



Milwaukie Courtyard Housing Project (MCHP) Energy Analysis



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Milwaukie Courtyard Housing Project (MCHP) Analysis

Prepared for:

Jessy Ledesma
HomeWork Development

Prepared by:

Energy Studies in Buildings Laboratory
Department of Architecture
University of Oregon
Portland, Oregon | Eugene, Oregon

Research Team:

Mark Fretz (PI)
Alen Mahic
Dale Northcutt
Judith Sheine (Co-PI)
Jason Stenson

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1.0 INTRODUCTION

Our society is facing a set of converging challenges. Climate change, with its associated health impacts, social inequalities, homelessness, access to healthcare, caring for an aging population, unaffordable housing and a pandemic are all affecting the health of individuals, communities and the planet.

The Milwaukie Courtyard Housing Project (MCHP) is a proposed systematic response to these challenges through the innovative use of panelized Mass Plywood Panel (MPP) wood products in single-family residential construction coupled with new urban cluster housing infill development and infrastructure models. Higher-density courtyard infill housing of small individual or paired units can provide an alternative to multifamily developments in traditional single-family neighborhoods for what is called “workforce housing” aimed at affordability at 80% -120% of area median income (AMI).

By working to meet Net Zero energy goals, the homes are designed to be energy efficient, have significantly less embodied carbon than light wood frame assemblies, and be affordable to middle income families. The MPP panelized designs are optimized for aesthetics, affordability, energy efficiency, resilience and biophilic benefits of wood.

This new approach to residential construction seeks to decrease land costs per unit, reduce travel distances to work and play (thus, lowered transportation carbon emissions and cost savings), and provides shared ‘grid-enhancing’ solar microgrid energy and water infrastructure. This infrastructure will provide benefits to the larger grid during normal conditions while being capable of sustaining operations within the courtyard “cluster” during grid-disrupting events. The courtyard cluster model is intended to be

large enough to take advantage of economies of scale but small enough to facilitate construction without requiring significant municipal investment. On-site infrastructure is intended to increase the resiliency of water and energy resources while reducing lifetime operational costs. The research and development team hopes to demonstrate that this approach is affordable over time and thereby increase access to resilient clean energy and water resources in underserved communities that are increasingly exposed to the adverse impacts of climate change.

The Milwaukie Courtyard Housing Project brings an affordable, replicable, mass timber, small-plex solution to a overpriced housing market. The project addresses overlapping issues that are designed to benefit the end users, including Energy Trust customers: smart densification, sustainable building, and below market-rate housing. All aspects of the project are ‘energy sensitive,’ from the design to the construction of the energy-efficient homes themselves. The energy efficiency goals will contribute to housing affordability for Energy Trust customers.



Figure 1: Neighborhood context for Milwaukie, Oregon demonstration project. Sites indicated in yellow.

1.1 RESEARCH GOALS

This research intends to reduce the cost of net zero energy construction in the residential sector, a primary barrier to deploying net zero construction at scale without substantial subsidy, by examining the use of a new construction technology in the residential market, mass plywood panels (MPP), to create a higher performing thermal envelope. The improved envelope is more monolithic than stick-frame construction and is coupled with energy efficient heat pump technology to thermally condition a high-mass floor slab. The panelized wall assemblies facilitate a novel window integration that seeks to increase the energy performance and aesthetics of affordable off-the-shelf windows while maintaining simplicity to reduce construction costs. Moreover, the new panelized construction technology is deployed as distributed multifamily units in urban infill site configurations of “clustered” courtyard housing to create opportunities where the units could share solar energy while balancing loads across the site and larger grid, thus, simultaneously preserving existing tree canopy. The buildings themselves will serve as thermal storage, facilitating proactive strategies for optimizing when and how energy is consumed on site. The goal of this research is to create net zero residential construction that can be produced and delivered affordably, targeting the workforce segment of the housing market.

The research scope includes:

1. An energy model of a prototypical MPP panelized single-family house with slab-on-grade, and an all-electric heat pump system configured either individually for each unit or as a district strategy across the entire site.
2. A physical mockup of a frameless MPP higher-performance window that includes infiltration testing and thermal imaging.
3. A courtyard “cluster” housing solar analysis that preserves existing tree canopy on three pilot testing sites in Milwaukie, Oregon.
4. A cost and affordability analysis of solar cluster microgrid.

2.0 ENERGY MODEL

This energy analysis is based on a combination of Honeybee 1.4.0 (via Grasshopper and Rhinoceros 7) and OpenStudio 3.3.0, both of which rely on EnergyPlus 9.6.0 for the annual energy calculations. The MPP model geometry is based on the most recent design documents, as shown in Figure 1, while the model performance is reflective of the Department of Energy (DOE) Zero Energy Ready Homes (ZERH) standard, which is summarized in Table 1. The model is currently set with a packaged air-to-air heat pump HVAC system as baseline. The team is exploring system options, including a district heat pump and hot water strategy to serve multiple units.

The simulated results show an EUI of 17.1 kBtu/ft² for the packaged heat pump baseline. The three radiant slab HVAC schemes show EUI values of 25.3 kBtu/ft² for the single-unit, 23.3 kBtu/ft² for a 15-unit district scheme, and 23.3 kBtu/ft² for a 21-unit district scheme. The majority of energy consumption attributed to heating and interior equipment, as shown in Figures 2.1 through 2.4. To break this down further, the monthly energy consumption by each end use is shown in Figures 3, 6, 7, and 8. The monthly peak energy demand is shown in Figure 6 for the baseline only. And the monthly district heating for the hot water service system is shown in Figure 7 for the baseline only.

2.0.1 Scheduling

The baseline model relies on established schedules that make up the DOE reference models and prototype residential models as developed by the Pacific Northwest National Laboratory (PNNL). The mid-rise apartment and

single family models are functionally the closest match to the MPP house and courtyard cluster and allow us to base our assumptions on existing generalized modeling data.

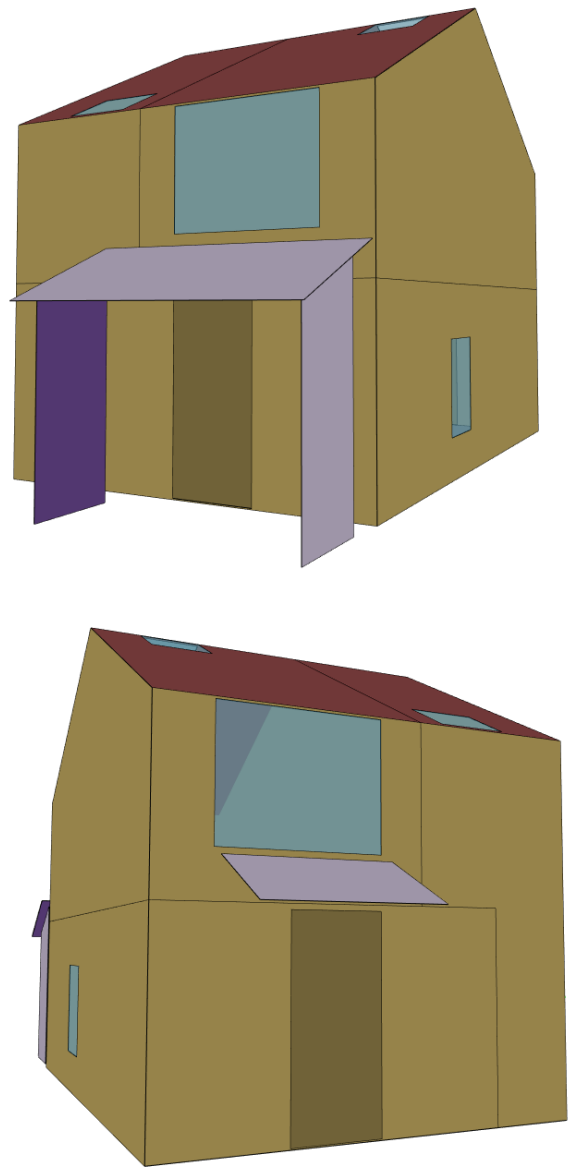


Figure 1: Open Studio Model of MPP geometry

2.0 ENERGY MODEL

	Component	Input
ENVELOPE	Slab Edge Perimeter	R-10 w/ 2-ft. Vertical Depth (F-0.540)
	Wall Insulation - Above Grade	R-20 (U-0.060)
	Windows	U-0.27/SHGC 0.30
	Exterior Doors	U-0.32
	Flat Ceilings	R-49 (U-0.021)
MECHANICAL COMPONENTS	Split Heat Pump (Electric)	HSPF 10.0
	Split Cooling (Electric)	13 SEER
	Heating Set Point	71F
	Cooling Set Point	76F
	Thermostat	Programmable
	Water Heater (Electric)	EF = 2.0
	HW Pipe Insulation	None
	Air Sealing	2.5 & 3.0 ACH@50 Pa
	Ventilation Type	Balanced
	Ventilation Quantity/Time	62 cfm 24-Hours/Day
	Ventilation Fan Energy	52 watts
LIGHT	Interior Lighting	80% LED. 20% FL + CFL.
	Exterior Lighting	
EQUIPMENT	2-in-1 Washer/Dryer	16 W ENERGYSTAR
	Dishwasher	13 W ENERGYSTAR
	Refrigerator	12 W ENERGYSTAR
	Misc. Plug Loads	0.23 W/ft ²

