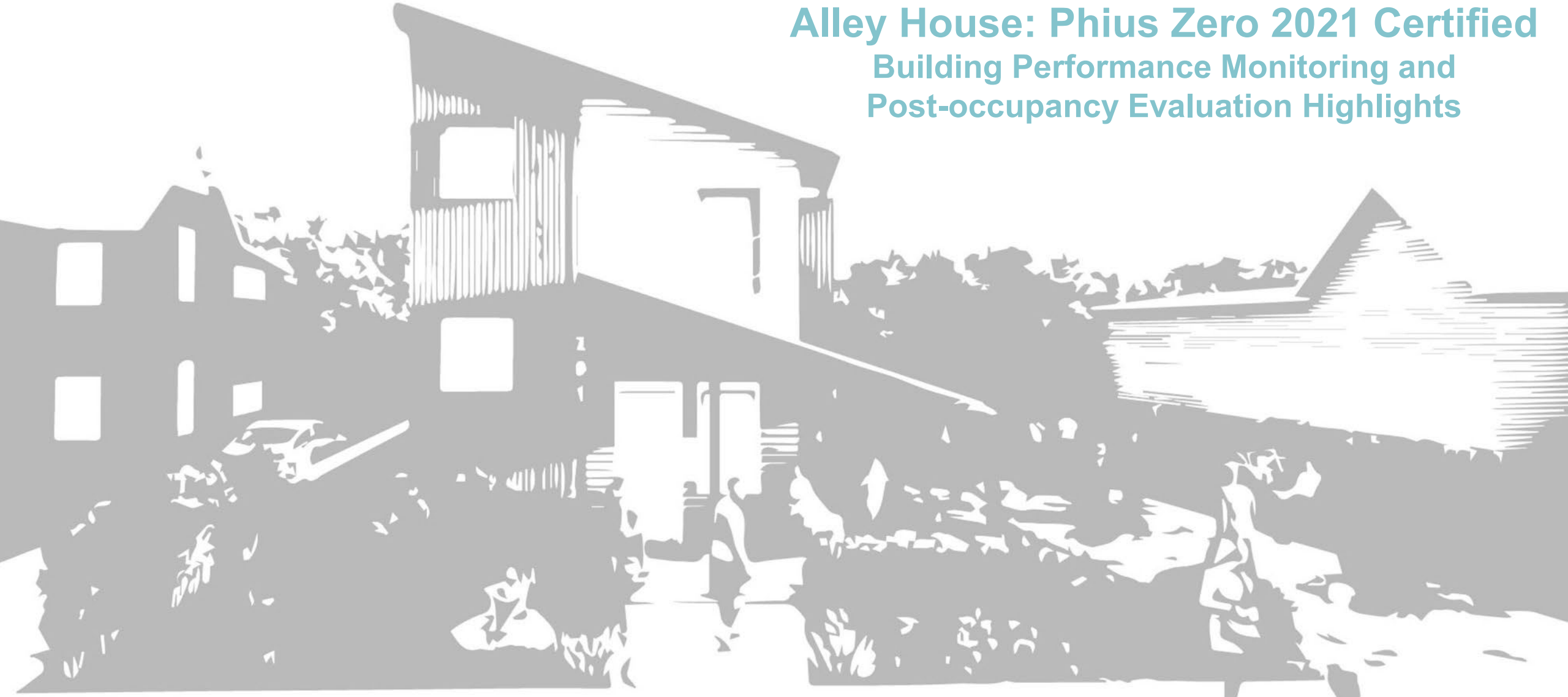
Alley House: Phius Zero 2021 Certified

Building Performance Monitoring and Post-occupancy Evaluation Highlights



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Professor of Architecture
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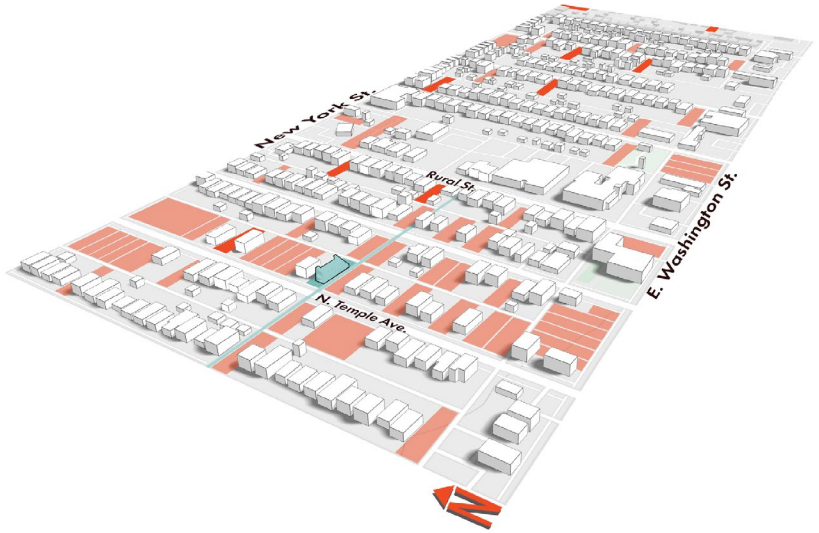
Shannon Stendel, PMP
Senior Manager
Slipstream

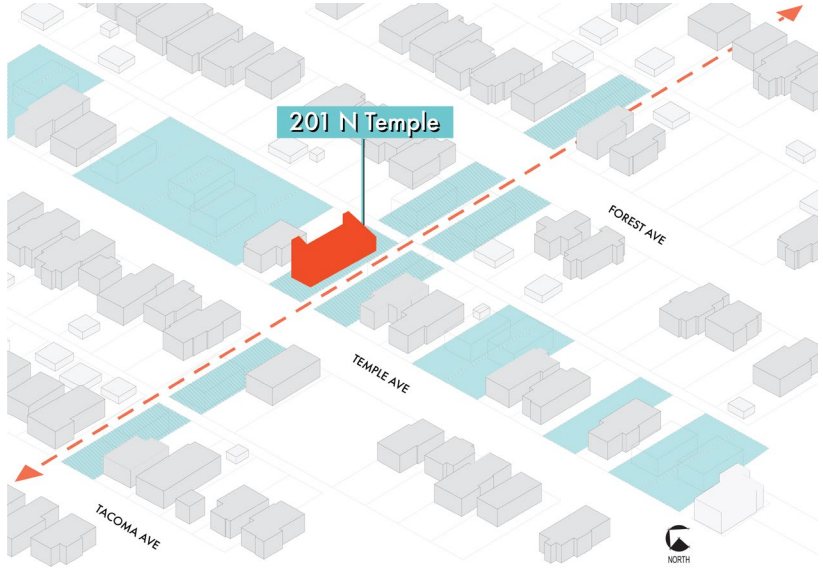
Background: The Alley House, Indianapolis

Solar Decathlon Build Challenge 2023

Form Development: Solar Equity

The alley, giving the Alley House its name, highlights an existing east west alley.





INITIAL VOLUME

Long south face toward alley

CREATE TWO UNITS

Short demising wall between units

EXTEND STAIR CORE & ACTIVATE THE ALLEY

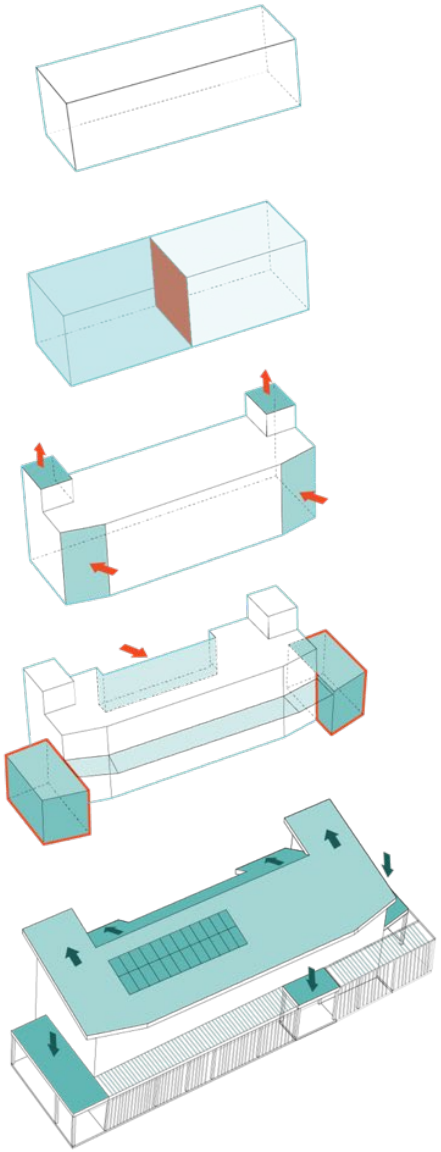
Elevate stair angled wall for view to alley

DEFINING ENTRANCES & SECOND FLOOR SPACES

Porch placement and secondary entries

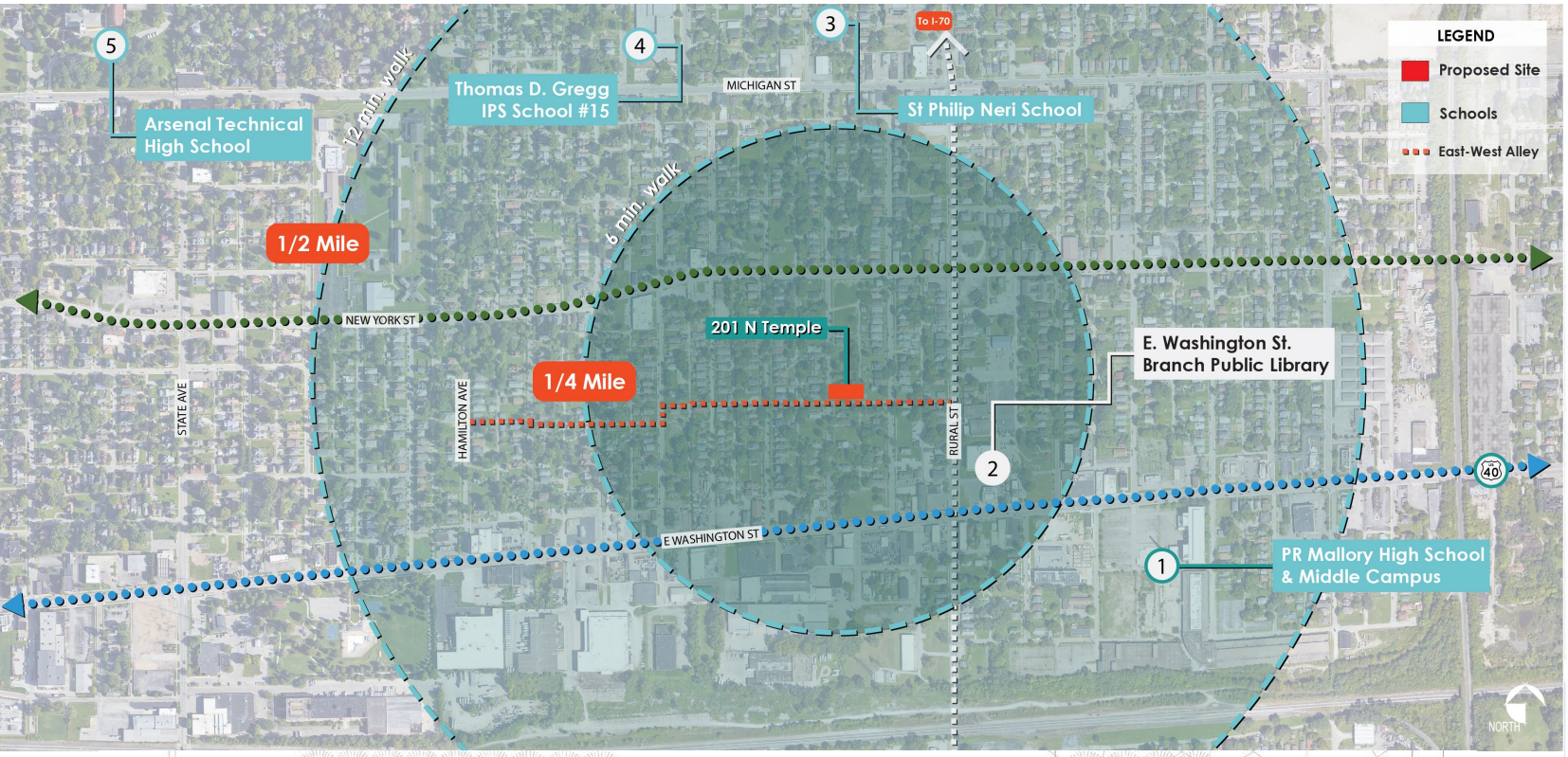
ROOF PITCH STUDY & ADDITION OF EAST AND WEST PORCHES

