In Hot Pursuit of the Cold Facts

Mechanical Systems in the Mount Vernon Library Commons

phius con
MILWAUKEE 2025

Mount Vernon Library Commons

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Kriegh Architectural Studio (Sustainability Lead)

WSP (WUFI, WBLCA, Envelope)

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Pacific Survey & Engineering (Survey)

GeoEngineers (Geotechnical)

Swift Company (Landscape)

KPFF (Civil and Structural)

FSi Engineers (Mechanical)

TFWB (Electrical)

Dark | Light Design (Lighting)

The Greenbusch Group (Acoustics, AV, Vertical Trans)

Studio Pacifica (Accessibility)

Clevenger Associates (Food Service)

BrandQuery (Wayfinding and Graphics)

DCW (Cost Engineering)

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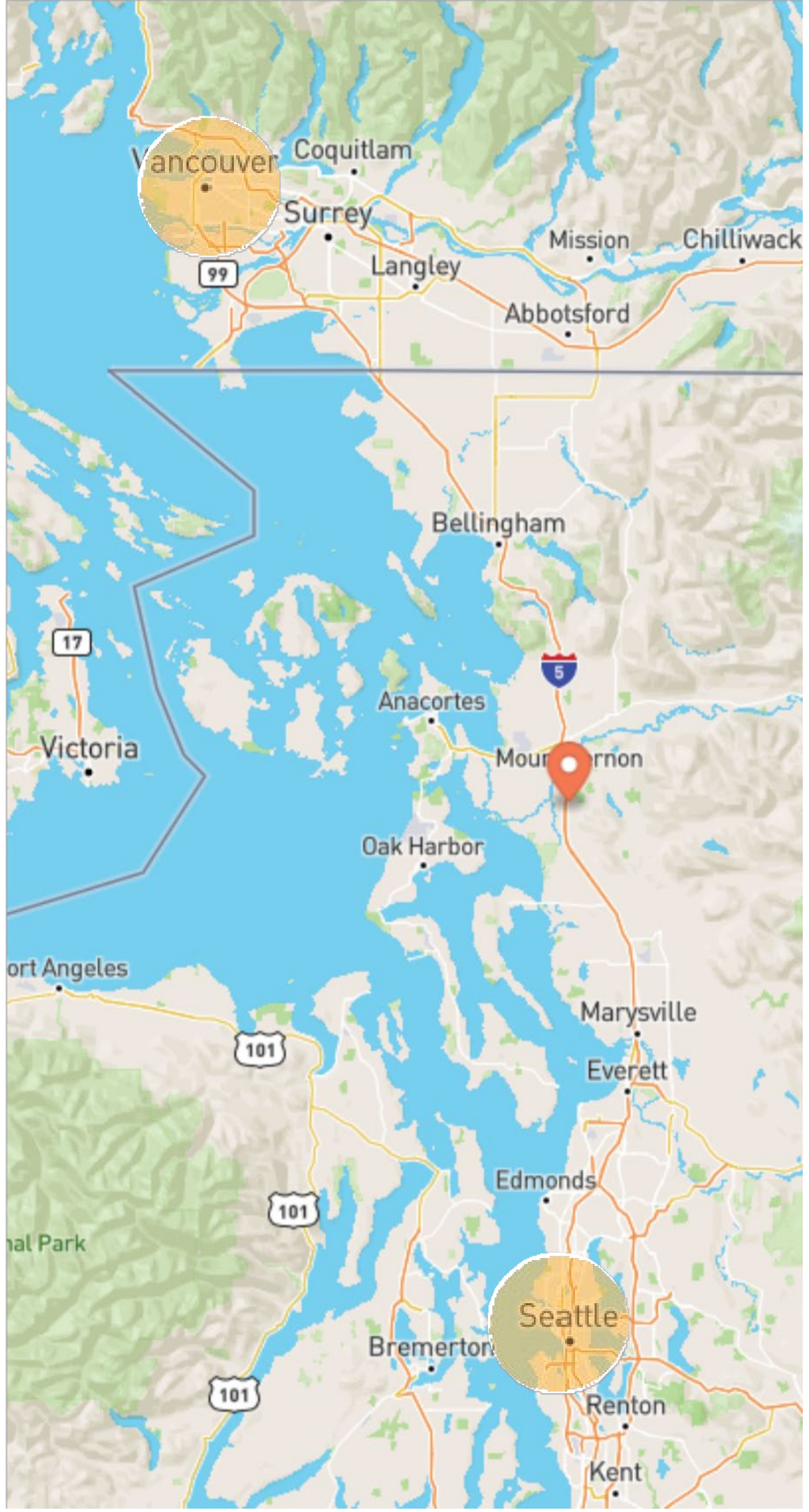