Table 1: DOE ZERH performance inputs

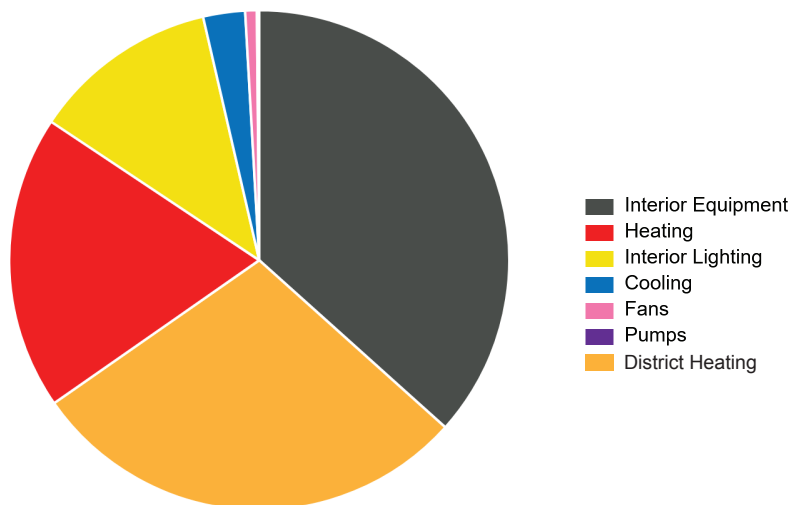


Figure 2.1: Annual energy end use breakdown for packaged heat pump baseline

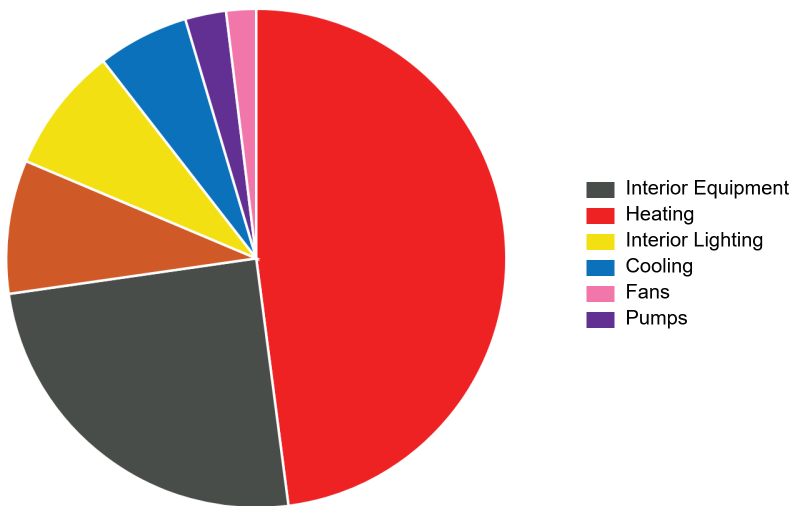


Figure 2.2: Annual energy end use breakdown for single-unit district HVAC scheme

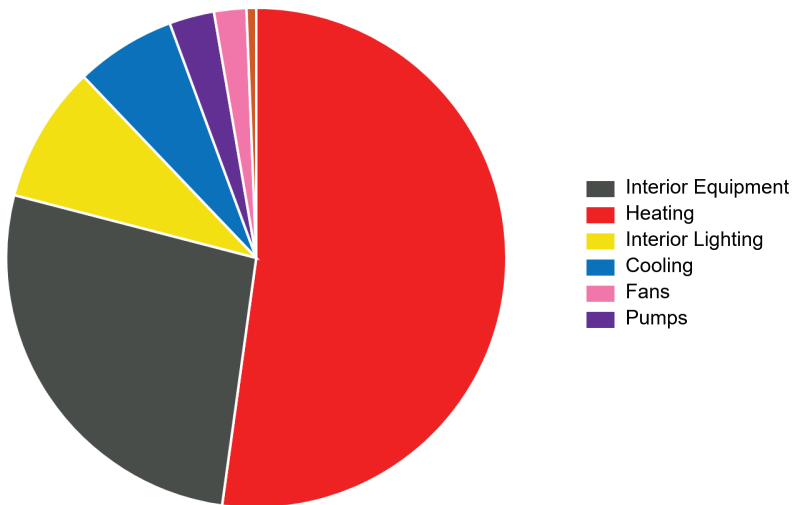


Figure 2.3: Annual energy end use breakdown for 15-unit district HVAC scheme

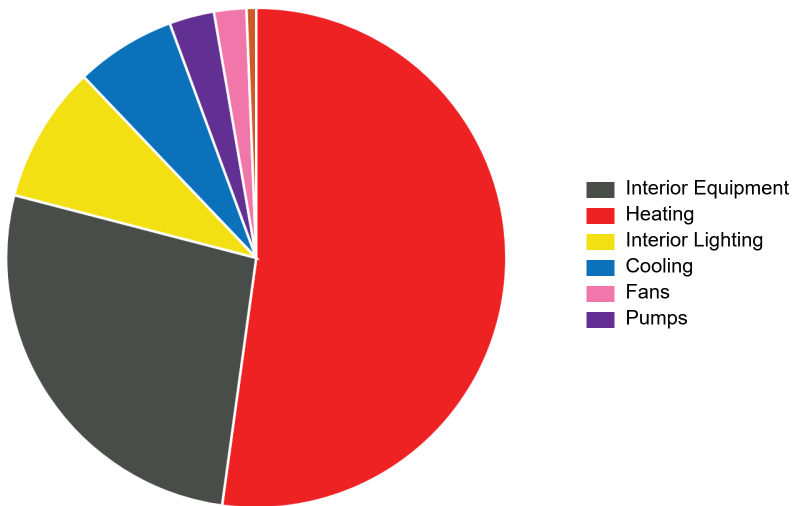


Figure 2.4: Annual energy end use breakdown for 21-unit district HVAC scheme

2.0 ENERGY MODEL

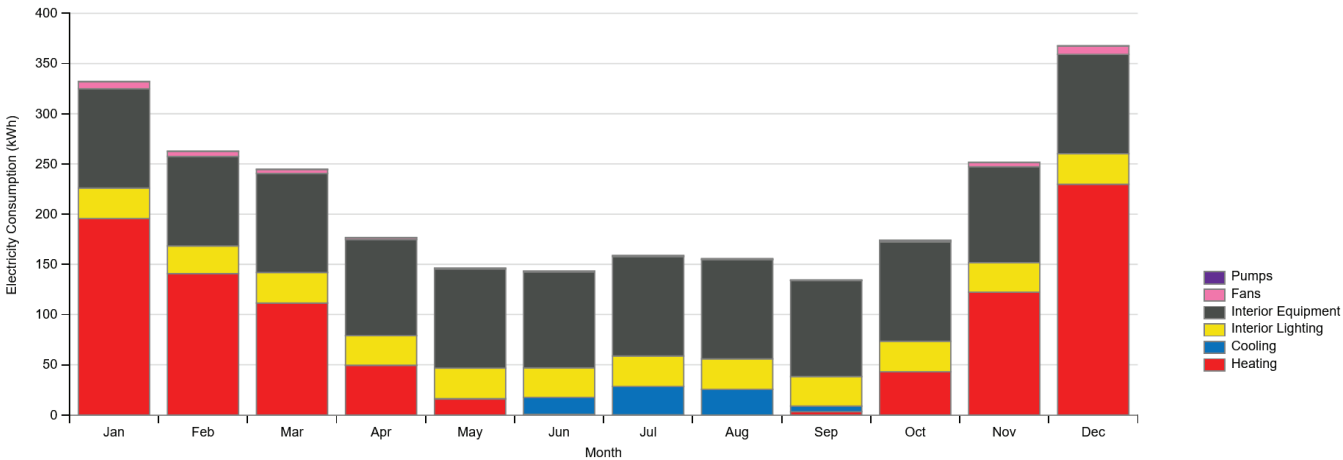


Figure 3: Monthly overview of energy consumption by end uses for packaged heat pump baseline

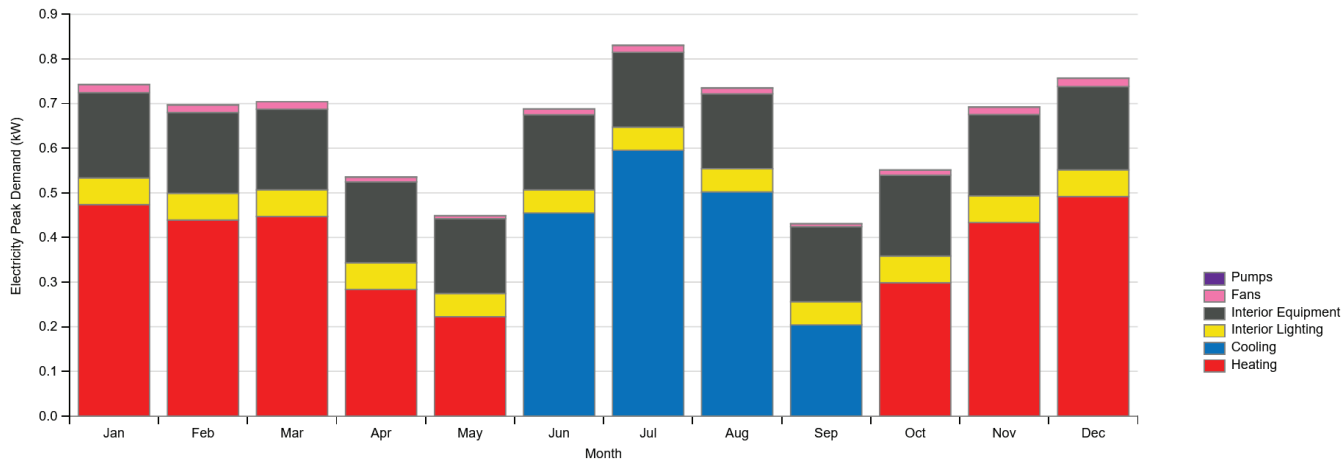


Figure 4: Monthly energy peak demand by end uses for packaged heat pump baseline

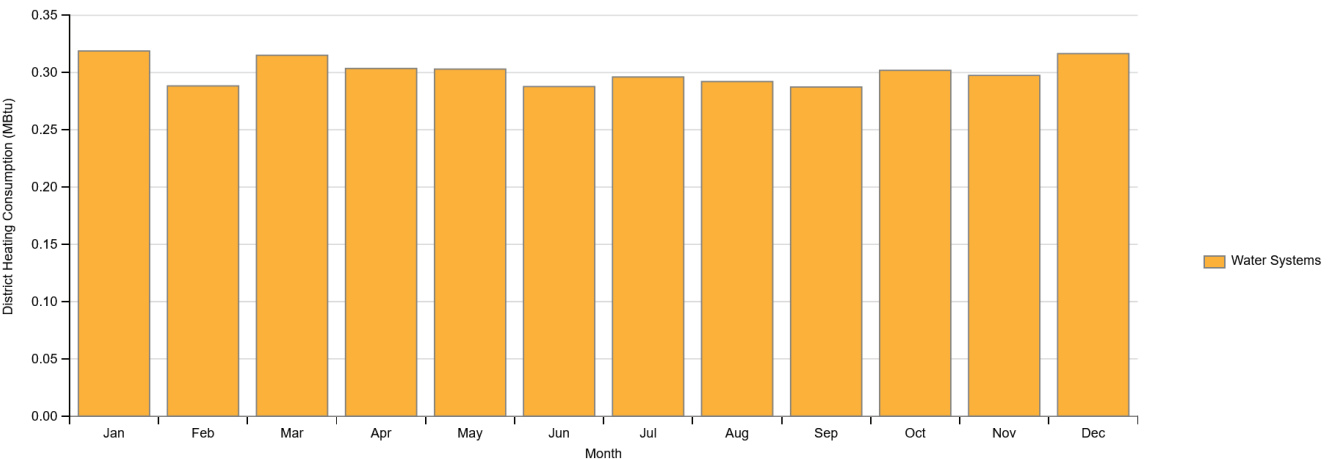


Figure 5: Monthly district heating energy consumption demand by end uses for packaged heat pump baseline

2.0 ENERGY MODEL

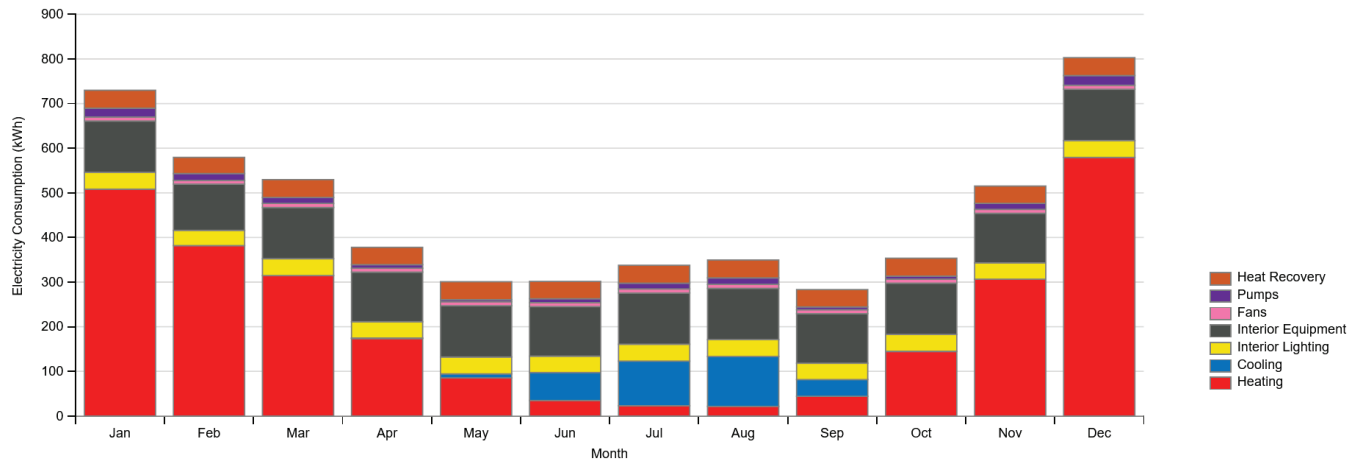


Figure 6: Monthly overview of energy consumption by end uses for single-unit radiant slab HVAC scheme