Addition of PV array on 4/12 pitch facing south roof



Urban Planning: Front to Back Family Units

"Cradle to college" planning strategy allows families to walk to local schools



Variety of Family Types

The Alley House achieves the priorities of Architecture, Affordability, and Inclusivity set by the community and Englewood CDC where the median household income is $25,000 providing with-

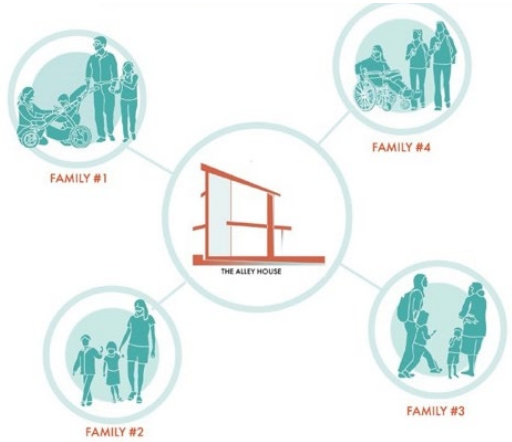
- Affordable & attainable housing
- Environmentally conscious designs

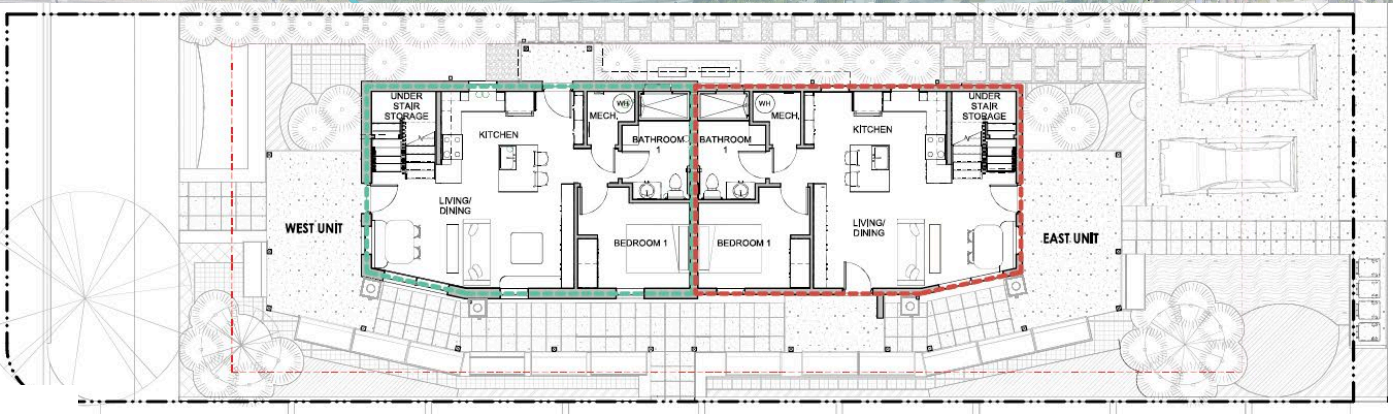
FAMILY#1
A family with couple and young children

FAMILY#2
A family with young children and single parent

FAMILY#3
A family with elderly member

FAMILY#4
A family with specially able member





First Floor Plan: West and East Unit

1st floor: 1 bedroom, 1 full bath, kitchen/living, porch, & mechanical. Each unit is 1,380 SF

FIRST FLOOR PLAN

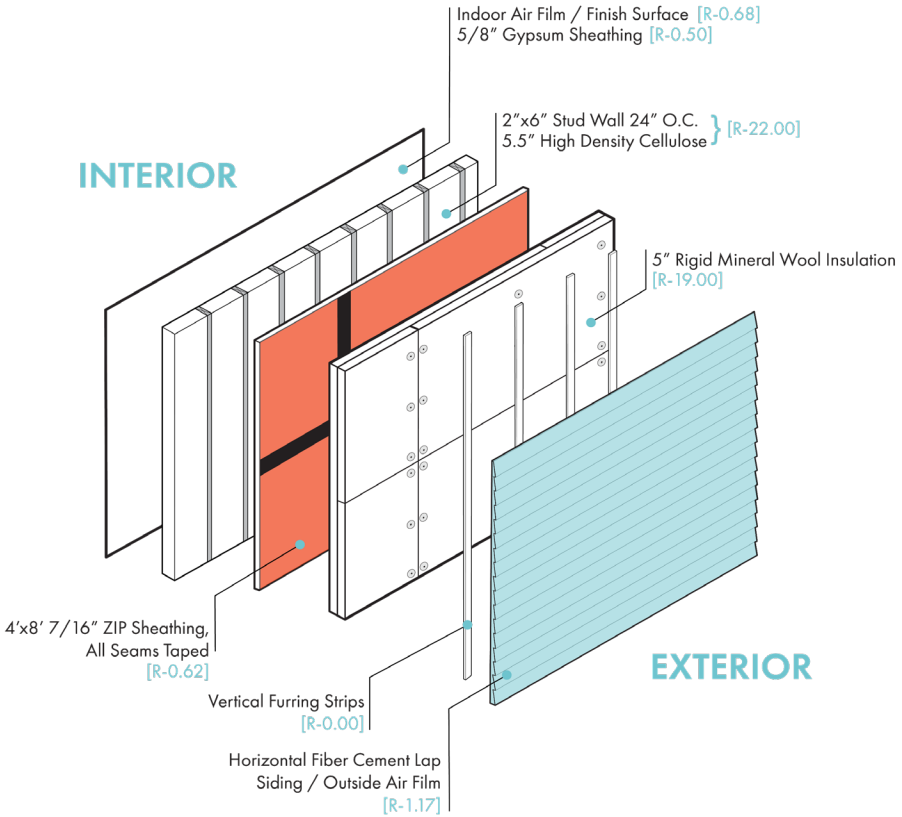
2 0 2 4 6 8 10
SCALE FEET

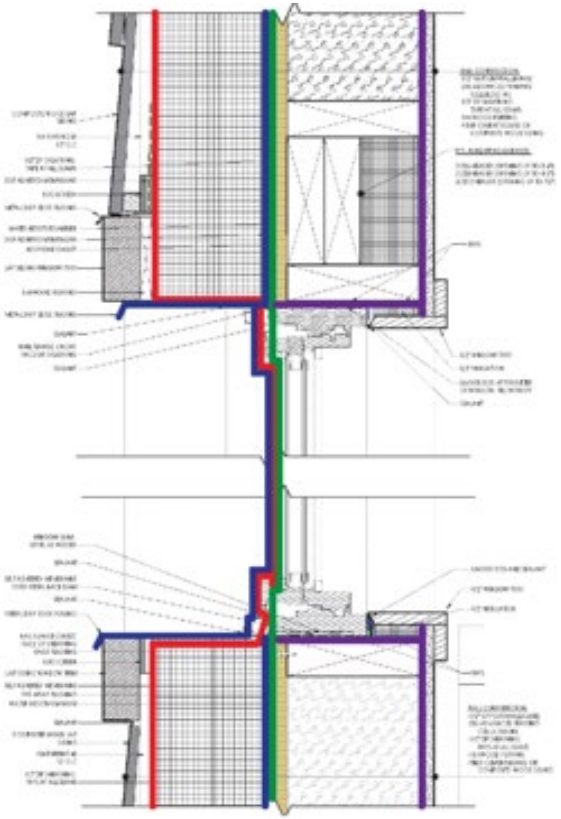
Kitchen as the Heart of Home

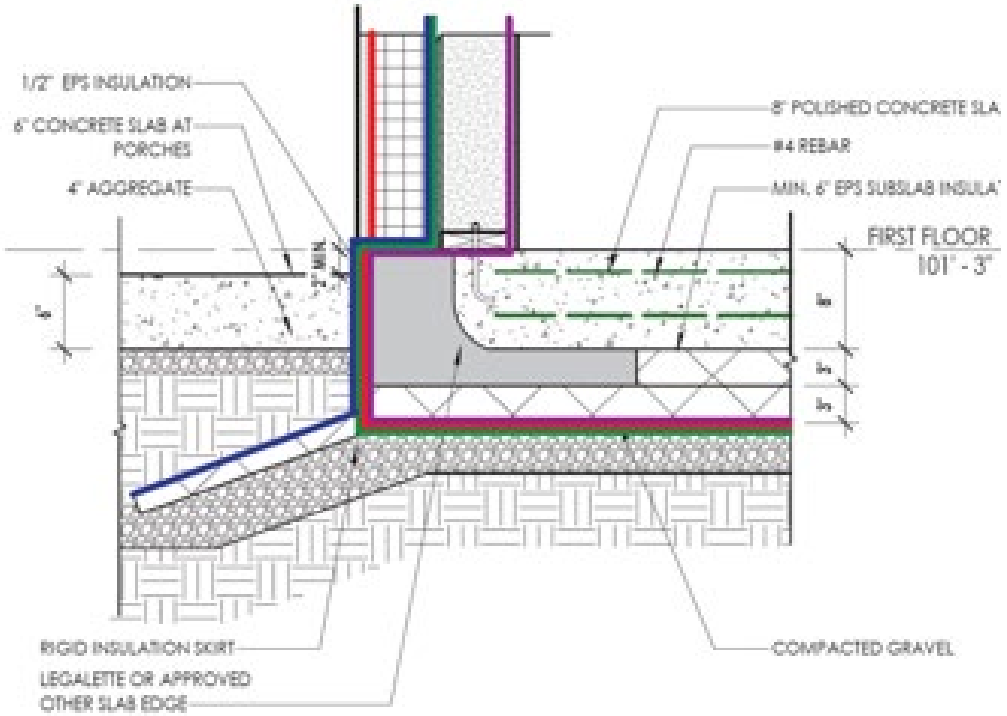
Second Floor Plan: West and East Unit

2nd floor: 2 bedrooms, 1 full bath, laundry, a multi-purpose flex space, and a special space at the top stair landing.

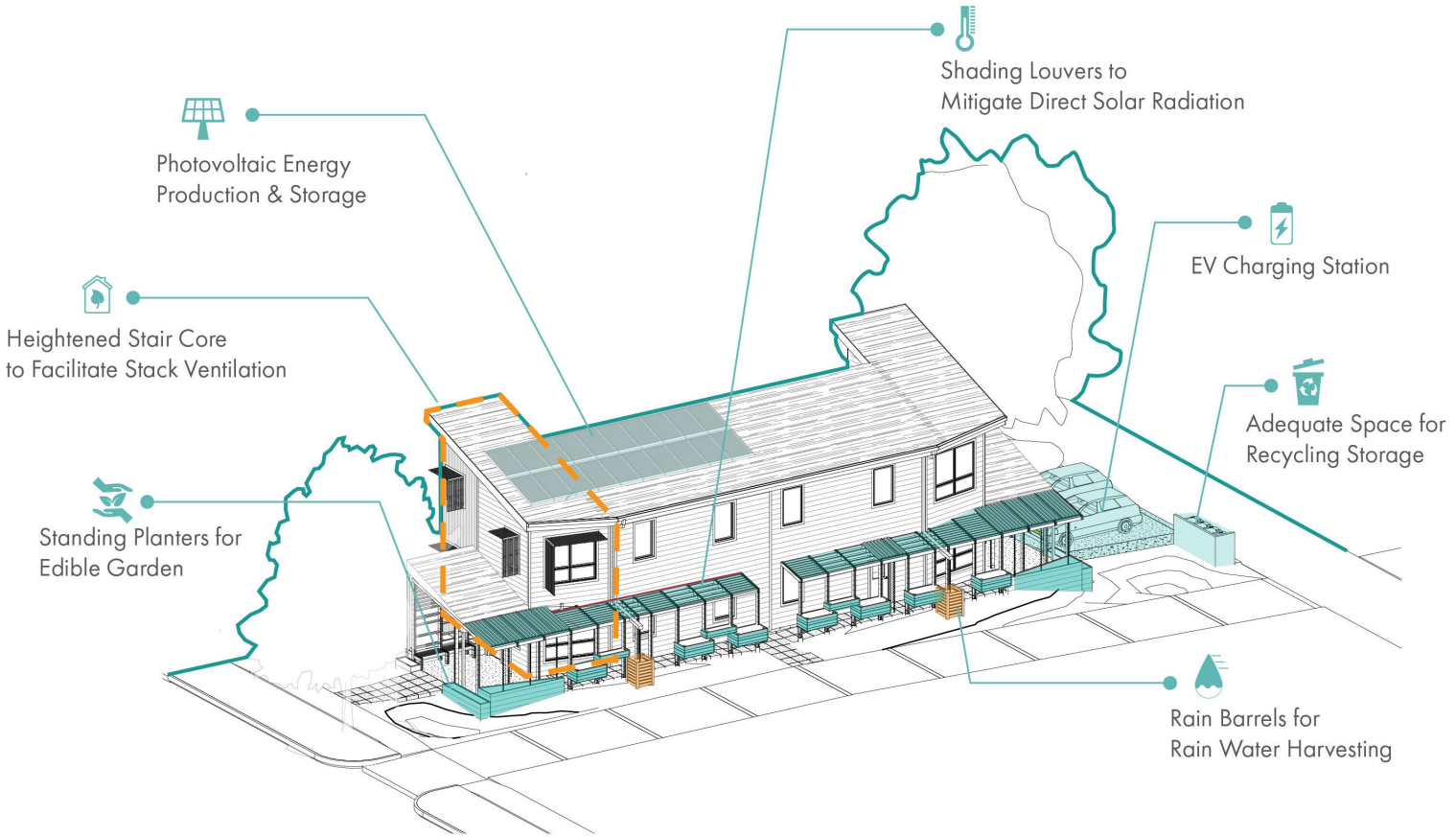
Exterior Envelope: 5.5” dense-pack cellulose cavity insulation with 5” mineral wool board continuous insulation.

