 73 °F
Altitude: 121.0 ft	Time Average Period: 10 seconds
Test Date and Time: 2024-06-06 09:50:50	



# WHOLE BUILDING AIR TIGHTNESS FINAL TESTING

- Whole Building Air Tightness Target = 3654 CFM @ -50 Pa (**0.06 CFM/SF**)
- Test 1 = **0.12 CFM**
- Test 2 = **0.08 CFM**
- Test 3 = **0.07 CFM**
- Final = **0.053 CFM** avg depressurization/pressurization  
**0.061 CFM** untaped

Envelope Leakage Test			
<b>Testing Company:</b>		<b>Technician:</b>	
Name:	Integral Building + Design	Name:	Anthony Lisanti CEM, CPHC
Address:	15 N. Mill Street Suite 218 Nyack, NY 10980 Phone: 845 535 3035	Credentials:	CEM CPHC Phius Rater/Verifier QAD
		Email:	tony@integralbuilding.com
<b>Building Information:</b>		<b>Customer Information:</b>	
Project ID:	LaMora Whole Bldg Final	Name:	LaMora /Mulford/MHACY
Address:	23 Mulberry St Yonkers, NY 10701	Address:	23 Mulberry St Yonkers, NY
Year Built:	2024		
Geo-Tag Data:	Latitude: 40.937088 Longitude: -73.882623 Timestamp: 2024-03-27 10:29:14		
<b>Measured Leakage:</b>	0.05 CFM50/ft <sup>2</sup> (Env. Area)		
<b>Leakage Target:</b>	0.06 CFM50/ft <sup>2</sup> (Env. Area)		
<b>Compliance with Leakage Target:</b>	Pass		
Test ID:	Depressurization Taped Whole Bldg Test 8-8-24		
Purpose of Test:	RESNET Multi-Pt Env. Leakage		
Measured CFM50:	3,257.4 (+/- 1.2%)	Effective Leakage Area:	153.4 in <sup>2</sup>
Building Volume:	443,142.0 ft <sup>3</sup>	Enclosure Surface Area:	60,803.0 ft <sup>2</sup>
Coefficient (C):	201.8 (+/- 4.6%)	Exponent (n):	0.711 (+/- 0.013)
Correlation Coefficient:	0.99995		
Test Standard:	RESNET 380 Multi-Point	Test Mode:	Depressurize
Test Characteristics:	Indoor Temp: 73 °F Altitude: 121.0 ft	Outdoor Temp:	73 °F
Test Date and Time:	2024-06-06 09:43:45	Time Average Period:	10 seconds



# PHIUS CERTIFICATION ACHIEVED IN OCTOBER 2024





# ENTRY CORNER



Photograph by Andrew Ruggie. Copyright Perkins Eastman

# SOUTH ELEVATION VIEW



Photograph by Andrew Ruggie. Copyright Perkins Eastman

# MAIN ENTRANCE



Photograph by Andrew Ruge. Copyright Perkins Eastman

# ROOF DECK



Photograph by Andrew Ruggie. Copyright Perkins Eastman

# RESIDENT LOBBY



Photograph by Andrew Ruggie. Copyright Perkins Eastman

# CORNER APARTMENT VIEW



Photograph by Andrew Ruggie. Copyright Perkins Eastman

# LESSONS LEARNED



**AIA**<sup>®</sup>

**Document G701<sup>®</sup> – 2017**

## ***Change Order***

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**PROJECT:** *(Name and address)*

La Mora Senior Living  
23 Mulberry Street  
Yonkers, NY 10710

**OWNER:** *(Name and address)*

La Mora LLC  
1511 Central Park Avenue  
Yonkers, NY 10710

**CONTRACT INFORMATION:**

Contract For: General Contracting

Date: 06/16/2022

**ARCHITECT:** *(Name and address)*

Perkins Eastman  
677 Washington Boulevard  
Stamford, CT 06901

**CHANGE ORDER INFORMATION:**

Change Order Number: 007

Date: 06/23/2023

**CONTRACTOR:** *(Name and address)*

Andron Construction  
21 Anderson Lane  
Goldens Bridge, NY 10526

## LESSONS LEARNED & TAKE-AWAYS

- Better to use consultants who have prior Passive House experience
- Allow time in the design schedule for the design team to refine and revise documents based on reviews by the CHPC (i.e. WUFI analysis) – and make sure CHPC performs the reviews on schedule.
- Make sure Passive House requirements are well defined in the Construction Documents
  - Detail the continuous envelope – make it clear
  - Include diagrams – Don't just rely on plans/sections/details
  - Use color to highlight critical membranes and air control layers
  - Include required testing (and related scheduling) in Specifications
  - Define contractor's responsibilities regarding passing necessary tests



## LESSONS LEARNED & TAKE-AWAYS

- Engage the Rater/Verifier early in the design phase- not after construction scope is completed to ensure co-requisite programs are integrated into the design process
- Optimize building envelope/air barrier design – did we need three layers of sheathing on the bldg.? Possibly minimize layering and maintain the fireproofing qualities with two layers- i.e. eliminate the ZIP- R and the USG Green Board in favor of Rockwool panels with battens over factory applied OSB/Plywood
- Understand the limitations of central ventilation systems – inability to boost airflow, difficulty with air balancing/commissioning
- Redefine phius boundaries – i.e. including crawl space within Phius envelope.
- Renew effort to optimize how water distribution system i.e.- decrease pipe volume, time-to-to hot, ultimately reducing installation costs.
- Include power monitoring systems in work scope for critical equipment- DWH, back up storage tanks, recirc pumps, ERU's, apartment level consumption for ASHP's, exhaust fans
- There was no comprehensive post construction lessons learned, trading of information to make improved design decisions directly with ownership. The cost of learning was steep- why not leverage that for any future projects?

# LESSONS LEARNED & TAKE-AWAYS

- Identify the phius certified enclosure quickly and with the input of the air-testing agent. Areas of attention in large buildings: trash chutes, laundry rooms, egress stairs and elevator shafts
- Trash chutes - cost benefit analysis between
  1. the detailing required to cut it out of the phius enclosure
  2. including it in the enclosure and taking the energy hit from ventilation requirements
- Laundry rooms - how will makeup air be provided for direct-exhaust dryers. Does it make sense to cut the laundry room out of the enclosure to reduce heat loss in the rest of the building
- Egress stair / Elevators - how do these connect the phius enclosure to non-enclosure spaces and what level or airtightness is required for doors, etc.
- Active systems in large buildings have more pump, fan and aux energy that will need to be accounted for - potentially jeopardizing the source energy phius target
- Insulated floors must adhere to the Certification guidebook appendix B moisture control requirements - generally they must follow the same guidelines as wells, however floors with vapor-open "fluffy" insulation must ALSO pass a bulk-wetting test if 'wet' programs are located above
- Modular construction may require different detailing than stick-built. For instance, the mating joint between floor and ceiling of modular units was double-framed and the connection must be designed to provide air, vapor and thermal continuity when joined onsite