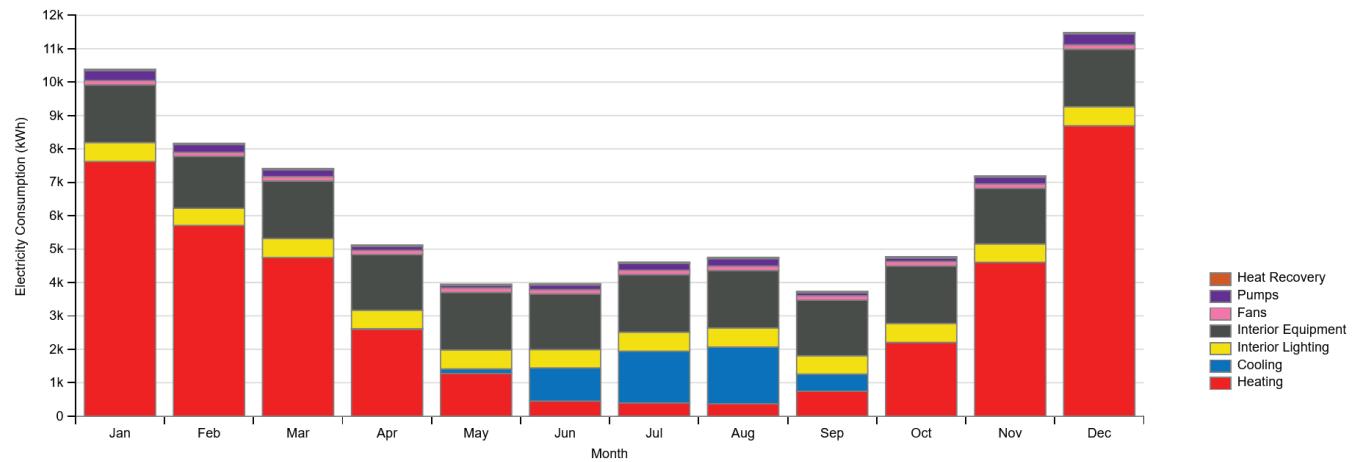


Figure 7: Monthly energy peak demand by end uses for 15-unit radiant slab HVAC scheme

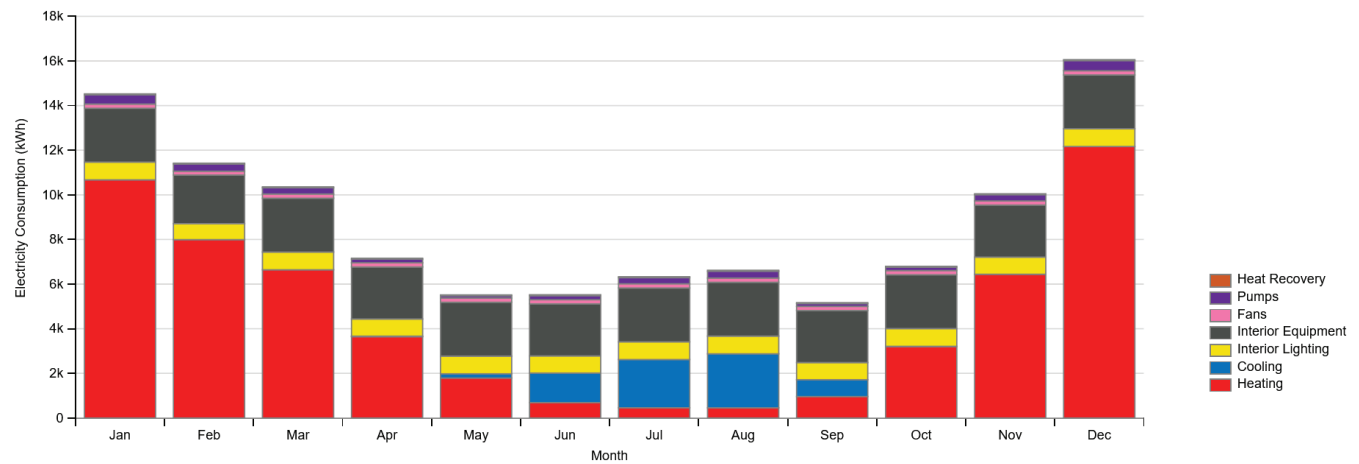


Figure 8: Monthly district heating energy consumption demand by end uses for 21-unit radiant slab HVAC scheme

2.0 ENERGY MODEL

Figure 6 shows an example of a daily occupancy schedule that is used as part of the DOE/PNNL prototype single-family dwelling. This is a solid starting point that we can update with data that is more specific to the MPP housing project as it becomes available in the future.

2.0.2 Natural Ventilation

There are two ventilation strategies that have been implemented. The first is natural ventilation that simulates cross-ventilation on the first floor with the operation of the front and back doors, while on the second floor the operable windows and skylights in each bedroom allow for stack ventilation. The indoor temperature ranges from 22°C (71.6°F) to 27°C (80.6°F). Additionally, a balanced mechanical ventilation system is included to supplement the DOE ZERH ventilation requirements, as summarized in Table 1.

2.0.3 Zoning

The energy model is based on three spaces that are part of one thermal zone: (1) the living space that contains the entirety of the first floor, (2) the circulation corridor that contains the stairs and upstairs hallway, and (3) the upstairs bedrooms.

2.0.4 Equipment

The equipment loads are based on ENERGYSTAR appliances, as listed in Table 2. ENERGYSTAR reports the total annual energy consumption, on average. This value was extrapolated to a total wattage value that is specified as the design wattage level in the energy model. It is then operated by a simple “always on” schedule, which is to say operated at 100% level 24/7. With operation trend data, the model can incorporate a more representative equipment schedule, adjusting the total design wattage.

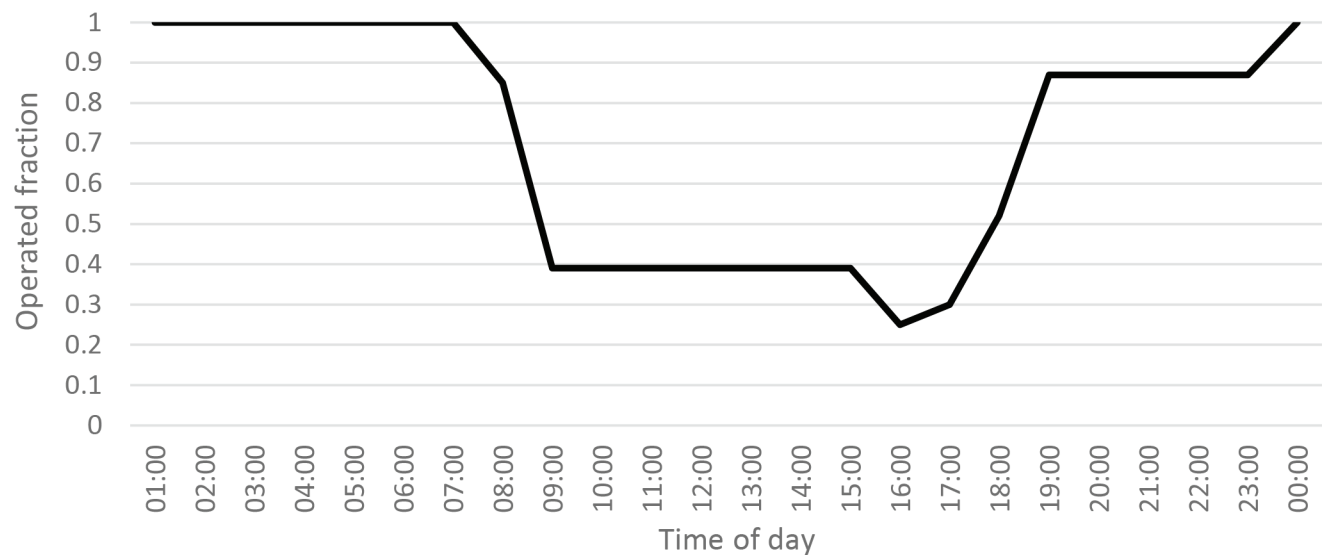


Figure 6: Example of generalized single-family dwelling occupancy schedule (DOE/PNNL)



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2.0 ENERGY MODEL

Type	Make/Model	Energy use	Cost
Laundry Washer (stackable)	Beko WTE7604XLW0	67 kWh/year	\$849
Laundry Dryer (stackable)	Samung DV25B69**H*	125 kWh/year	\$1,165
Dishwasher	Fisher & Paykel DD24STX6I1	113 kWh/year	\$1,199
Refrigerator	Insignia NS-RTM10BK2	283 kWh/year	\$360
Range	Magic Chef MCSRE24S	1200W-2200W	\$1,079
Microwave	Panasonic NN-SN67HS	1200W	\$155
TV	Spectre 435BV-F	65.4 kWh/year	\$158
Laptop	Misc.	10 kWh/year	\$1,300-\$3,500

Table 2: Examples of ENERGYSTAR rated equipment that make up the equipment loads

2.1 ENERGY MODEL MEP SYSTEMS SCHEMATIC

The design of each housing unit is configured for hydronic heating, cooling and coupled domestic hot water. Units can be coupled with a district heating loop using staged air-to-water heat pumps that supply domestic hot water all year using a dedicated heat exchanger and additional space heat to the floor slab during heating and shoulder seasons. During the cooling season, natural ventilation will provide the primary cooling with supplemental cooling provided by centralized heat pumps that are staged to deliver chilled water via a cooling loop and floor slab hydronics valved to switch from heating to cooling. For both space heating and cooling, the slab and centralized thermal storage tanks can be either heated or chilled at night to take advantage of off-peak electrical rates from the grid. This design is intended to not only reduce unit energy use but provide overall operational affordability, load sharing and resilience since the centralized heat pumps can be operated by site microgrid photovoltaics during a grid outage. For the SE 36th Avenue site, the district will serve 19 homes (replacing two existing homes) and for the SE Harvey Street site, the district will serve 14 homes (replacing one existing home).

In the case of a single unit configuration (e.g., ADU), the district heating and cooling loops can be substituted by an air-to-water heat pump (BOD: Sanco₂) and a small indoor hot water thermal storage tank.