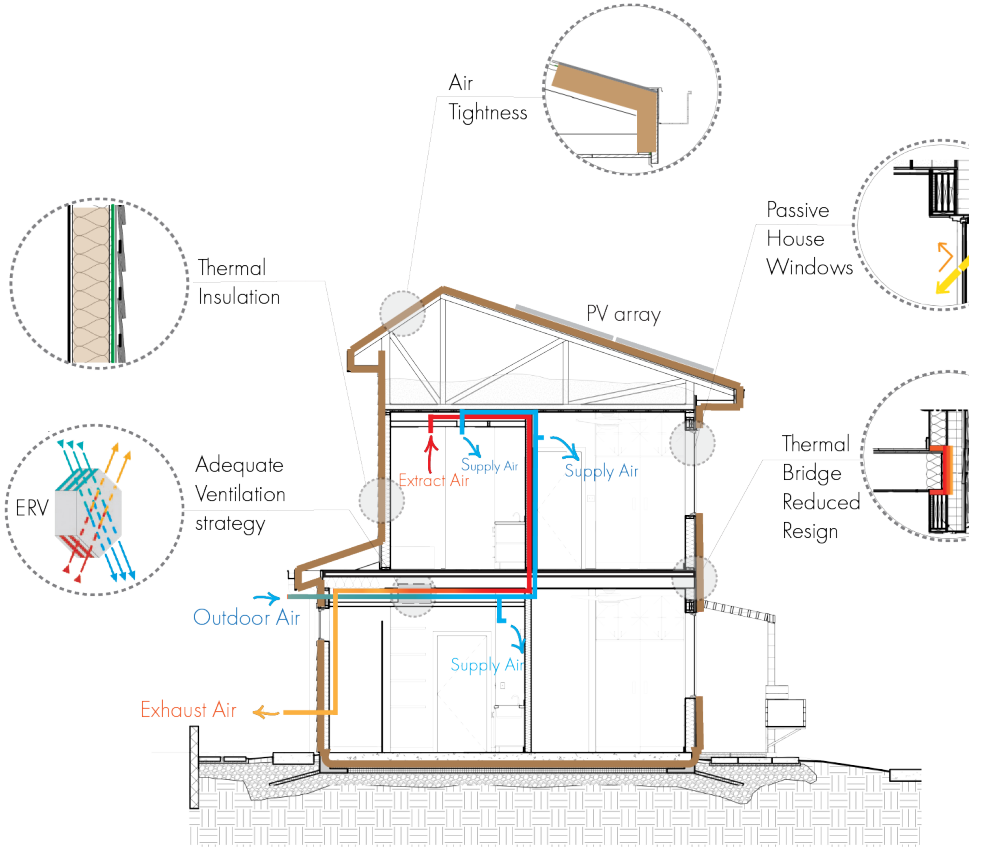




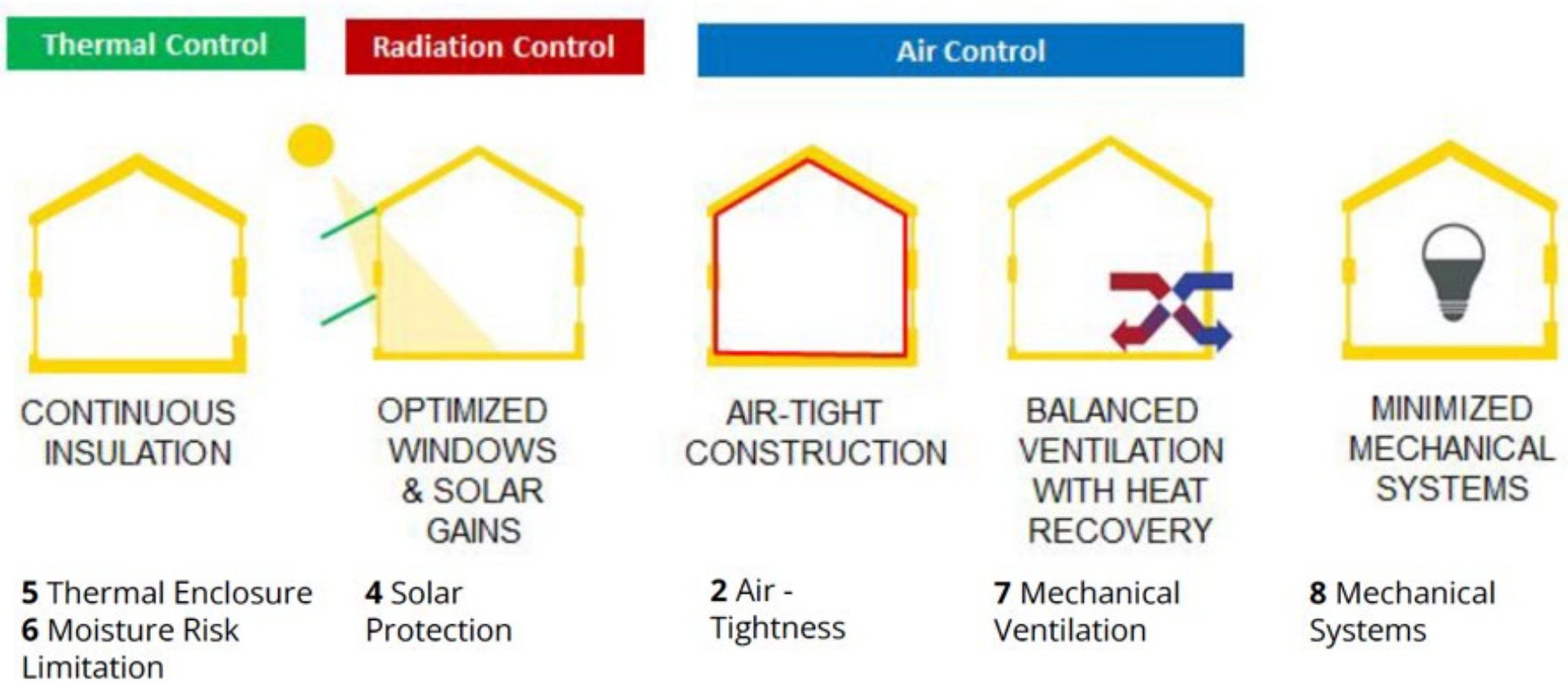


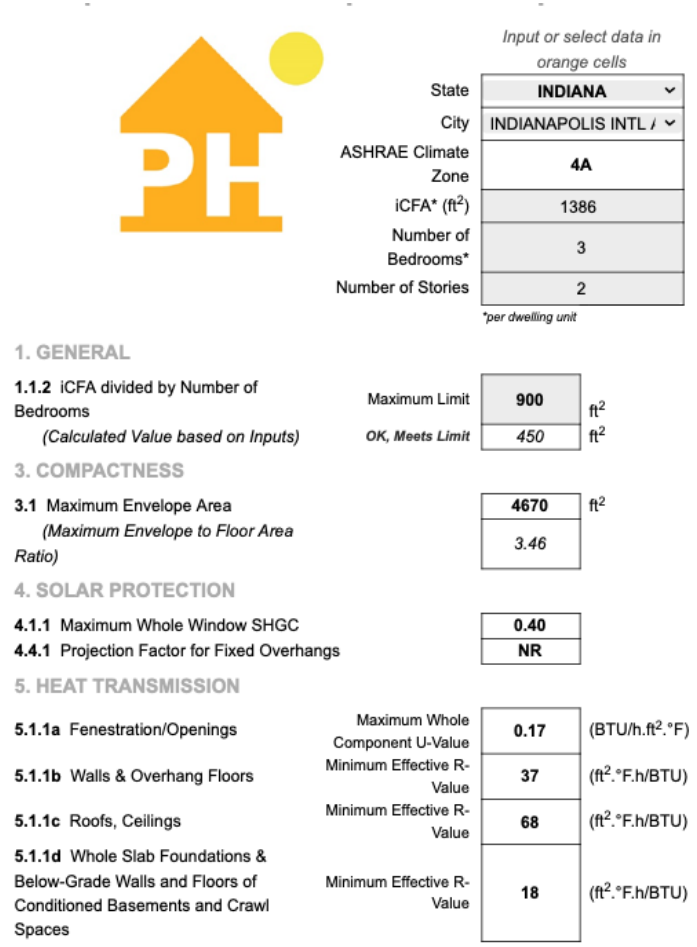
Sustainability strategies are visible on the exterior.
Building envelope performance focuses on airtightness & thermal bridging





PHIUS Core 2021 Certified – Alley House West Unit (PB) was initially Designed to meet the PHIUS Core Prescriptive Certification





Input or select data in orange cells

State	INDIANA
City	INDIANAPOLIS INTL /
ASHRAE Climate Zone	4A
iCFA* (ft^2)	1386
Number of Bedrooms*	3
Number of Stories	2

**per dwelling unit*

1. GENERAL

1.1.2 iCFA divided by Number of Bedrooms	Maximum Limit	900	ft^2
(Calculated Value based on Inputs)	*OK, Meets Limit*	*450*	ft^2

3. COMPACTNESS

3.1 Maximum Envelope Area		4670	ft^2
(Maximum Envelope to Floor Area Ratio)		*3.46*	

4. SOLAR PROTECTION

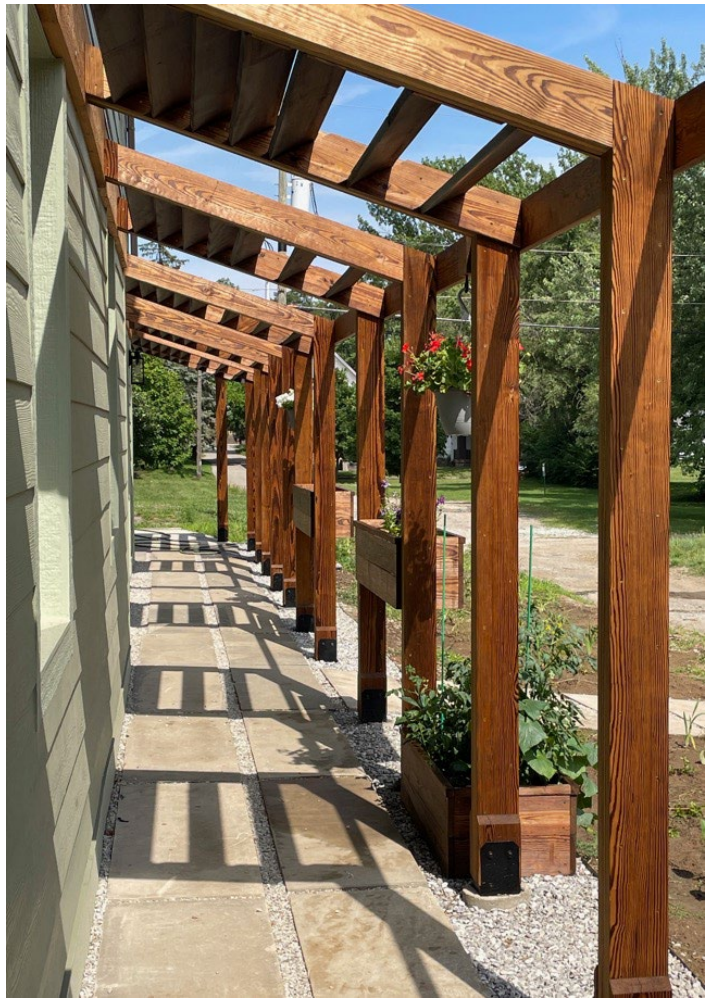
4.1.1 Maximum Whole Window SHGC		0.40	
4.4.1 Projection Factor for Fixed Overhangs		NR	

5. HEAT TRANSMISSION

5.1.1a Fenestration/Openings	Maximum Whole Component U-Value	0.17	(BTU/h.ft^2.°F)
5.1.1b Walls & Overhang Floors	Minimum Effective R-Value	37	(ft^2.°F.h/BTU)
5.1.1c Roofs, Ceilings	Minimum Effective R-Value	68	(ft^2.°F.h/BTU)
5.1.1d Whole Slab Foundations & Below-Grade Walls and Floors of Conditioned Basements and Crawl Spaces	Minimum Effective R-Value	18	(ft^2.°F.h/BTU)

Thermally Modified Wood: Biophilic Design

The Alley House uses thermally modified wood (pine + poplar) inside and out to create biophilic spaces.



Community Engagement Activities

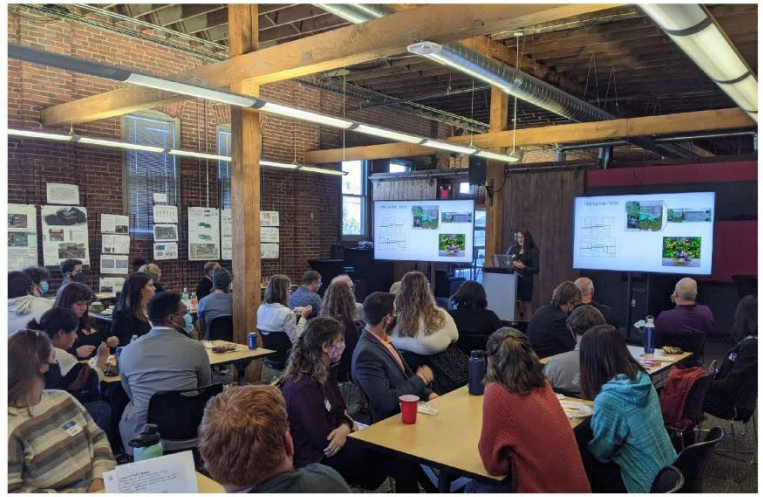
Extensive community engagement during the design process with students.

Ground Breaking Ceremony July 2022

DayStar Childcare Visit and Interaction with Prototype Modular Storage Bins June 2022

Soil Sample Collection July 2022

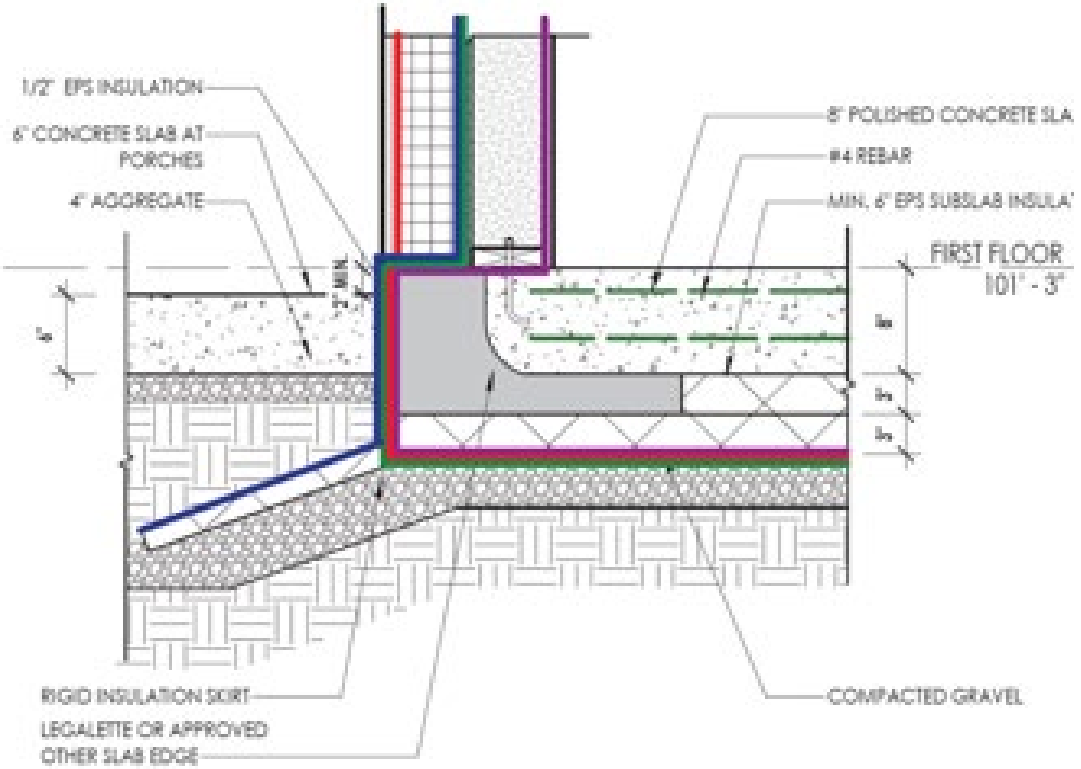
State Farm Neighborhood Assist Grant July 2022



Community Open House CAP:INDY Fall 2021

Frost-protected Shallow Foundation

8” Frost-protected shallow foundation (FPSF) by Legalett, sits on 6” EPS foam board.



Advanced Framing

2x6 Advanced framing wall system (studs 24” oc) was used with TJI floor framing

West unit built to PHIUS (PB) standards, East unit built to better than code-compliant standards

Student Design-Build: Cabinetry + Modulars

Ball State students designed, built, & installed all interior cabinetry, from kitchen cabinets to media

Installation of Modular, Stackable Cubes

Students building the stair screen and installing built-in storage cubby units. The shelf is reclaimed walnut.

Public Open House Events

We held public open house events to showcase the units and interact with the community.

Alley House: National Awards

The Alley House has won several national awards from SARA, AIA, & USDOE. And TODAY a Phius Award!

Resident Guide: Meeting with Amber

We created a resident guide explaining the sustainable features of each unit and met with the tenants to go over with them

We worked with a high-performance builder who helped students to understand and apply important energy optimization details.

Cedar Street Builders

- Zionsville, Indiana
- Owner: Dan Porzel
- Project Coordinator: Anne Rendaci
- https://www.cedarstreetbuilders.com
- Built the first Certified Passive House in Indiana

Performance Specifications

	West Unit (Phius) PB	East Unit (Code+/ZERH)
EUI (Before PV)	17.94	37.54
EUI (After PV)	-13.02	N/A
PV	8.8kW (11,819 kWh/yr)	N/A
Airtightness	0.97 ACH50 (0.06 CFM/SF)	1.98 ACH50
Roof	R-92	R-92
Slab	R-21.6	R-21.6
Walls	R-40	R-20
Window U-factor	0.16-0.18	0.27-0.30
Window SHGC	0.24-0.27	0.26
Window Tvis	0.43-0.50	0.49-0.56
Exterior Doors	0.23	0.23
ERV	0.54 w/CFM	N/A
Multizone Ducted HP **SEER 17.3** **COP Heat 3.10** **COP Cooling 4.82**	1-ton	1.5-ton

Component	Purpose	Issues
eGauge electric energy meter	Electric power measurement on individual circuits	PV offline (8/8/2024-11/16/2024)
Current Transformers (CTs)	Current signal to eGauge	
Hobo MX1101 indoor temp/RH logger	Indoor air temperature & RH	Offline after 11/24/2024
Hobo MX1104 analog logger with current sensor	East-Code+ unit bath fan operation	
Hobo 1105 analog logger with current sensor and temperature sensor	Supply air temperature and blower current at each fan coil	Offline 2/26/25-4/4/2025

Monitor and analyze differences in thermal performance, mechanical ventilation, and load characterization

Thermal Performance	Mechanical Ventilation	Load Characterization
• Characterize system operation • Calculate heating and cooling energy use • Evaluate ability of HVAC to meet loads	• Estimate mechanical ventilation rates (equipment run time and flow rates)	• Net utility energy demand • PV surplus • Overall and peak energy use of HVAC and appliances

- Monitoring equipment to see circuit level usage (eGauge)
- Indoor temperature/RH loggers at thermostats and air vents
- Balometer readings and current sensors used for SeeStack modeling to estimate mechanical ventilation

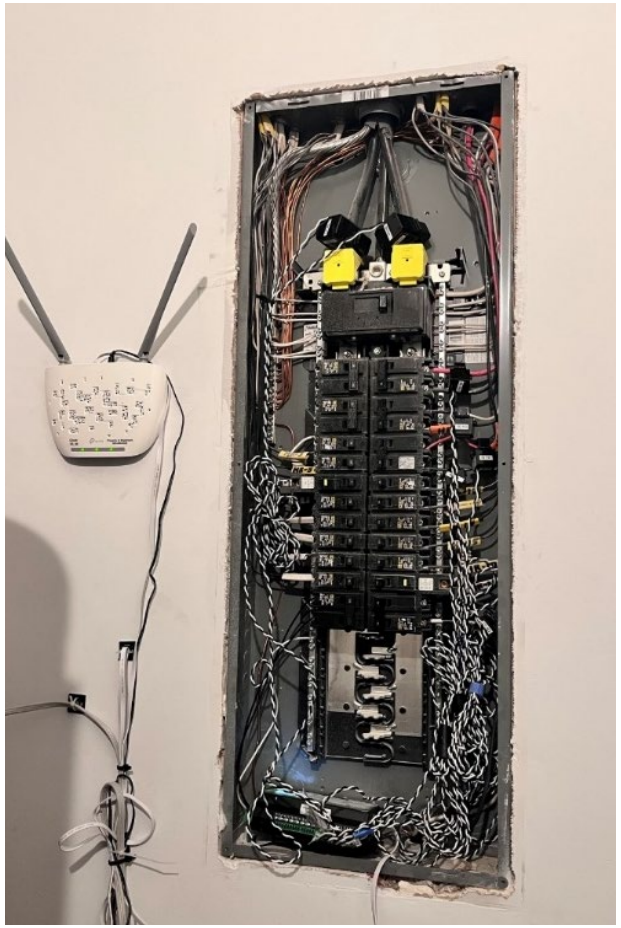
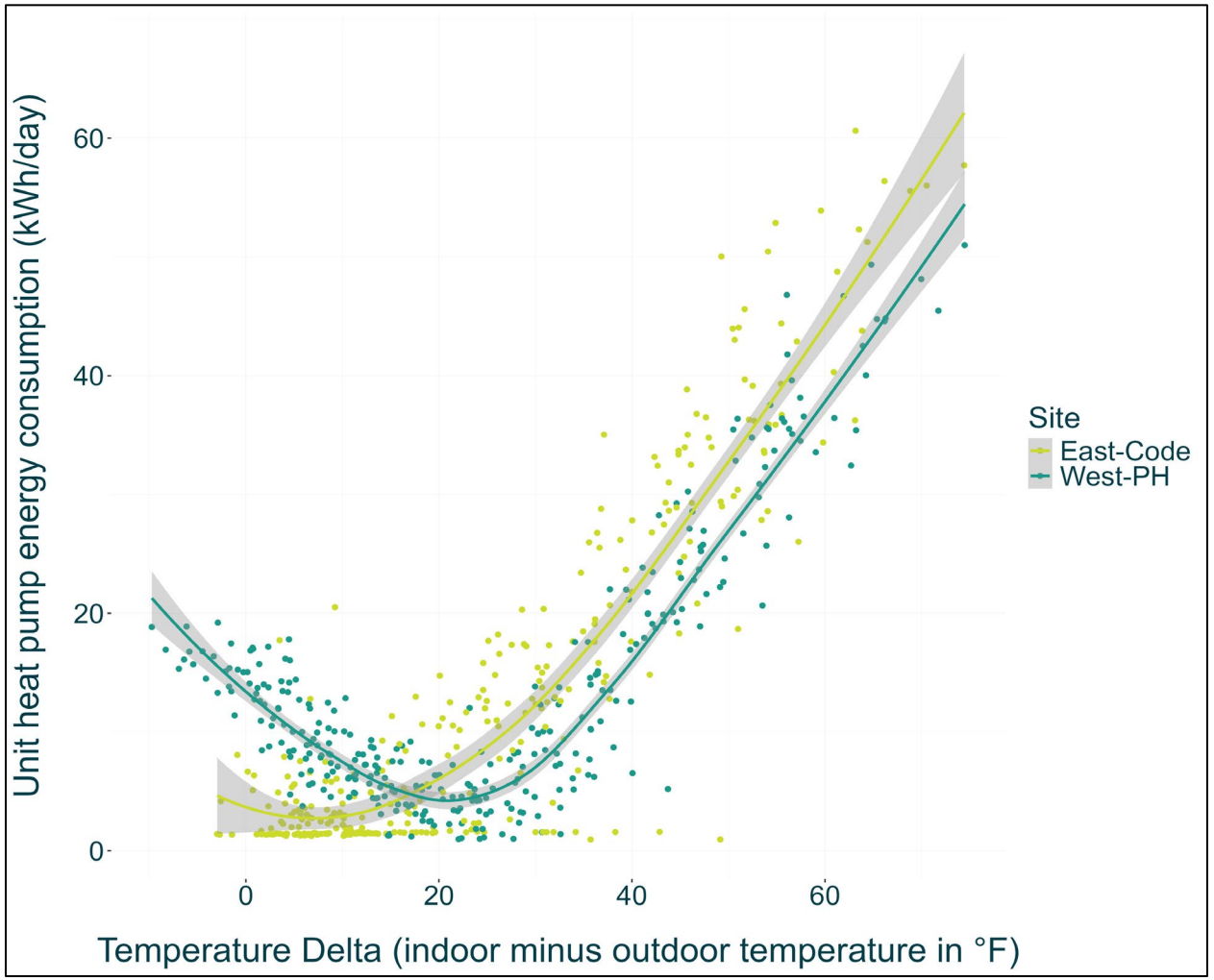