SINGLE UNIT

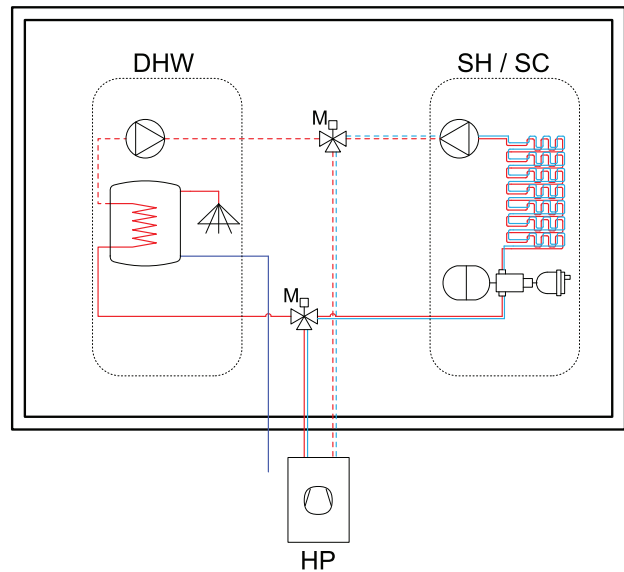


Figure 7: Single unit hydronic configuration

DISTRICT UNIT

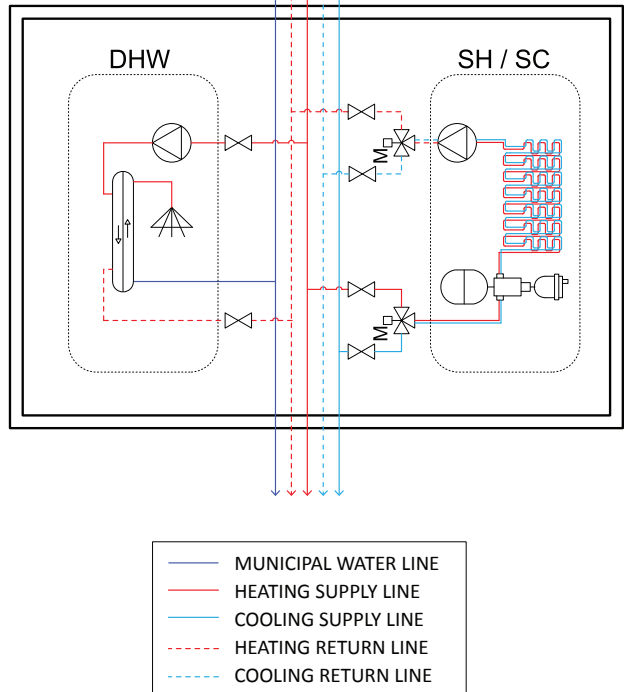


Figure 8: District unit hydronic configuration

2.2 ENERGY MODEL MEP SYSTEMS SITE SCHEMATIC - SE 36TH AVENUE

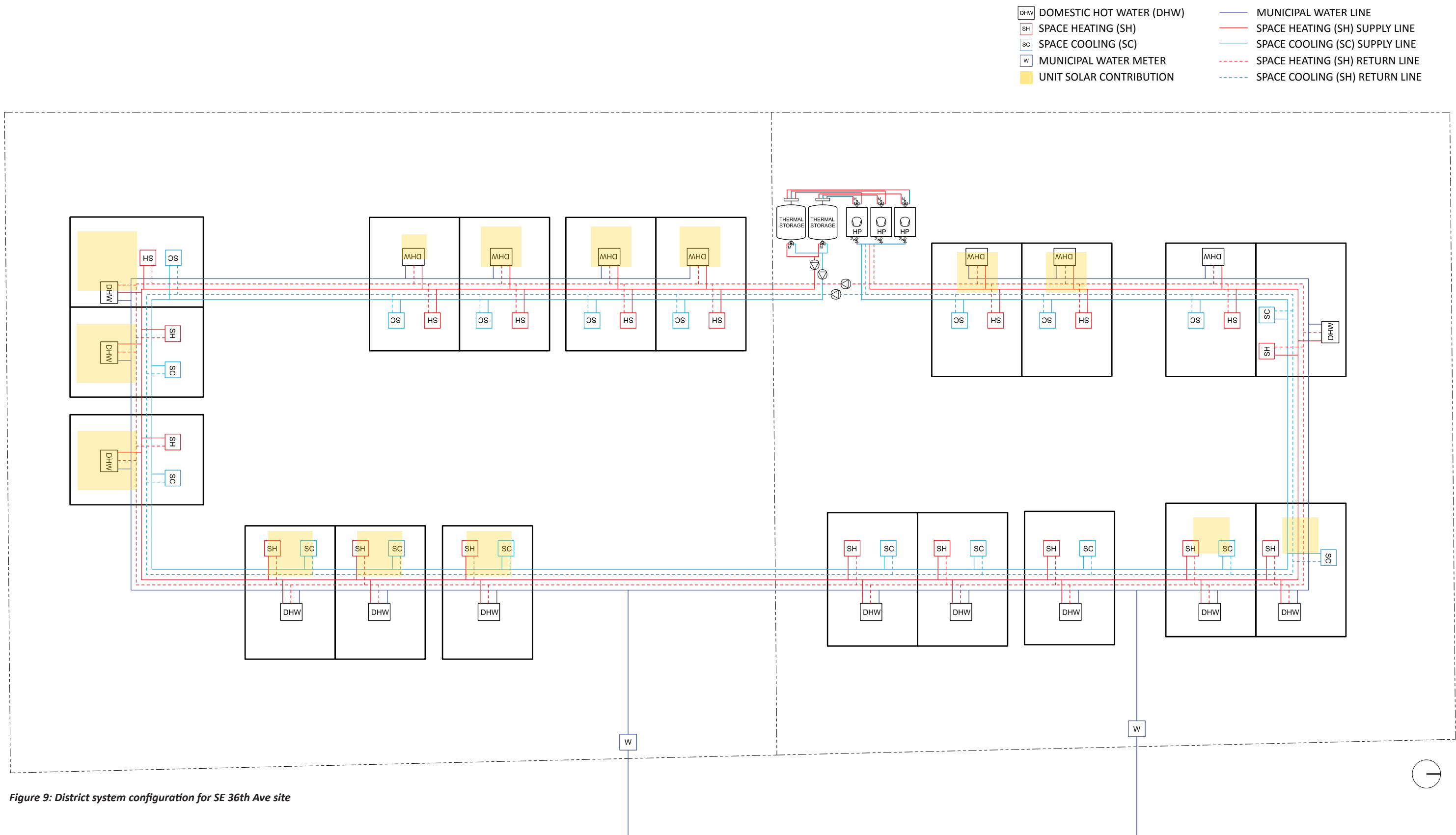


Figure 9: District system configuration for SE 36th Ave site

2.3 ENERGY MODEL MEP SYSTEMS SITE SCHEMATIC - SE HARVEY STREET

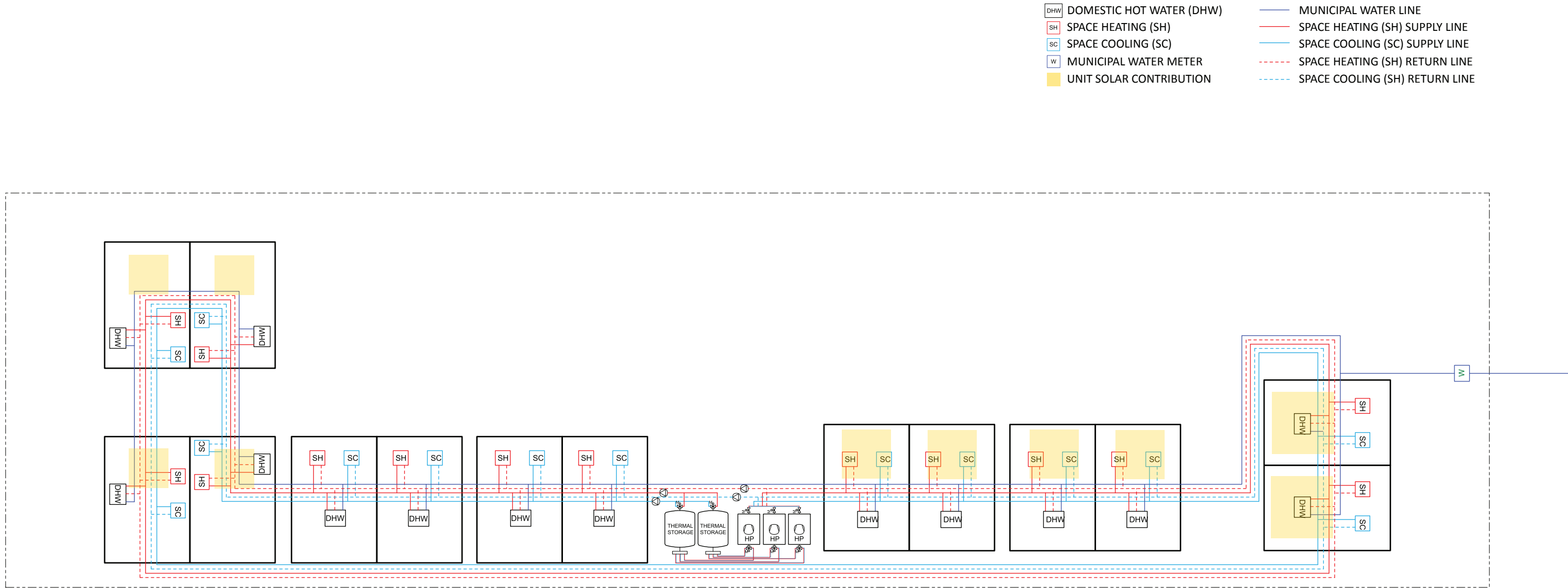


Figure 10: District system configuration for SE Harvey St site



2.4 ENERGY MODEL NATURAL VENTILATION COOLING

Visualizations of two wind speeds (1 m/s and 2 m/s) at three directional conditions with either stack ventilation provided by a skylight and downstairs inlet or a combination of stack + cross ventilation. Downstairs has an inlet/outlet on opposing walls. Upstairs stack is above stair and bedrooms have wall and ceiling inlet/outlet.