Image Credit: Slipstream

Thermal Performance

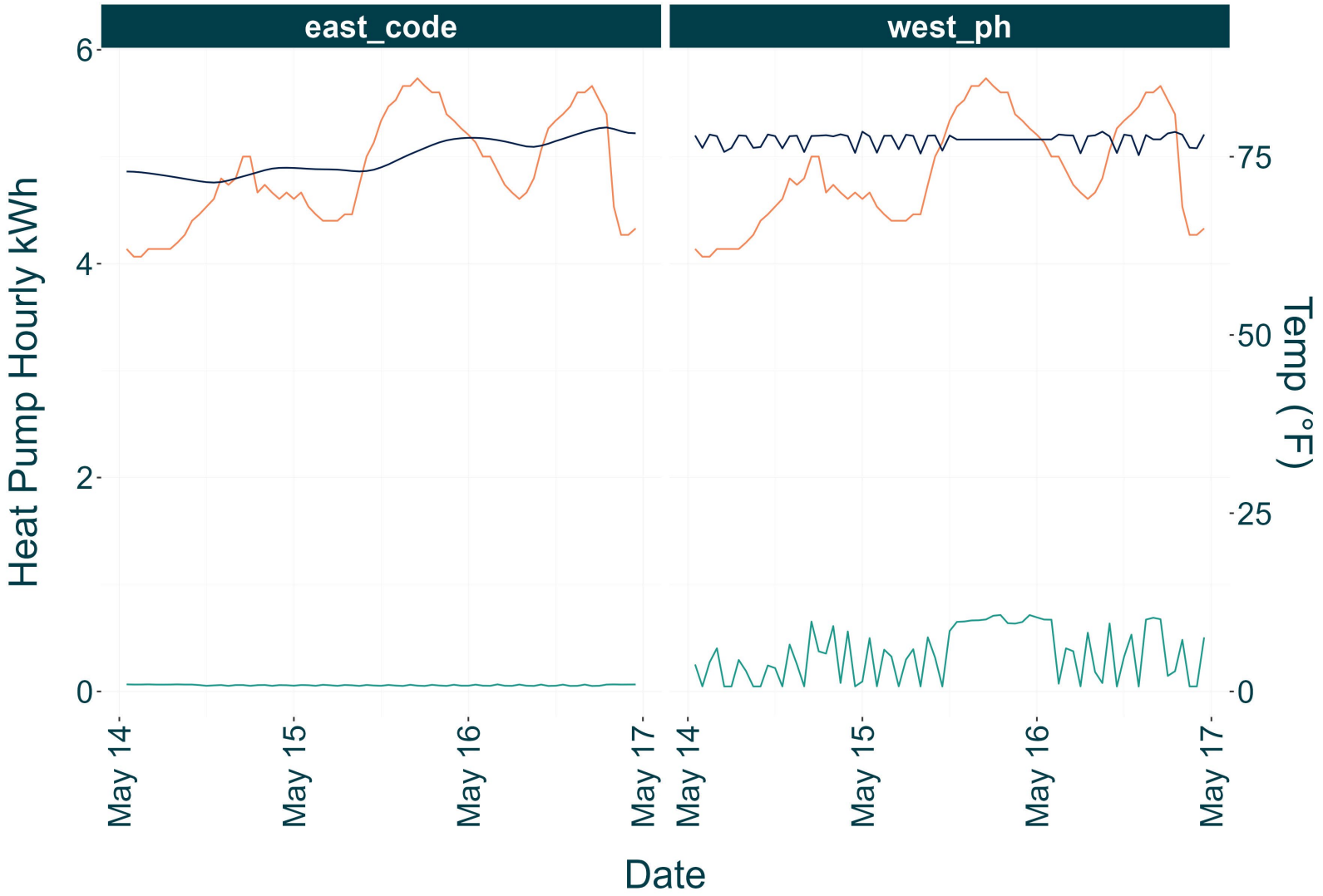


	East-Code unit	West-PH unit	Diff	Diff (%)
Heating Load (kWh/year)	4,130	3,448	681.7	20%
Cooling Load (kWh/year)	446*	1,672	N/A	N/A

* East-Code unit had limited cooling system usage making it difficult to compare cooling usage with the West-PH unit.

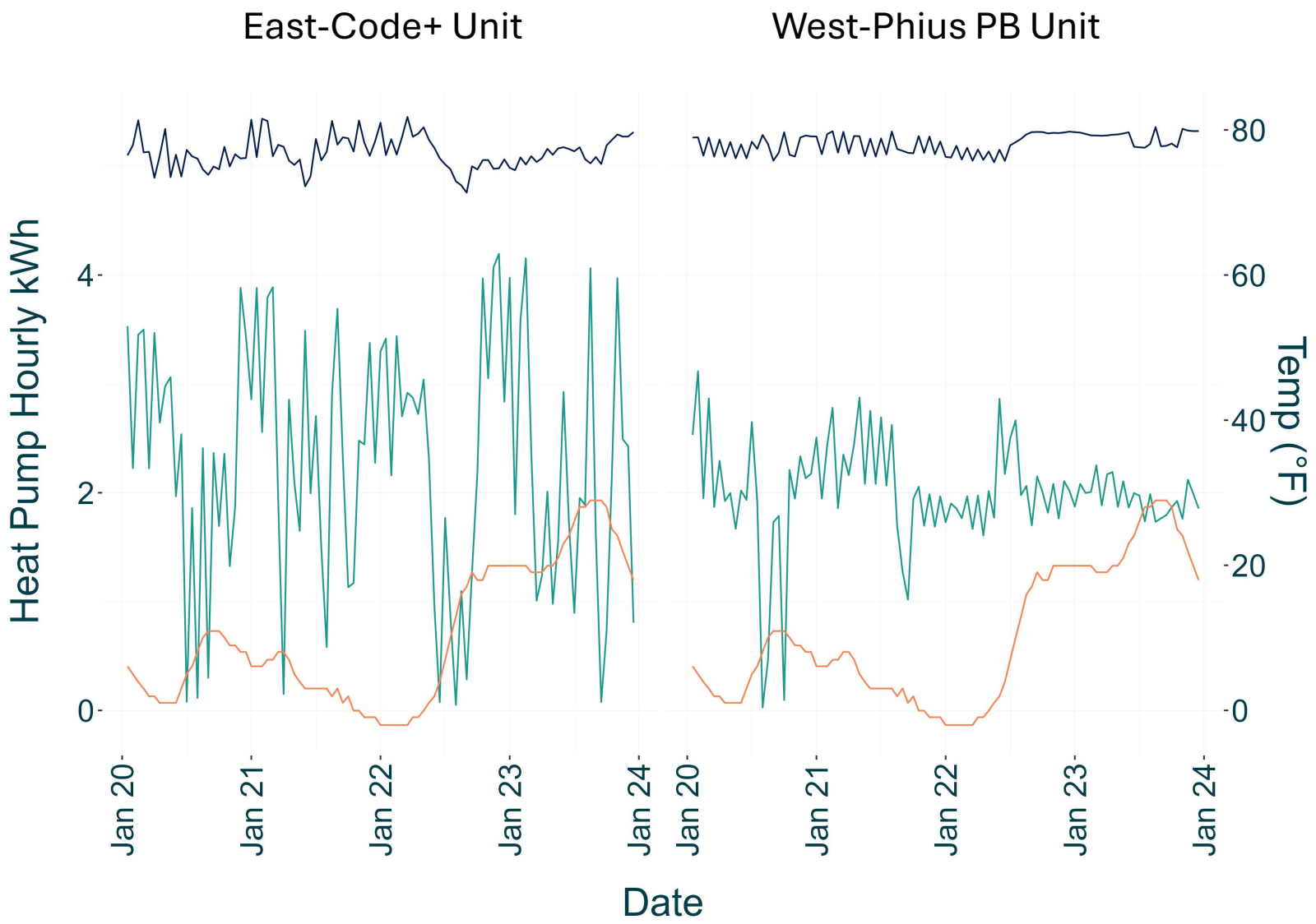
- Heating: Average indoor temperature similar between units
- Cooling: Lower average indoor temperature in West-PH

Occupant Behavior - Cooling



East-Code+ unit: No measurable heat pump power usage

West-PB unit: Consistent HP cycling



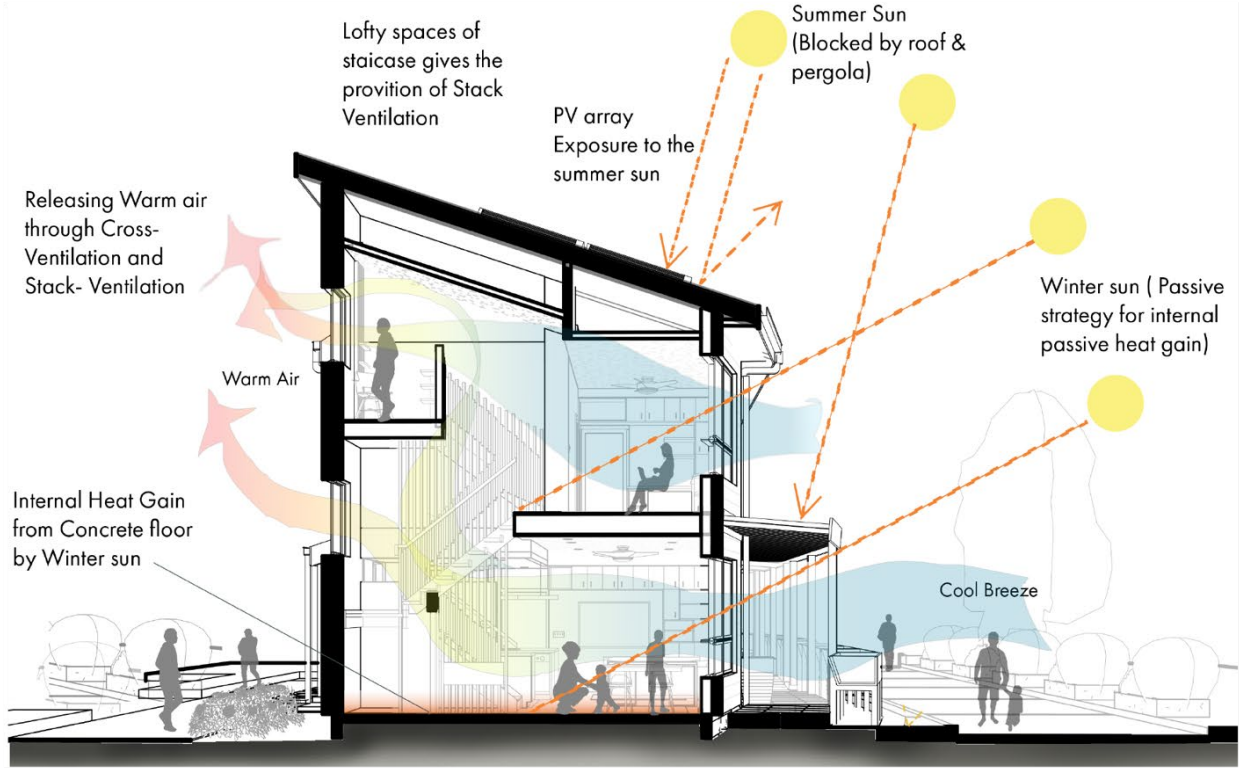
East-Code+ unit: Heat pump is working harder to provide comfortable indoor temps likely due to building envelope differences between the units and less consistent thermostat settings

West-Phius PB unit: Stable cycling

Considering comfort and indoor environment, how would you rate the following?	Survey 1 West Unit-Phius PB	Survey 2 East Unit-ZERH Code+
Overall Temperature	Very Satisfied	Very Satisfied
First Level Temperature	Very Satisfied	Very Satisfied
Second Level Temperature	Very Satisfied	Dissatisfied
Humidity	Very Satisfied	Satisfied
Air Quality	Very Satisfied	Very Satisfied
Ventilation	Very Satisfied	Very Satisfied
Control Window Opening	Very Satisfied	Very Dissatisfied
Natural Lighting	Very Satisfied	Neutral
Energy Efficient Features	Very Satisfied	Very Dissatisfied
Comment		Windows don't open enough. The stone floor is not good for my feet, I would like carpet under feet and not stone

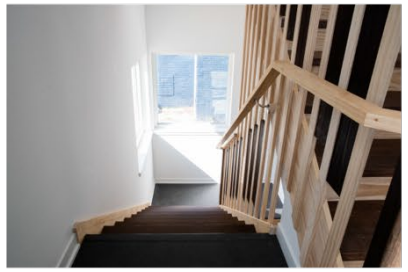
Considering energy efficiency, how would you rate the following features in your home?	Survey 1 West Unit-Phius PB	Survey 2 East Unit-ZERH Code+
Insulation and sheathing	Very Satisfied	Very Satisfied
Windows	Very Satisfied	Dissatisfied
Electric Lighting	Very Satisfied	Very Satisfied
Natural Light and Shading	Very Satisfied	Very Satisfied
Overall Energy Costs	Very Satisfied	Very Dissatisfied
Comments		Some windows don't open on days I don't run AC. Very high electric bill $600 Water bill unaffordable disconnected $363.94

Reflection: Passive Design Strategies



PASSIVE ELEMENTS

STAIR TOWER



INTERNAL HEAT GAIN

OPERABLE WINDOWS

- Envelope
- Passive Heating
- Passive Cooling
- Daylighting
- Storm Water Management

Mechanical Ventilation

West-PB (all units in CFM)	Cooling	Fall Transition	Heating	Spring Transition
Natural ventilation estimation	2	5	10	6
Average ERV exhaust flow	68	66	68	67
Total natural + mechanical	68	66	68	67
Average net added	66	61	58	61
East-Code+ (all units in CFM)				
Natural ventilation estimation	9	14	27	14
Weighted mechanical exhaust flow	4	3	4	1
Weighted natural + mechanical	12	16	30	15
Average net added	3	2	3	1

RESIDENT
GUIDE

COMFORT
FRESH AIR

SYSTEM
- Fresh air keeps you happy & healthy
- The ventilation system runs all the time
- The system brings in fresh air
- The system gets rid of stale air
- You don't need to adjust it at all
- Equipment is in the mechanical room

BOOST
- TIMER SWITCHES behind the stove and in the bathrooms
- USE when there is a lot of steam from cooking
- USE when there is a lot of steam from showers
- It turns the exhaust up for a few minutes

CEILING FANS
- TURN ON Ceiling fans in each room
- Fans will make you feel cooler
- Fans use very little electricity
- Fans make a house feel less stuffy
- Fans let you set thermostats higher to save energy

COMFORT
HEAT & AC

HEAT
- On thermostat, select **Mode** and then **Heat**

Set the thermostats to:
- 68-70 degrees WHEN YOU ARE HOME
- 61 degrees WHEN SLEEPING OR AWAY
- Thermostats can be programmed. Ask Englewood CDC to help

AIR-CONDITIONING (AC)
- On thermostat, select **Mode** and then **Cool**

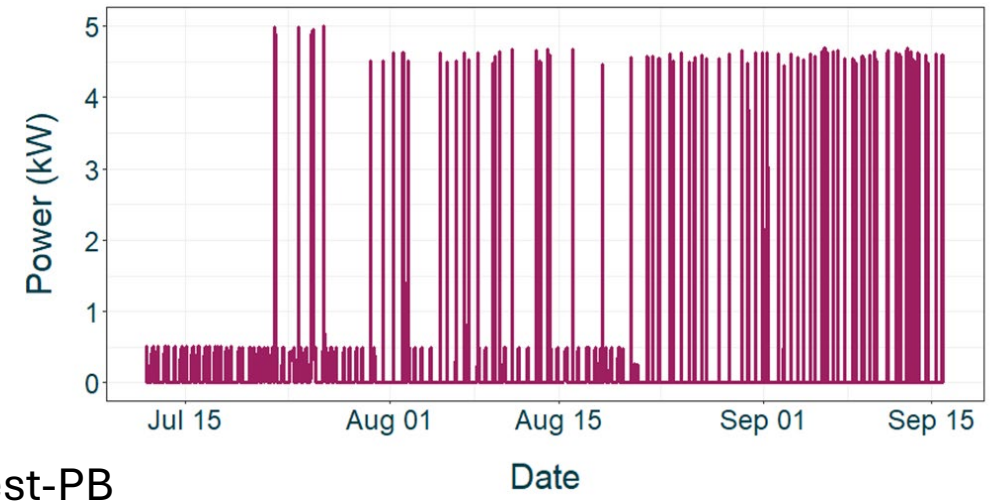
Set the thermostats to:
- 77-78 degrees WHEN YOU ARE HOME
- 77-78 degrees WHEN SLEEPING
- 84 degrees WHEN AWAY
- 80-82 degrees IF USING CEILING FANS
- Pull blinds in summer to keep sun out
- Thermostats can be programmed. Ask Englewood CDC to help

WASTING ENERGY
- Keeping the heat too high in winter or the AC too low in summer wastes energy.
- Energy is expensive
- Turning thermostats down or up when not home or sleeping **saves you money**

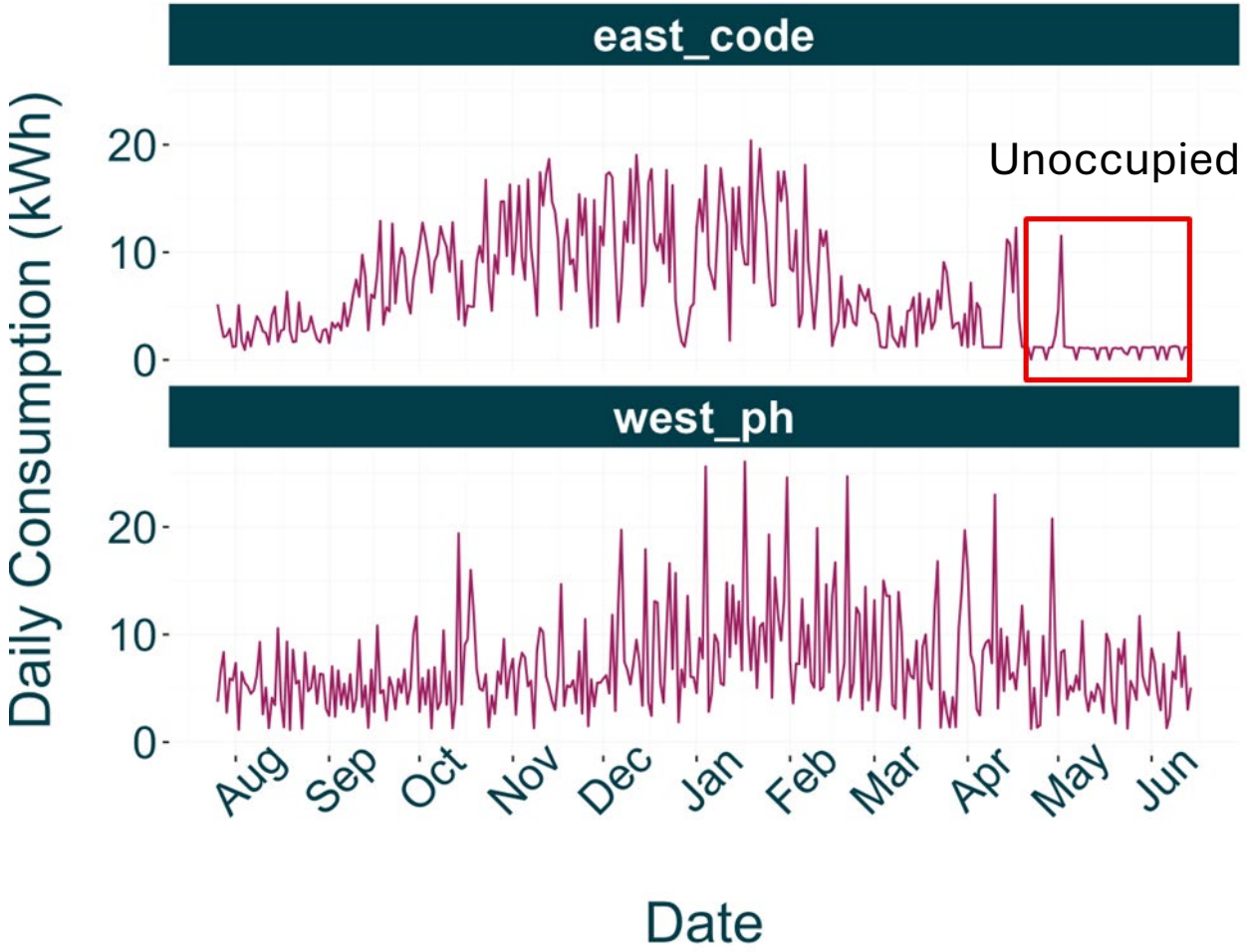
SYSTEM
- Equipment is hidden in the drop down ceilings in the kitchen and upstairs flex space
- Thermostats are near downstairs bathroom & upstairs bedroom doors
- Upstairs has one thermostat
- Downstairs has one thermostat
- Outdoor unit will blow warm air