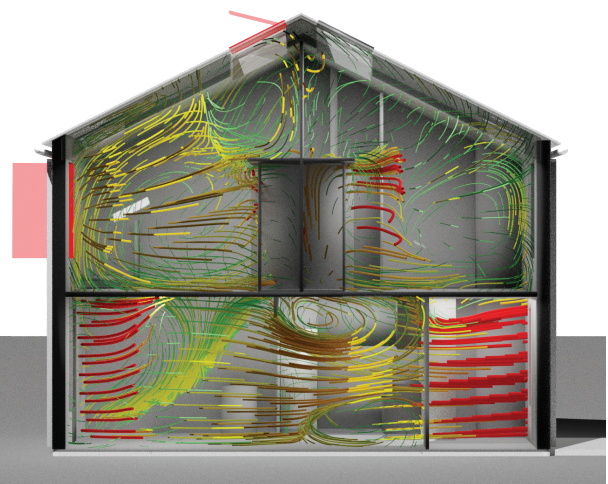
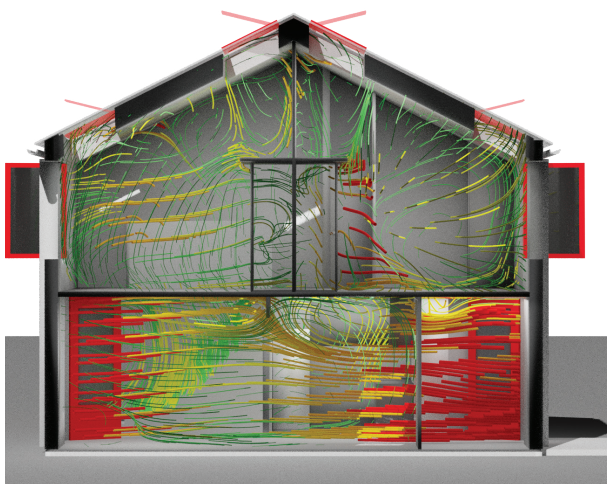
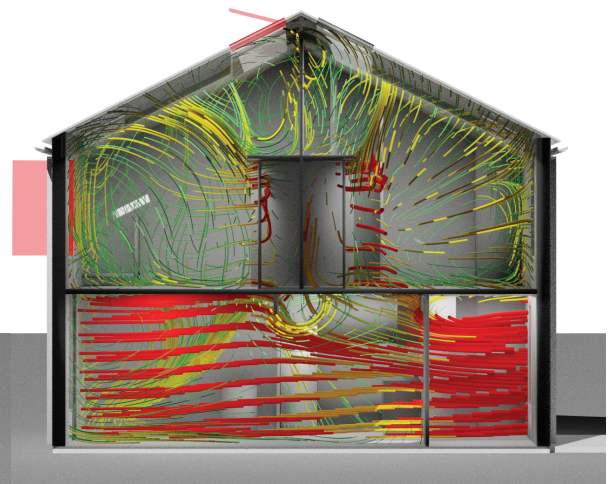
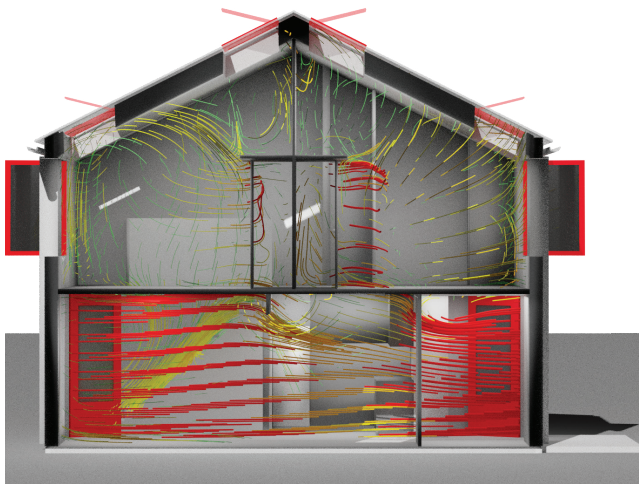
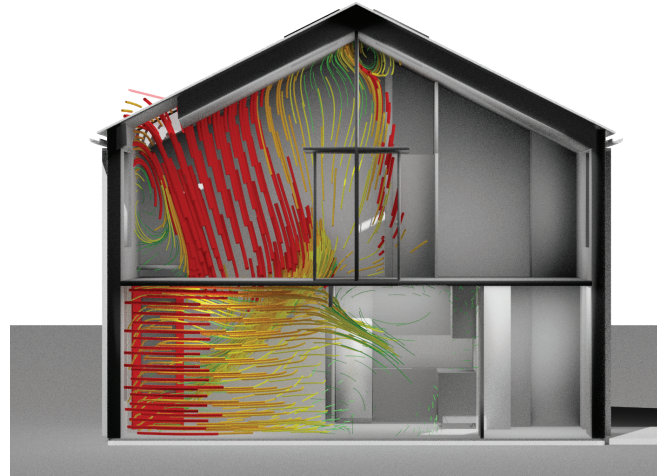
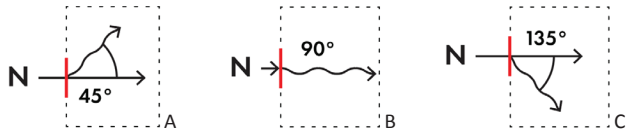


Figure 11: Cross and stack ventilation shown at two different wind speeds and three different wind directions

3.0 PHYSICAL MOCK-UP

Window mock-up fabrication

The process of modeling and fabricating finished window openings in MPP was put to the test at the time of window installation. Translating window dimensions to 3D model form and then again to CNC fabrication cut files for an inset rough opening that would also serve as interior finish surface was largely a success.

The tolerance for a CNC-cut window opening was thought to be allowed to be held much tighter than that of a conventional stick framed rough opening, where a process of shimming and squaring a window during installation requires extra space in the site-built structure. The precision fabrication possible on the CNC allowed for the rough opening in the MPP to be 1/16" larger than the window itself on all sides, whereas window manufacturers require rough openings for conventional construction to be anywhere from 1/2" to 1" larger on each side. The tighter tolerance meant that the window was square as soon as it was placed in the opening and air sealing becomes more precise.

An assembly detail prototyped with the mock-up had the window frame sit within the thickness of the MPP panel, including 2" of MPP (R-value of 2.50) covering the window frame when viewed from the interior. The intent was to have the MPP serve as both structure, finish material and frame insulation; thus, requiring no additional trim work or finish treatment. Furthermore, situating the window frame and operable casement sash in this configuration allowed for the addition of an "energy shutter" on the interior, which was fabricated from twin-wall

polycarbonate and allowed privacy, shading and additional insulation as a secondary system over the glazing. Functionally this window placement worked well. The one exception was additional relief of the MPP was required for the specific window operator selected to have clearance to operate. This was corrected in the field and the operable window works well and as intended in this configuration.

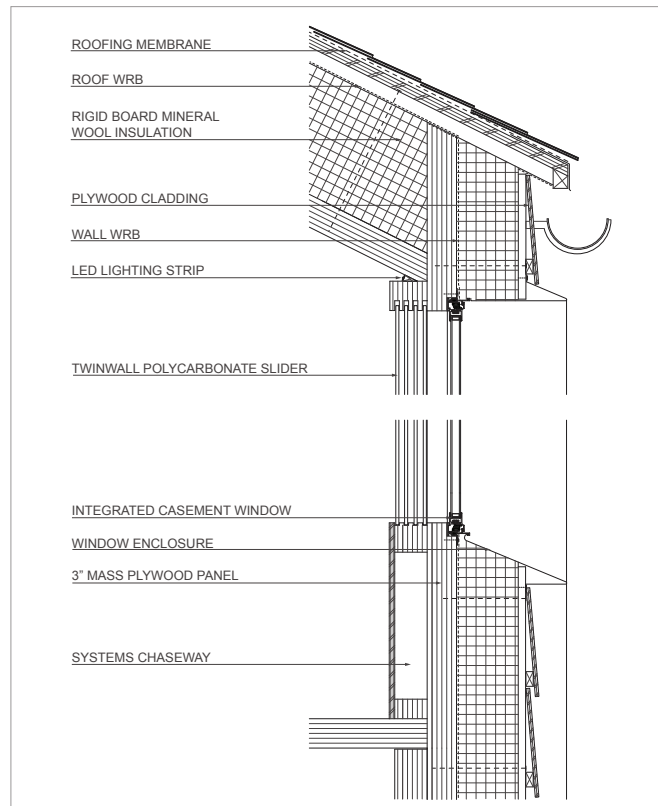


Figure 12: Window mock-up section detail

One drawback of having the cut edge of the MPP serve as finish material, identified through mock-up construction, is that special care and attention must be taken during CNC operations that wouldn't be necessary if the MPP were intended to be covered with additional finish material. For example, the MPP needs to be secured to a spoil board to minimized fiber tear

3.0 PHYSICAL MOCK-UP

out, cutting tool selection and speed need to be optimized to produce the best finish surface, and the practice of tabs being left between the wall panel and the cutout material to be cutout by hand later is not ideal to achieve a uniform surface finish. Some additional manual steps such as sanding may still be required which reduces some of the cost savings gained through limiting additional finish materials. For the mock-up, MPP window corner tabs were hand cut; however, the team should consider leaving a small corner radius to allow a fully machine operation.

One benefit to panelized wall construction using MPP is a significant reduction in the possible locations for air infiltration to occur. With fasteners not penetrating the surface, potential infiltration locations are limited to panel-to-panel joints and panel penetrations like window openings. Furthermore, electrical outlets located on exterior walls are all surface mounted, thereby reducing the need to pay particular attention to outlet air sealing.

Hoisting hardware for maneuvering panels during fabrication and again on-site during installation are an avoidable additional MPP penetration. We piloted the use of hardware requiring a panel through hole as lifting point. The advantage of this type of lifting point is that it is easily installed and retrieved without tools or fasteners, however it leaves an additional panel penetration that must be properly sealed on site as part of the installation process. Lifting hardware that requires fasteners that do not penetrate the full depth of the MPP may offer

better option from the standpoint of infiltration. Custom lifting hardware that remains attached after installation and serves an additional purpose in the building, such as being part of a panel-to-panel connection, is an area we hope to explore further based on the lessons learned from this mock-up.

Performance testing

An enclosure was constructed and air sealed to the interior side of the mock-up for use of a blower door fan and instrumentation to positively pressurize the interior of the wall assembly. Smoke was introduced to the pressurized interior side of the mock-up at 30 Pascals and ramped to 62 Pascals while the exterior was visually inspected for smoke leakage. The only apparent smoke leakage was found in the vicinity of the windows. The operable window had some ex-filtration occurring at the sealing surface. The weep holes in the frame of the windows, included as part of the window assembly to allow condensation to drain to the exterior were another source of visible smoke exiting mock-up while pressurized. Some additional smoke was visible around the window assembly and cladding interface. This air path is not immediately identifiable and will be further investigated when the mock-up is deconstructed. With some of the cladding removed the ex-filtration location should be more apparent.

Window penetrations were sealed with a liquid applied membrane (Soprema Sopraseal Liquid Flashing, SKU: A508) and should provide



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3.0 PHYSICAL MOCK-UP

a good air seal between the window flange and the weather barrier (Soprema Sopraseal Stick VP, SKU: D21501) over the MPP. Potential air leakage may be occurring through the window frame itself. If air leakage is occurring around the window, there is an opportunity for additional air sealing installation steps (that were not used in the mock-up) to be employed in the future, as this current installation trialed only the liquid applied membrane when sealing the windows to the panels.

On the interior side of the mock-up an integrated sliding “energy shutter” system was piloted utilizing 6 mm twin-wall translucent polycarbonate panels that slide horizontally in an MPP track at both the head and sill of the window. The upper track additionally conceals LED strip up-lighting. The space between the lower track and the floor allows for a service chase running the length of the window wall to be used for electrical and other services without any penetrations or chases occurring through the MPP wall panel.

The polycarbonate shutters provide a building integrated privacy, shading, and radiant barrier allowing some thermal envelope improvement and user control in a space where it is believed most homeowners would install some type of blinds for privacy anyway. Additional design iterations of the shutters will take lessons learned from the mock-up and improve how the panels slide in their track to reduce noise and develop a way for panels to interlock and move together and create a more contiguous thermal mitigation layer when deployed.

The relatively thick outboard insulation with rain-screen and cladding to the exterior allows the window plane to be recessed providing some inherent exterior shading. A sheet metal window surround including vertical mullion between the two windows adds some depth and improves shading performance while acting as window trim. The sheet metal work proved a complex process between model, fabrication, and installation. A number of interface issues are able to be refined and improved based on mocking up this façade integrated element. Alternate materials (e.g., fiberglass, plate steel, wood) may also be pursued for constructibility, cost, thermal and durability considerations.

The mock-up is located outdoors and able to be reoriented to different solar exposures. Infrared images were taken when a large temperature differential could be achieved between artificially elevating the interior air temperature of the mock-up and cooler ambient outdoor conditions. These false color images investigate the thermal performance of the façade and will inform future design refinement.

This window and façade mock-up has allowed the research and development team to secure additional funding to advance the larger project and we will continue to use the mock-up and what we’ve learned from constructing it to advance the energy performance and design of future full-scale prototypes and ultimately permanent workforce housing.