HPWH primarily using Electric Resistance mode

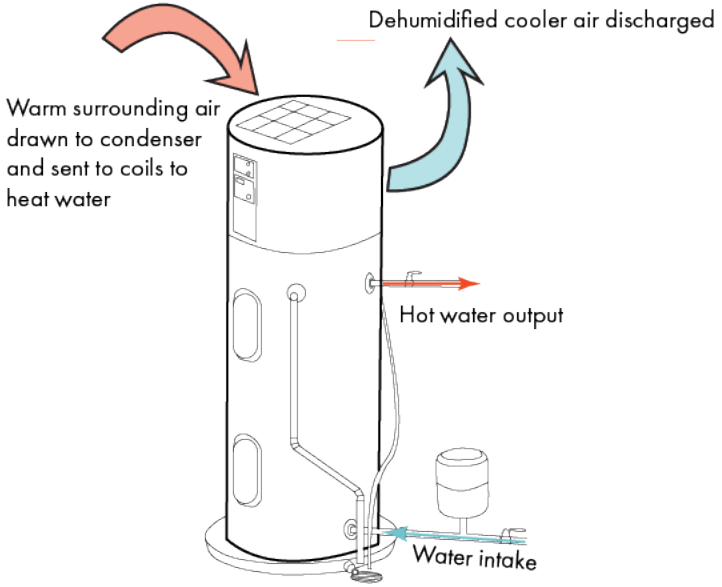
East-Code+

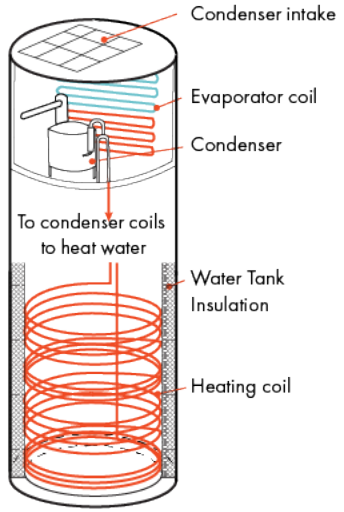


West-PB



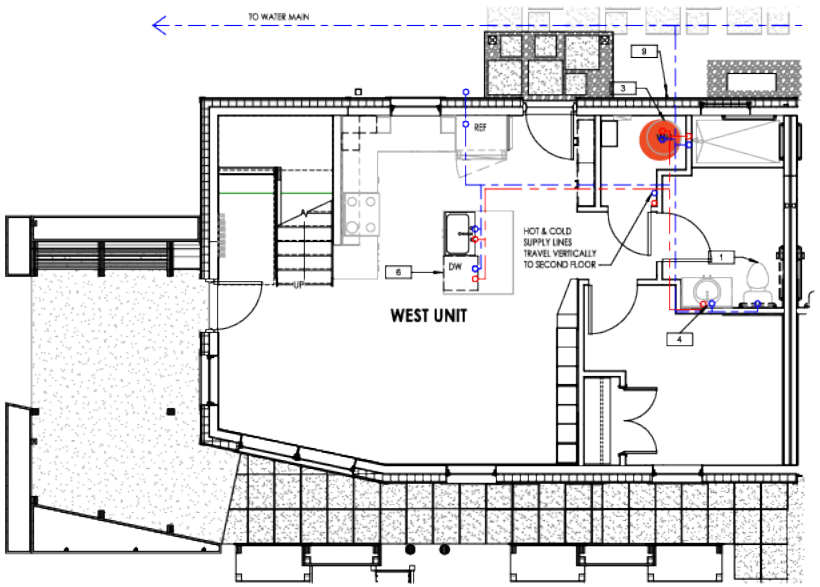
Reflection: Heat Pump Water Heater





Water Heater Diagram

View of First Floor Mechanical Room

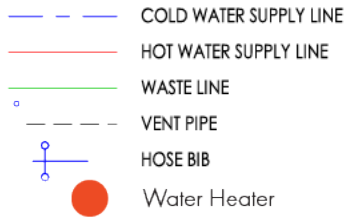


Location of Water Heater - West Unit First Floor

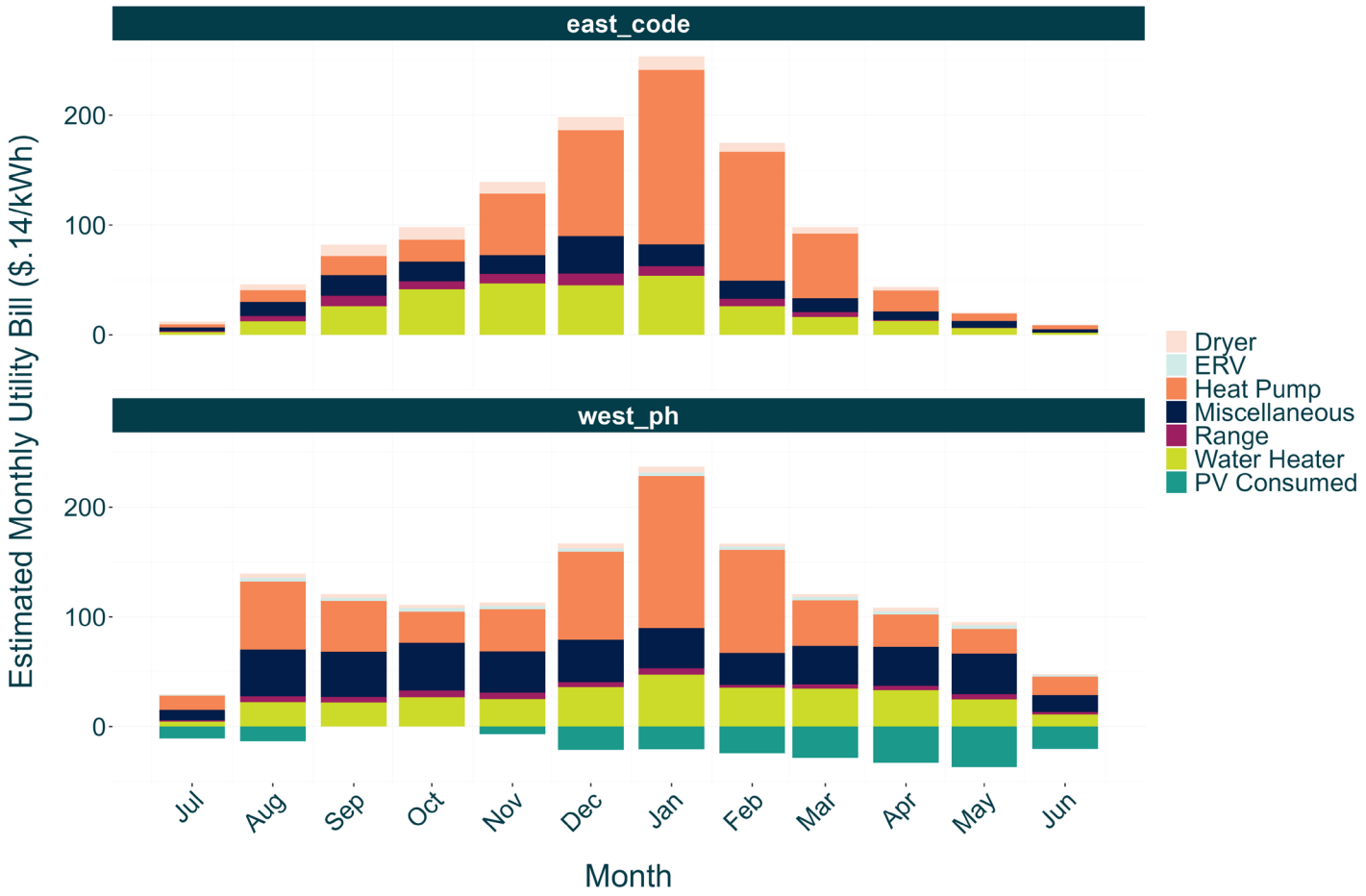
Heat Pump Water Heater

- Heat pump water heaters are 2-3 times more efficient than conventional electric resistance hot water heaters
- A.O. Smith water heater includes a user interface module (UIM) that allows real-time monitoring and control features such as vacation setbacks
- This heat pump water heater will extract ambient heat from the interior air in the home as part of the efficient vapor compression refrigeration cycle
- The tank also has 4" of insulation to prevent heat loss from the tank to the interior

PLUMBING SYMBOLS



Load Characterization

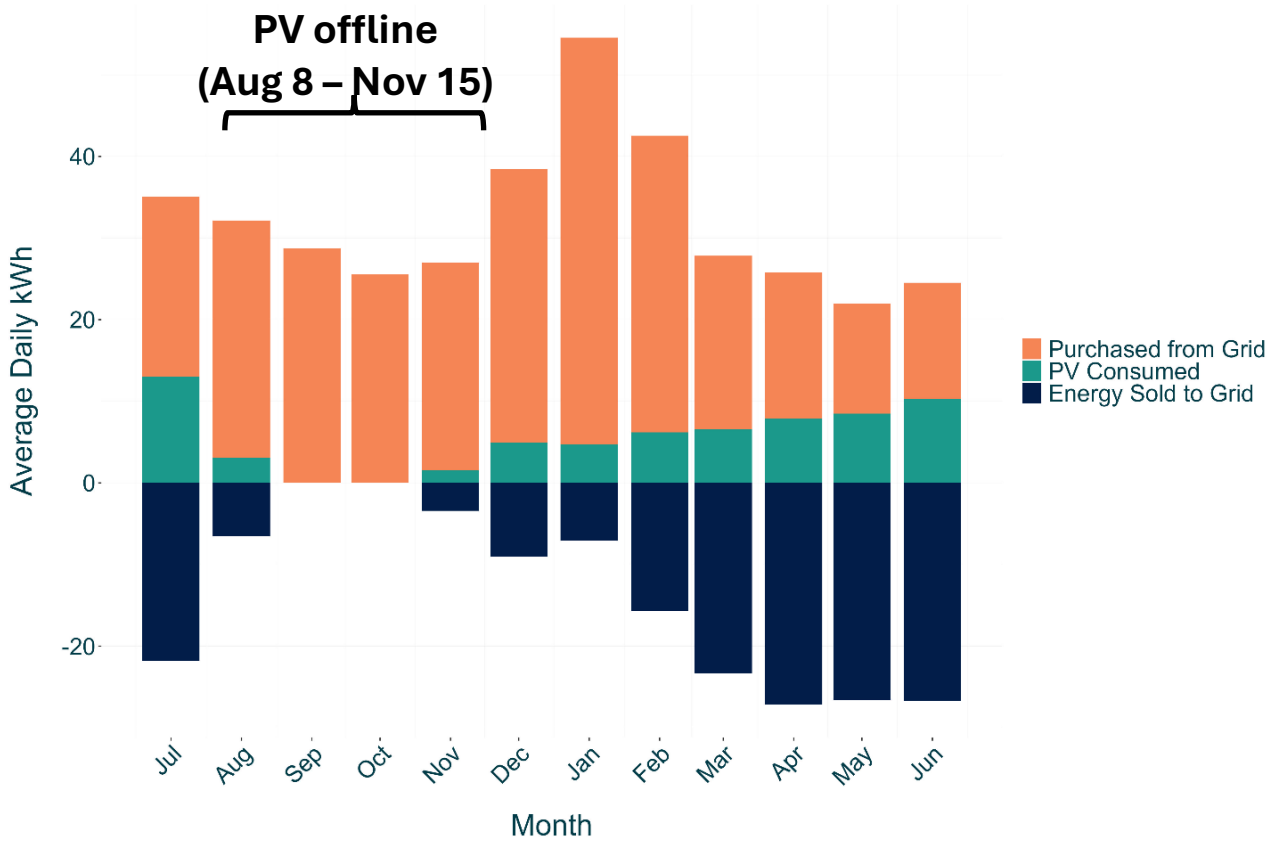


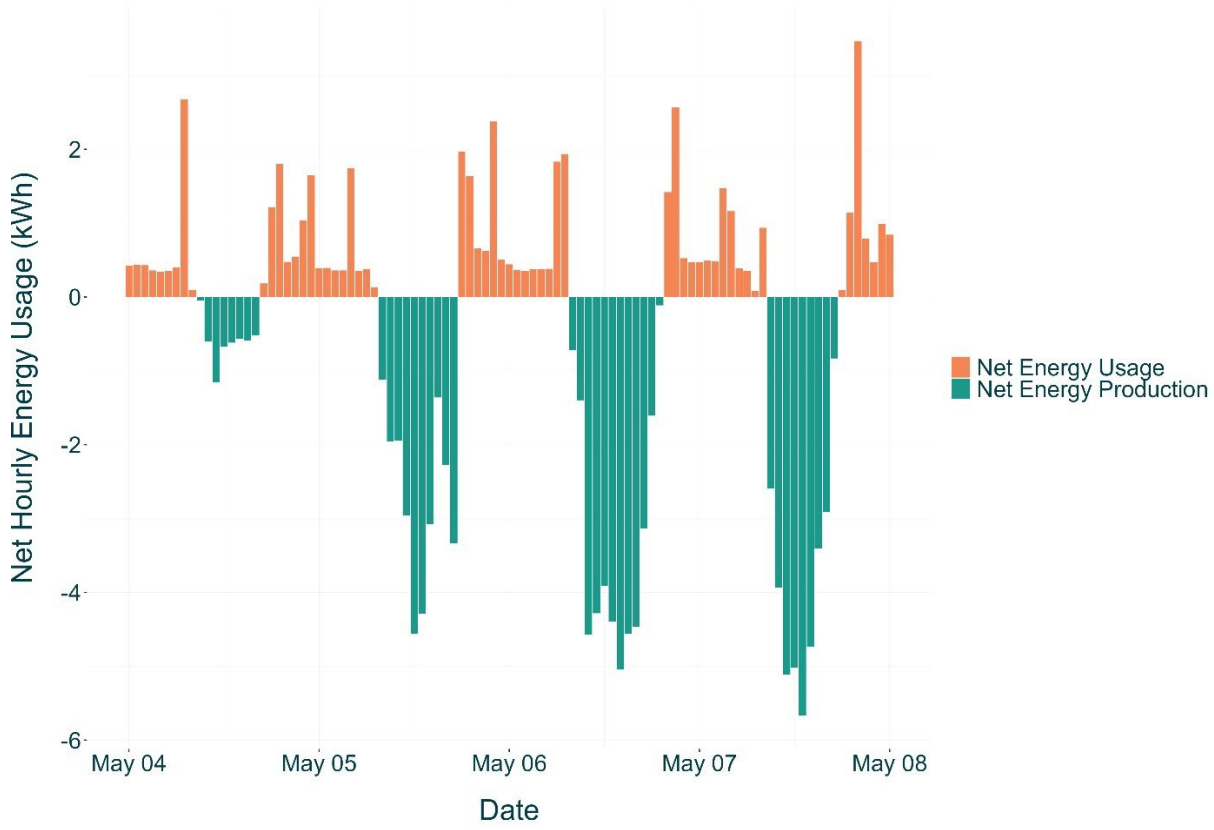
End-Use	East-Code+ (kWh/day)	West-PB (kWh/day)
Whole Unit	25.93	32.11
HP Heating	11.32	9.45
HP Cooling	1.22	4.58
HPWH	6.41	7.14
Range	1.40	1.14
Dryer	1.86	0.77
ERV	0.00	0.77
Misc	3.75	8.84

Resident Reflection: Equipment

How satisfied are you with the following equipment in your home?	Survey 1 West Unit-Phius PB	Survey 2 East Unit-ZERH Code+
Heating/cooling system	Very Satisfied	Very Satisfied
Water Heater	Very Satisfied	Very Satisfied
Laundry equipment	Very Satisfied	Very Satisfied
Smoke detectors	Very Satisfied	Very Satisfied

PV offline for a few months, net energy production during daylight hours sometimes.