3.0 PHYSICAL MOCK-UP

Window Cost Comparison

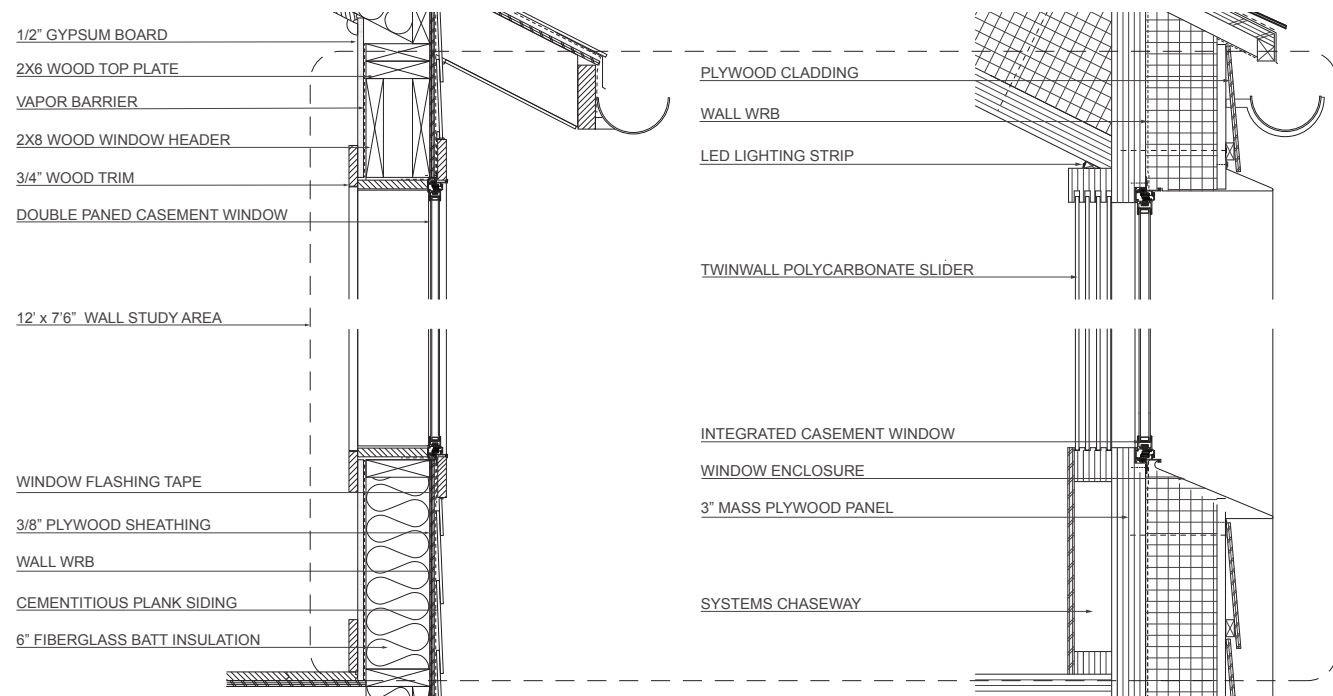


Figure 13: Conventional window and MPP mock-up window section detail

Labor Cost Comparison

Conventional Window System

task	\$/hr	minutes	cost
wall framing with rough opening	\$25	50	\$20.83
sheathing	\$25	30	\$12.50
cut rough opening in sheathing	\$25	5	\$2.08
place WRB	\$16	20	\$5.33
shim, square, attach window	\$25	5	\$2.08
flash window with tape	\$16	3	\$0.80
trim window exterior	\$25	10	\$4.17
fabricate and install metal drip cap	\$25	10	\$4.17
cladding	\$25	60	\$25.00
caulk exterior window joint	\$16	5	\$1.33
interior insulation	\$16	15	\$4.00
interior vapor barrier	\$16	15	\$4.00
interior drywall	\$30	45	\$22.50
Spray foam rough opening gap	\$16	2	\$0.53
window casing	\$40	10	\$6.67
window trim interior	\$40	10	\$6.67
tape and mud drywall	\$30	50	\$25.00
paint drywall/trim	\$20	30	\$10.00
install window coverings	\$16	10	\$2.67
TOTAL		385	\$160.33

MPP Window system

task	\$/hr	minutes	cost
manual panel cutting/finishing	\$25	20	\$8.33
manual routing with jig	\$25	60	\$25.00
WRB application	\$16	20	\$5.33
install insulation	\$25	60	\$25.00
liquid flashing, window install	\$25	30	\$12.50
window flashing	\$16	10	\$2.67
cutting polycarbonate sheet	\$16	10	\$2.67
dado MPP for slider	\$25	20	\$8.33
cladding	\$25	60	\$25.00
install sheet metal surround	\$25	30	\$12.50
caulk exterior window joint	\$16	5	\$1.33
TOTAL		325	\$128.67

Table 3: Conventional window and MPP mock-up window labor cost comparison

3.1 PHYSICAL MOCK-UP PANEL PREPARATION



Figure 14: MPP window mock-up construction process photos



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3.2 PHYSICAL MOCK-UP WINDOW INTEGRATION



Figure 15: Window installation in MPP mock-up construction process photos



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3.3 PHYSICAL MOCK-UP ENERGY SHUTTER AND SHADING



Figure 16: Completed MPP mock-up photos including polycarbonate energy shutter

3.4 PHYSICAL MOCK-UP INFRARED IMAGING

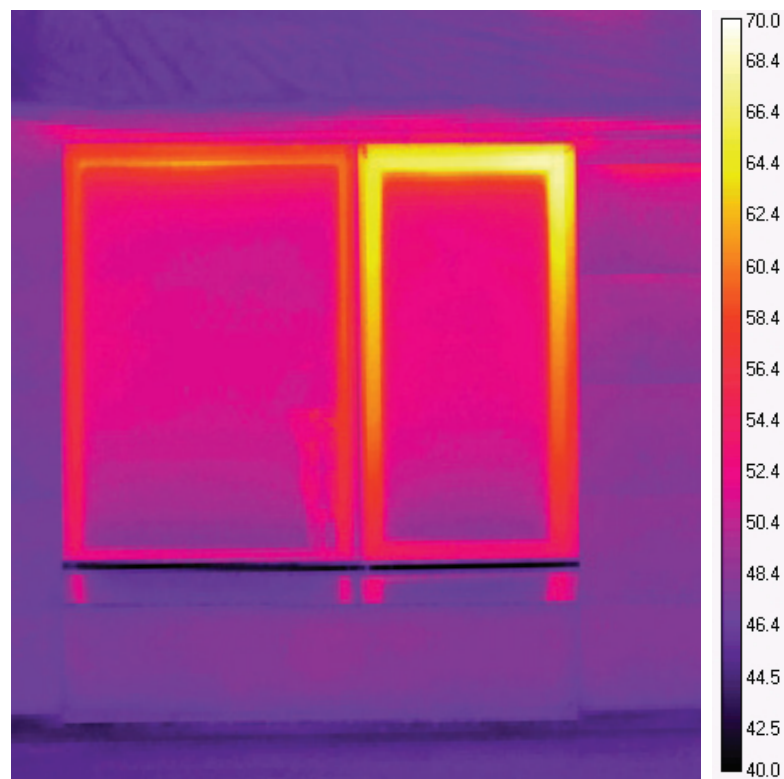


Figure 17: Exterior thermal imaging of enclosed and heated mock-up

3.4 PHYSICAL MOCK-UP INFRARED IMAGING



3.4 PHYSICAL MOCK-UP PRESSURE TESTING



Figure 20: blower door testing and pressurized smoke testing photos

4.0 PV SOLAR STUDY

The City of Milwaukie, Oregon has placed an emphasis on preserving existing tree canopy for any new development, recently adopting a tree code. The demonstration sites used for this analysis have legacy trees, most of which will be

preserved, and the research team is interested in tree-preserving solar models made possible by courtyard cluster infill, such as renewable microgrids with battery storage and peer-to-peer sharing.



Figure 21: Site images of tree canopy on both project sites

4.1 PV SOLAR STUDY SITE PLANS

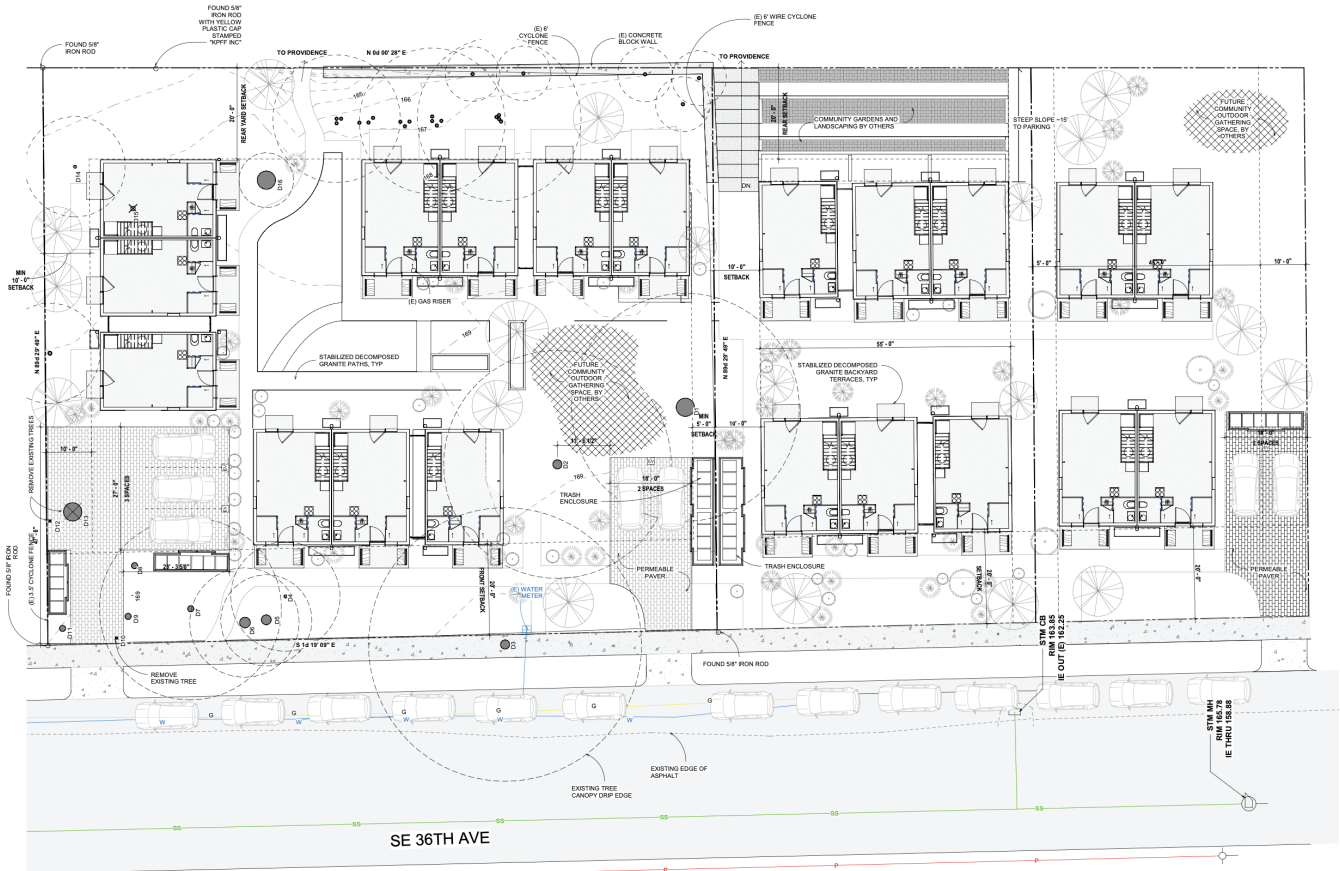


Figure 22: Site plan, 36th Ave site



Site plans (NTS) for proposed demonstration projects in Milwaukie, Oregon. Plan above is 36th Avenue site, which includes three tax lots and is approximately 120' deep x 280' wide and below is the Harney Street site that is 300' deep x 80' wide. The research and development team engaged Vince McClellan of **Energy Design** (Eugene, Oregon) for **site solar analysis, system design and pricing**. Energy Design's analysis and proposal for each site is presented in the following pages.

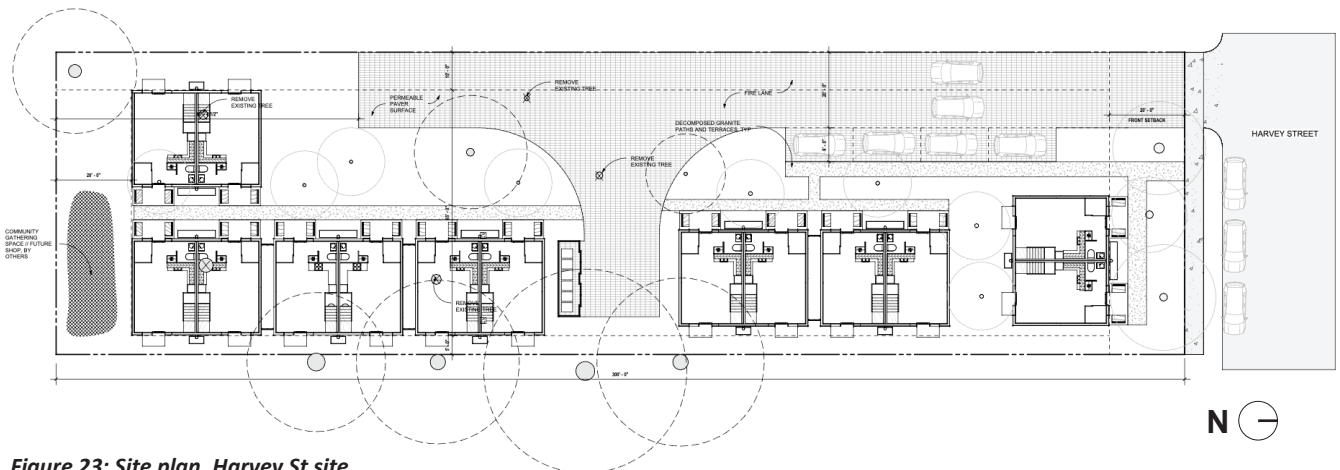


Figure 23: Site plan, Harvey St site



4.2 PV SOLAR STUDY 36 AVENUE SITE PROPOSAL BY ENERGY DESIGN



Energy Design

The sun is rising on a new energy future

SOLAR

energy for today

A customized proposal for:

Milwaukie Courtyard Housing

Project 36th Ave

Mark Fretz

10325 SE 36th Ave

Milwaukie, OR 97222

Energy Design

Designer Contact: Vince McClellan

541-517-2121

vince@solarenergydesign.com



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4.2 PV SOLAR STUDY 36 AVENUE SITE PROPOSAL BY ENERGY DESIGN

10325 SE 36th Ave
Milwaukie, OR 97222



You would generate

62%

of your energy from solar

System summary

118 REC REC370NP2 Black

Enphase Energy Inc. IQ 7+ (240V)

118

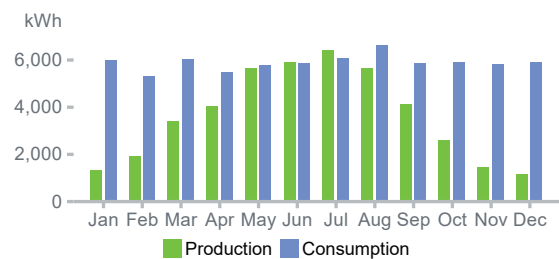
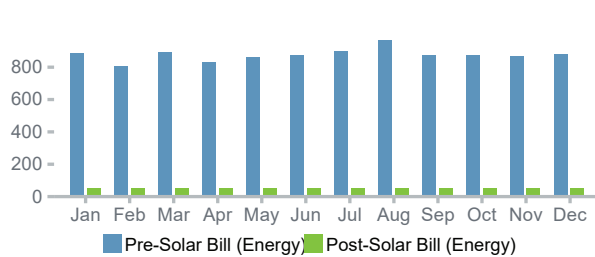
System size 43.66 kW

Year 1
Production 43,760 kWh

4.2 PV SOLAR STUDY 36 AVENUE SITE PROPOSAL BY ENERGY DESIGN



Average monthly electric bill



4.3 PV SOLAR STUDY HARVEY SITE PROPOSAL BY ENERGY DESIGN



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Milwaukie Courtyard Housing

Project SE Harvey ST

Mark Fretz

3736 SE Harvey St

Milwaukie, OR 97222

Energy Design

Designer Contact: Vince McClellan

541-517-2121

vince@solarenergydesign.com



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4.3 PV SOLAR STUDY HARVEY SITE PROPOSAL BY ENERGY DESIGN

3736 SE Harvey St
Milwaukie, OR 97222



You would generate

66%

of your energy from solar

System summary

92

REC REC370NP2 Black

Enphase Energy Inc. IQ 7+ (240V)

92

System size 34.04 kW

Year 1 Production 38,663 kWh



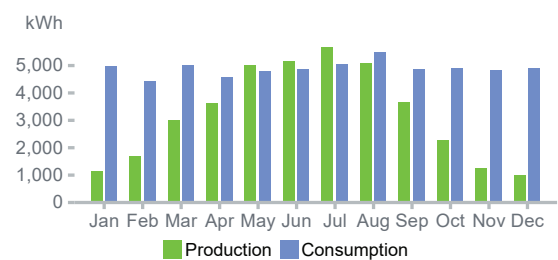
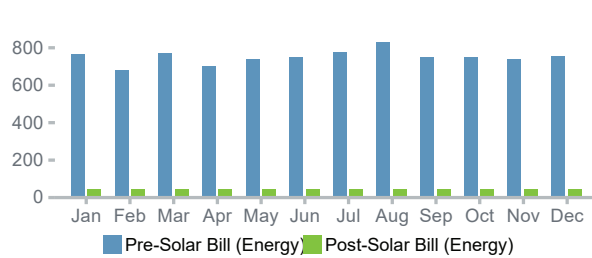
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4.3 PV SOLAR STUDY HARVEY SITE PROPOSAL BY ENERGY DESIGN



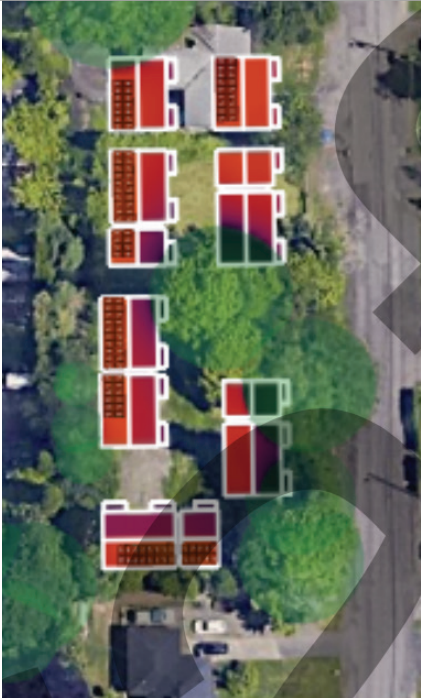
Average monthly electric bill



5.1 PV SOLAR PRICING FOR 36 AVENUE BY ELEMENTAL ENERGY



SITE PLAN



10325 SE 36th Ave Milwaukie, OR 97222

SCOPE OF WORK

☒ Solar PV

☐ Energy Storage

☐ Electrical Upgrades

☐ Electric Vehicle Charging

☐ Lighting Upgrades

☐ Consulting

☐ (Other)

PV SYSTEM SIZE

43.7 kW

ENERGY STORAGE

0 kWh

ITEMS INCLUDED

☒ Provide filing assistance for net-metering paperwork

☒ All local permits

☒ All wiring, conduit, disconnects, and grounding according to 2020 NEC

☒ 2 year workmanship warranty

☒ System operation and safety walkthrough

☒ Final energy storage price subject to change after technical audit

☒ Owner's manual with all design documentation

SYSTEM

**Modules (118)**
REC 370w or Tier 1
Warranty: 10 Years

**Enphase IQ8**
Warranty: 25 Years

**BATTERY (0)**
Tesla Powerwall 2

**EV CHARGING (0)**
Tesla Wall Connector

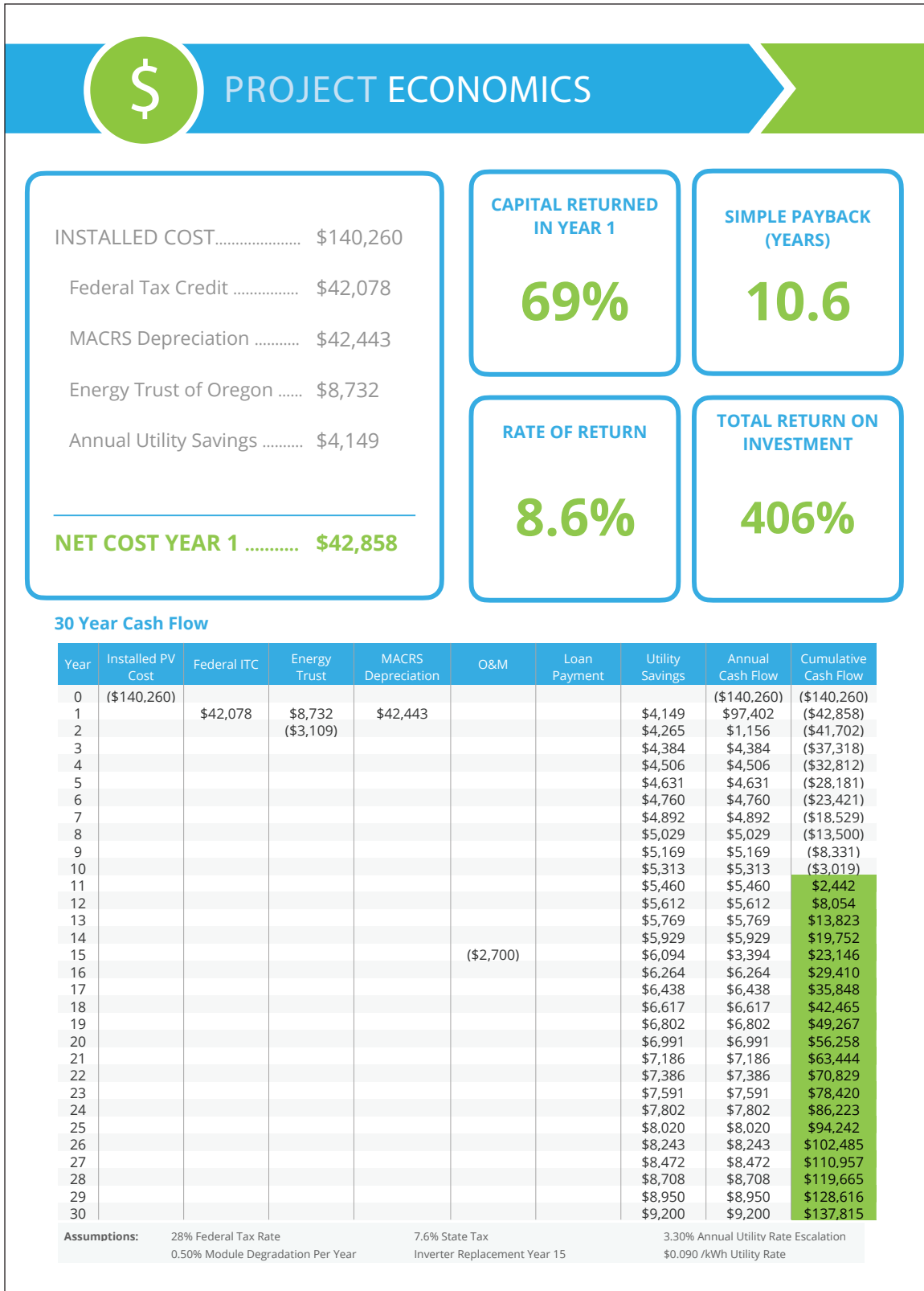
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5.1 PV SOLAR PRICING FOR 36 AVENUE BY ELEMENTAL ENERGY