Reflection: PV Array + Solar Edge

Installed Solar Array

PV Panel Array & Storage - Mechanical Room

Solar Array facts

- The Alley House provides onsite renewable energy generation via an 8.8kW solar photovoltaic (PV) system composed to 22 Panasonic Evervolt 400w PV modules mounted on a rack to the south facing roof

- Helioscope software suggest that the array can provide 12,181 kWh of renewable energy per year. With a 25-year warranty their expected module yield at the end of the warranty period of 92%

- The PV array collects energy in the form of direct current (DC). The energy then is moved through an inverter in the mechanical room to become the alternating current (AC) used by the appliances, outlets, and other equipment in the home

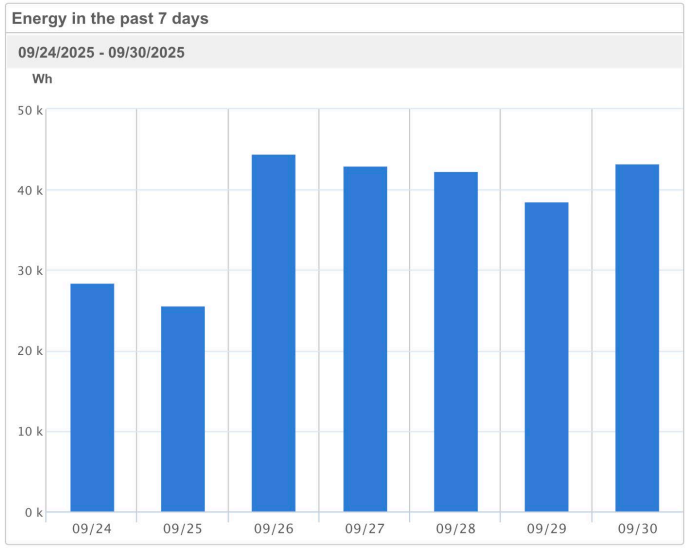
- The electrical system connects to an outdoor electric vehicle (EV) charging station for use by occupants with an electric vehicle

- Two Ecoflow modular, portable batteries can be charged during the daytime when occupants are using less solar energy and used in the event of a power failure or for load shedding

Resident Reflection: PV Array + Solar Edge

Current Power	Energy today	Energy this month	Lifetime energy
1.63 kW	43.2 kWh	1.19 MWh	22.24 MWh

Power and Energy



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Environmental Benefits

CO2 Emission Saved
34,437.47 lb

Equivalent Trees Planted
260.21

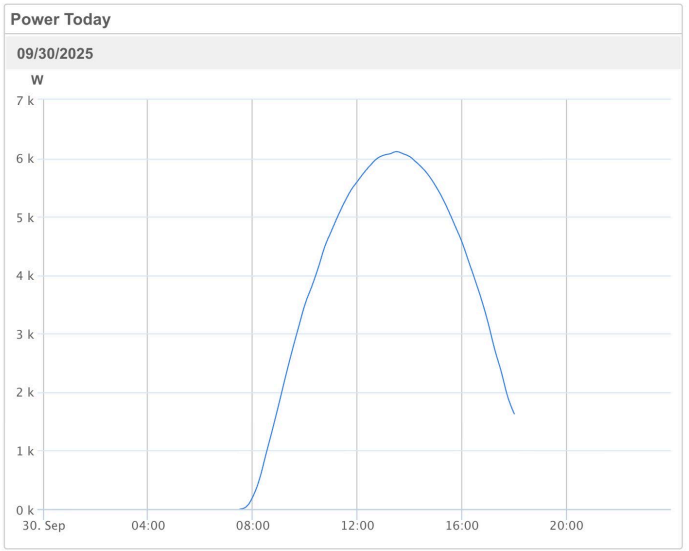
Sunny
85 °F
Feels like 83 °F
Wind NE, 3 MPH
Humidity 29 %
Sunrise at 07:40
Sunset at 19:28

Tuesday	Wednesday	Thursday
84 - 59 °F	86 - 59 °F	84 - 61 °F
Sunny	Mostly Sunny	Mostly Sunny

solaredge

Current Power	Energy today	Energy this month	Lifetime energy
1.63 kW	43.2 kWh	1.19 MWh	22.24 MWh

Power and Energy



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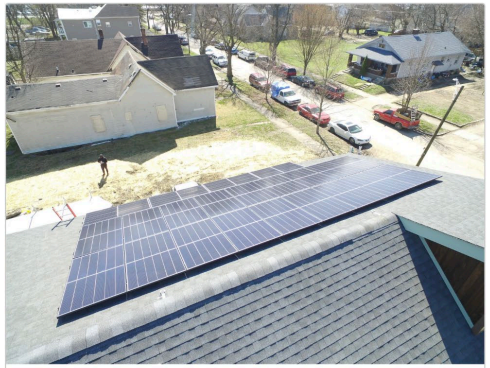
Environmental Benefits

CO2 Emission Saved
34,437.47 lb

Equivalent Trees Planted
260.21



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Reflection: PV Array + Battery Backup

EcoFlow Delta Pro 2

- Portable and expandable backup system
- Outlet to plug into when power outage to utilize battery backup
- Interlock in electrical panel can easily be toggled by the homeowner during power outages
- Two batteries – 7200W, 240V output
- 7.2 kWh capacity total

Solar Edge Inverter and power optimizer

Interlock device for toggling power source

Battery backup system set up in the mechanical room

Weathering an Outage

During an outage, it is estimated that the EcoFlow Delta Pro 2 system can power the following critical functions:

Refrigerator: 4 days

Lighting: 8 days

Air conditioner: 7 hours

Heat Pump Water Heater Operation

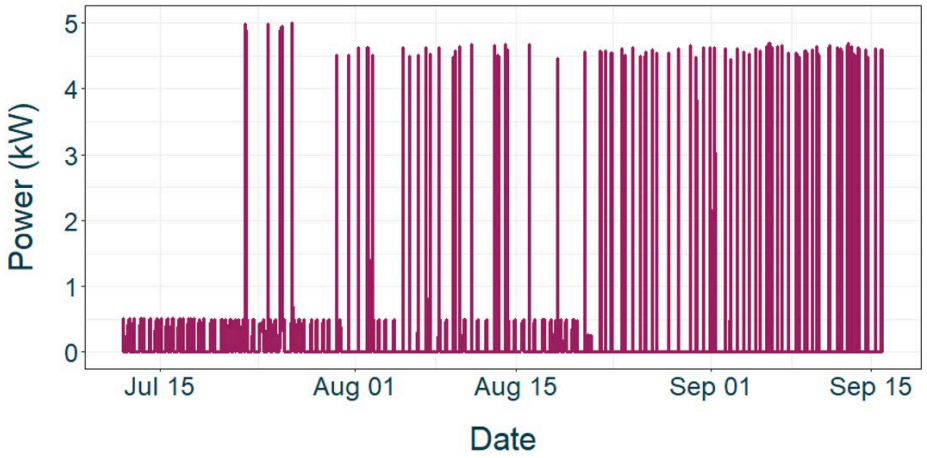
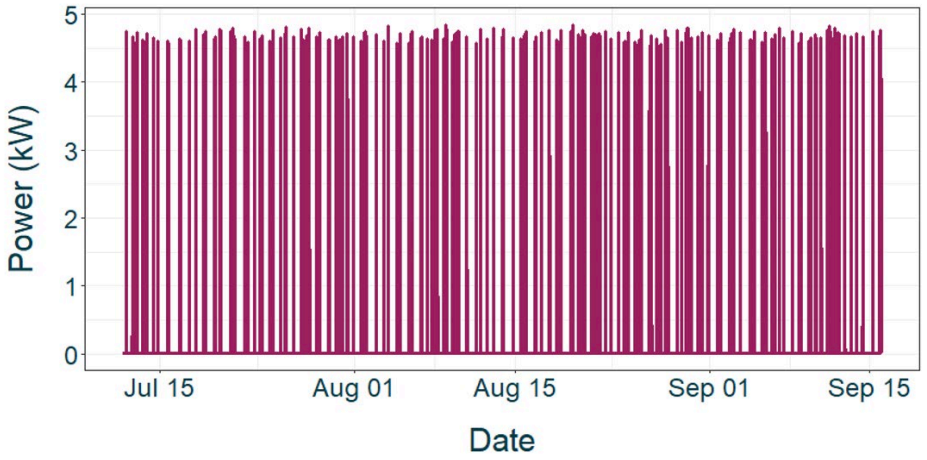
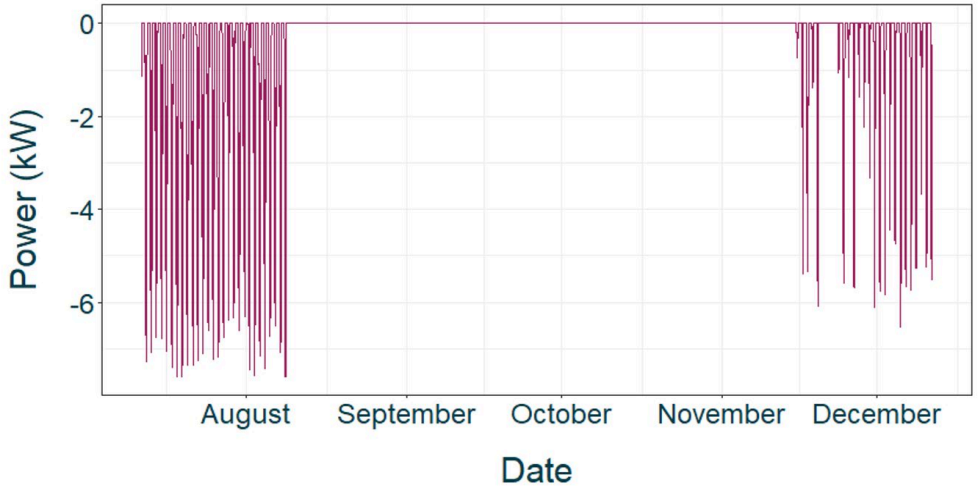


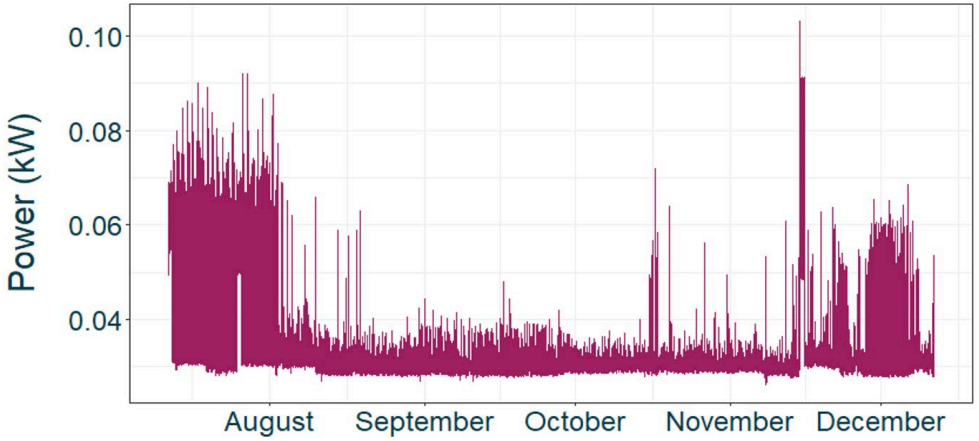
Figure 25. West-PH unit water heater power one minute interval selected period



PV Production



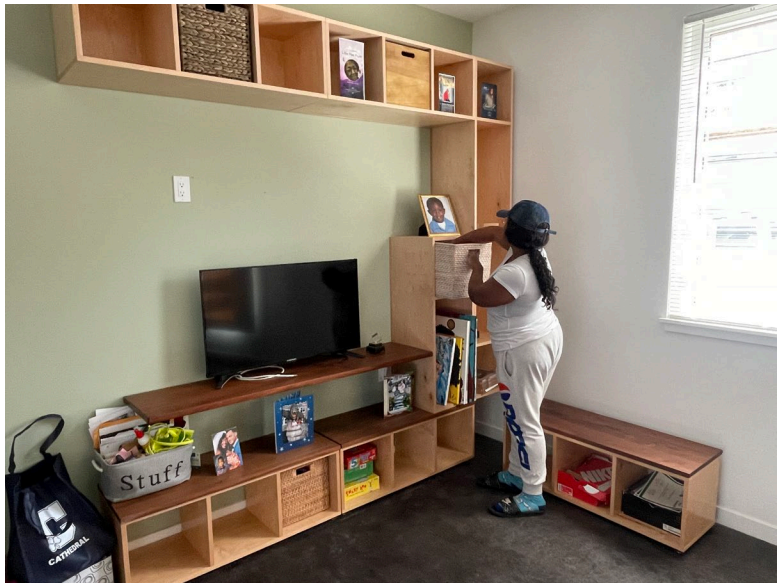
ERV Operation



Conclusions

- Occupancy impacts energy use and can undermine high performance building.
- Designing something to specs and delivering it doesn't mean it will perform that way.
- West-PH unit appears to have a more efficient building envelope based on heating season.
- East-Code unit used less overall energy during the monitoring period.
- Monitoring provides valuable insights, more investigation is needed to understand why.

Observations from Survey and Interview



Observations from Survey and Interview