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5.2 PV SOLAR PRICING FOR HARVEY STREET BY ELEMENTAL ENERGY



PROJECT DESIGN + SCOPE

SITE PLAN



3736 SE Harvey St Milwaukie, OR 97222

SCOPE OF WORK

☒ Solar PV
☐ Energy Storage
☐ Electrical Upgrades
☐ Electric Vehicle Charging
☐ Lighting Upgrades
☐ Consulting
☐ (Other)

PV SYSTEM SIZE
34.0 kW

ENERGY STORAGE
0 kWh

ITEMS INCLUDED

☒ Provide filing assistance for net-metering paperwork
☒ All local permits
☒ All wiring, conduit, disconnects, and grounding according to 2020 NEC
☒ 2 year workmanship warranty
☒ System operation and safety walkthrough
☒ Final energy storage price subject to change after technical audit
☒ Owner's manual with all design documentation

SYSTEM

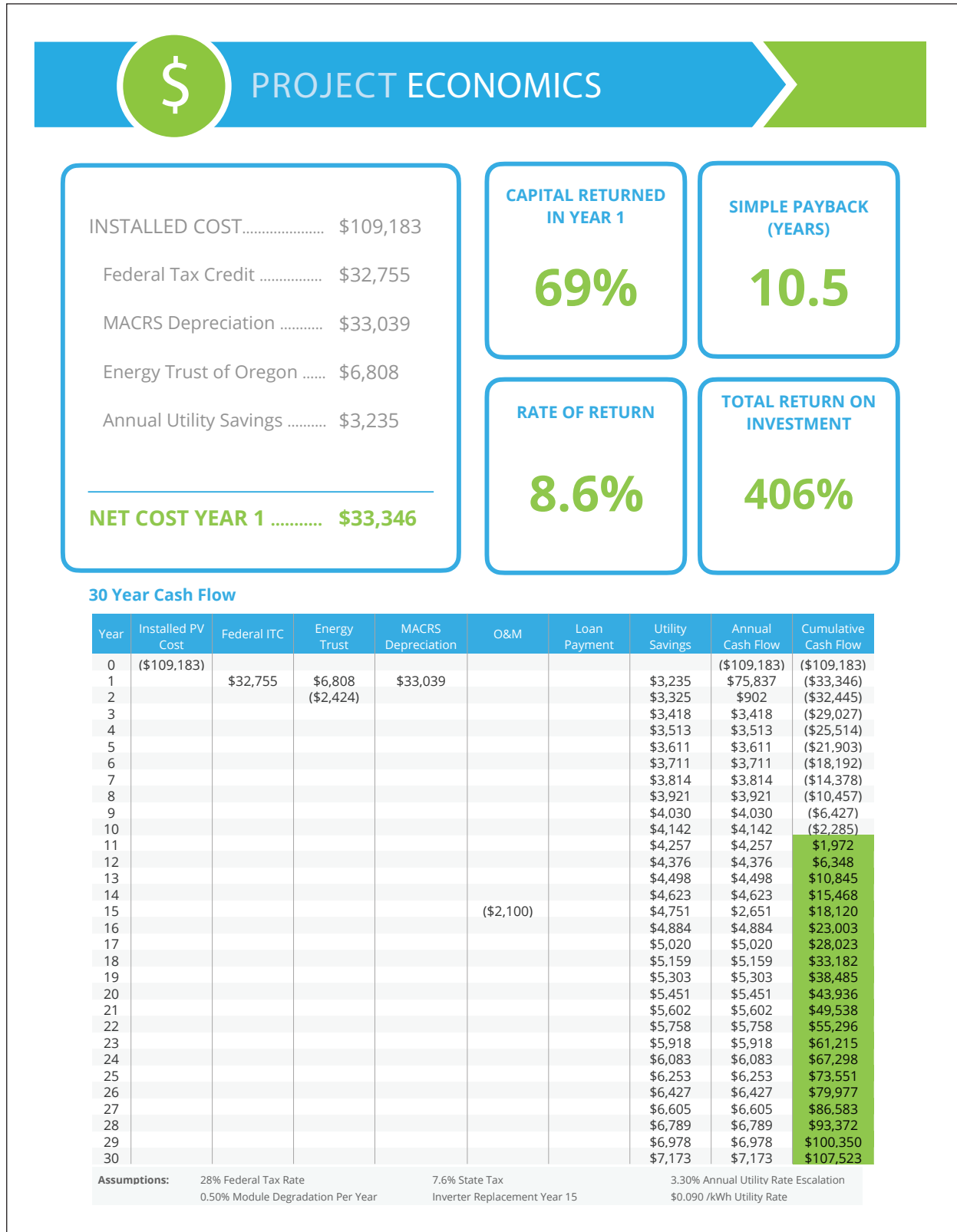
**Modules (92)**
REC 370w or Tier 1
Warranty: 10 Years

**Enphase IQ8**
Warranty: 25 Years

**BATTERY (0)**
Tesla Powerwall 2

**EV CHARGING (0)**
Tesla Wall Connector

5.2 PV SOLAR PRICING FOR HARVEY STREET BY ELEMENTAL ENERGY



6.0 MICROGRID

Roof mounted photovoltaic panels could be configured as a simple grid-tied system for each housing unit or all units on a given site, but PV alone would not provide power if there was a utility service disruption. Adding battery storage capacity would allow for some supplemental power when there is a utility disruption and would add functionality to the proposed rooftop PV for resilience. On-site energy storage would require equipment and controls in addition to batteries and could also happen at each house or collectively on the site. Adding an additional layer of smart control at the community level to manage all on-site energy generation, energy storage and when and how much to rely on utility grid distribution would mean the cottage cluster development was operating a microgrid.

With the proposed site-scale central heating and cooling system and a single utility grid electrical service drop tie-in for all units, centrally locating and controlling energy storage would be appropriate and reduce the number of components, complexity, and cost. It would also allow for system maintenance, repair, and fire suppression requirements to occur in a single location and not at every house.

Behind a site-level utility meter and microgrid controller, the on-site microgrid electrical distribution network and electrical service equipment at each house would be fairly conventional with the added provision for metering to track energy usage and production. With proposed rooftop PV being connected via micro-inverters at each panel, energy generation will be delivered via alternating current (AC) wiring from the rooftop array to the individual house main electrical panel and throughout the microgrid. The estimated circuit requirements for PV at each house would be

a double pole 20-amp breaker. The centrally located direct current (DC) battery bank would have its own inverter, eliminating any long DC wire runs and maintaining all AC distribution across the site. The battery bank could be considered as another node on the microgrid, equally able to draw and store energy from the utility and rooftop PV or deliver energy to meet demand loads from any house on the micro-grid.

Three scenarios of site-level microgrid system configurations are explored in Table 3. Power and energy requirements based on energy model derived loads are shown for each site, and microgrid rough order of magnitude installed costs are further estimated based on those values and the description of each scenario.

Scenario #1 sizes battery capacity for a full day of normal energy use, meaning the microgrid could both be completely disconnected from the utility grid for this period and additionally not reliant on PV generation. Any PV generation would extend the period the micro-grid could run self-sufficient or in “islanding” mode.

Scenario #2 aims to describe a lower cost, and consequently lower level of resilience than the previous scenario. But it also aims to capitalize on infrastructure and community structure inherent to the site. Energy storage for scenario #2 is sized to meet the full heating or cooling demand, as those systems are central site-level systems. It further provides emergency electrical circuits at a central location for changing devices and minor equipment loads. This supports and perhaps strengthens to the nature of such a community to come together and look out for one another in times of uncertainty or

crisis.

Scenario #3 describes an operational mode that could be in place most of the time, as a microgrid system will typically be connected to the utility grid and service interruptions are hopefully rare. The intent of this scenario is to size the on-site energy storage system to cover loads for all units for a five-hour period of peak demand. This relieves strain on the utility grid at critical times of high demand and is referred to as peak shaving. It can also lead to reducing the overall cost of energy from the grid, either by buying and storing energy when it is cheaper, or as has occurred in some cases, by negotiating a reduced rate based on an agreement to not draw from the grid during peak periods.

A cottage cluster microgrid system would be a relatively small system by the standard of today's existing installations. Most systems would be described in MW/MW-h and serve a campus, industrial complex, or large community. There is a wide range of normalized system costs for existing microgrid systems. Existing system cost data suggests that component cost per MW goes down as overall system size increases. Component cost has also been shown to go down as system complexity decreases. There may be a lower cost limit threshold for the microgrid controller that has a sufficiently sophisticated level of control complexity regardless of the relatively small sizing of a system for 15 or 21 housing units. A more detailed system specification would be needed to identify these issues and cost breakpoints.

Lithium iron phosphate batteries are used in this estimate and the batteries comprise roughly 90% of the energy storage system cost. Sodium-ion batteries are soon to be mass produced in the US (2023) and

should be available at a significant cost saving over current battery technologies due to the abundance and low cost of this much safer and environmentally friendly technology. Current pricing for sodium-ion batteries is three times less than lithium iron phosphate, and that margin could be expected to grow as production of sodium-ion batteries increases.

Electric vehicle charging is not included in the scenarios presented. The microgrid controller could provide some advantages when EV charging is done as part of the microgrid. Bi-directional charging, however, may not be viable in the time frame and ownership model of this project. Currently only the Nissan Leaf allows bi-directional charging, where the storage capacity of the EV can be depleted and used to meet demand on the microgrid. If such a system were included, a 2023 Nissan Leaf has a 40 or 60 kilowatt-hour battery pack.

An electrical microgrid system integrates well with other district-type systems and the community shared resource potential of rooftop photovoltaic panels planned for these sites. Like the cost of PV, battery cost for on-site energy storage should come down with the advancement of new technologies. Microgrid controller technology cost and capabilities vary widely. A utility grade microgrid controller with associated engineering and programming services could be more expensive than the rest of the system combined. A microgrid will help these communities put less strain on the utility grid, make full use of renewable energy generation and provide some level of energy resilience and piece of mind for residents.

6.1 MICROGRID SIZING AND COST

Site / System component	units	System Sizing Scenarios		
		1. Full day of normal use.	2. Full day of normal use for heat/cooling/pump only plus a couple central electric circuits for community to use for charging and minor equipment.	3. Utility peak shaving by removing community from the utility network for 5 hours.
15-unit development	kw	23.3	19.0	23.3
21-unit development	kw	32.6	26.6	32.6
15-unit development	kwh	240.9	170.8	116.3
21-unit development	kwh	337.2	237.0	162.8
15-unit installed battery/inverter/controller	\$	\$111,031	\$89,639	\$105,999
21-unit installed battery/inverter/controller	\$	\$155,379	\$125,409	\$148,335
15-unit installed microgrid controller	\$	\$7,211	\$5,889	\$7,211
21-unit installed microgrid controller	\$	\$10,091	\$8,245	\$10,091
15-unit total	\$	\$118,242	\$95,528	\$113,209
21-unit total	\$	\$165,469	\$133,654	\$158,425

Table 4: Microgrid system sizing and cost scenarios

7.0 ACKNOWLEDGMENTS

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PAE

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Andrew Comstock
Karina Hershberg
Erica Ross

Conflict of Interest Statement for Mark Fretz: I receive research funding from ShortStack Housing, LLC. and HomeWork Development to research and develop prototypical 2-bed and 3-bed panelized modular mass timber housing units. ShortStack Housing, LLC. may use a vacant lot I own with my spouse to use as a location for a development employing prototype units developed from this research. The sponsored project research funds would be used to inform the development of the prototype, but my property would only be used as a model for costs and code considerations. No actual work from the sponsored project would be done on my property.



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