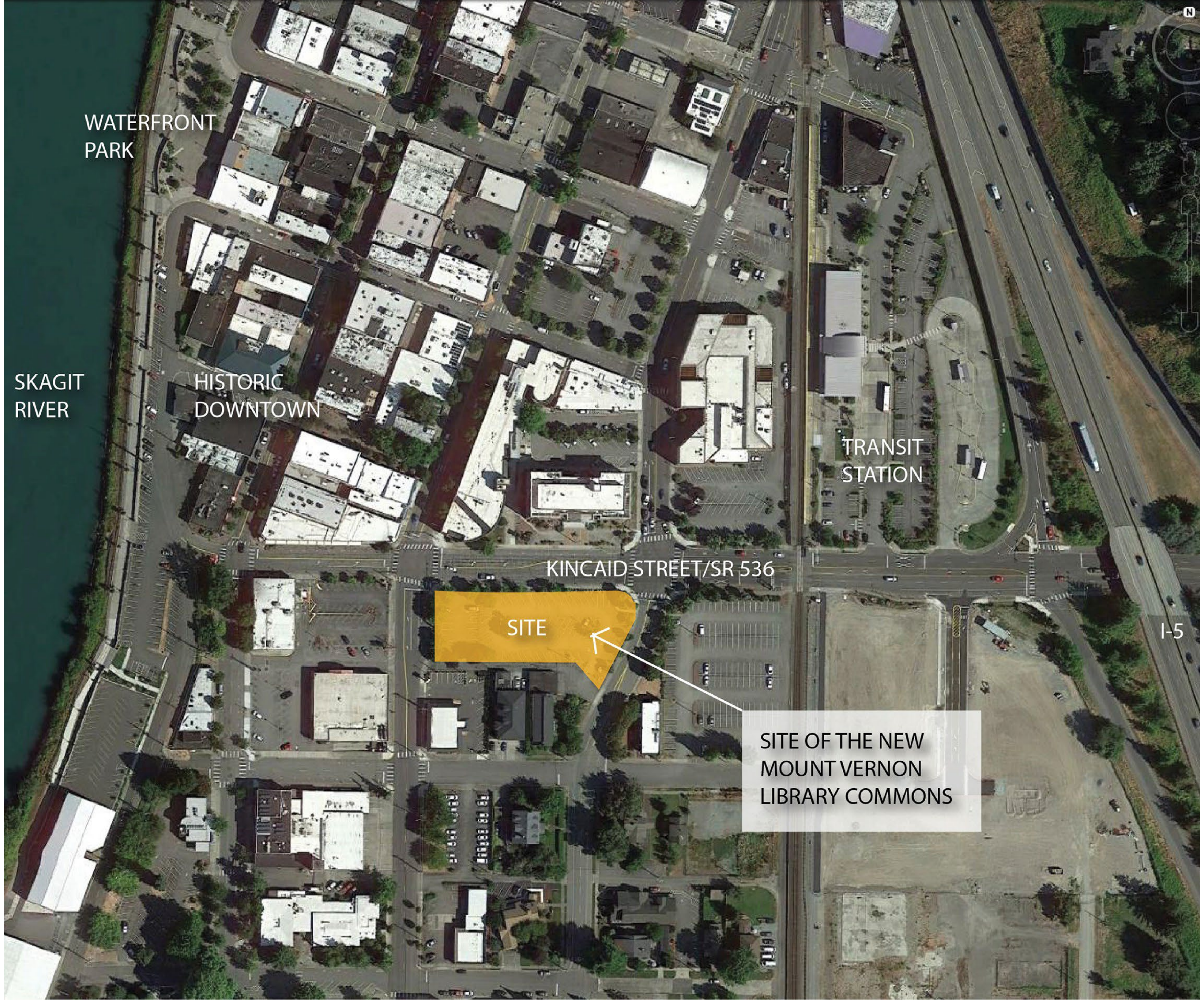

Gateway and Catalyst Project

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Community Hub

Library

Community Center

Parking/ EV Charging

Economic Development Catalyst

Climate Resilient Building

75-100 Year Building

60% Less Energy Use

35% Less Embodied Carbon

Overarching Goals

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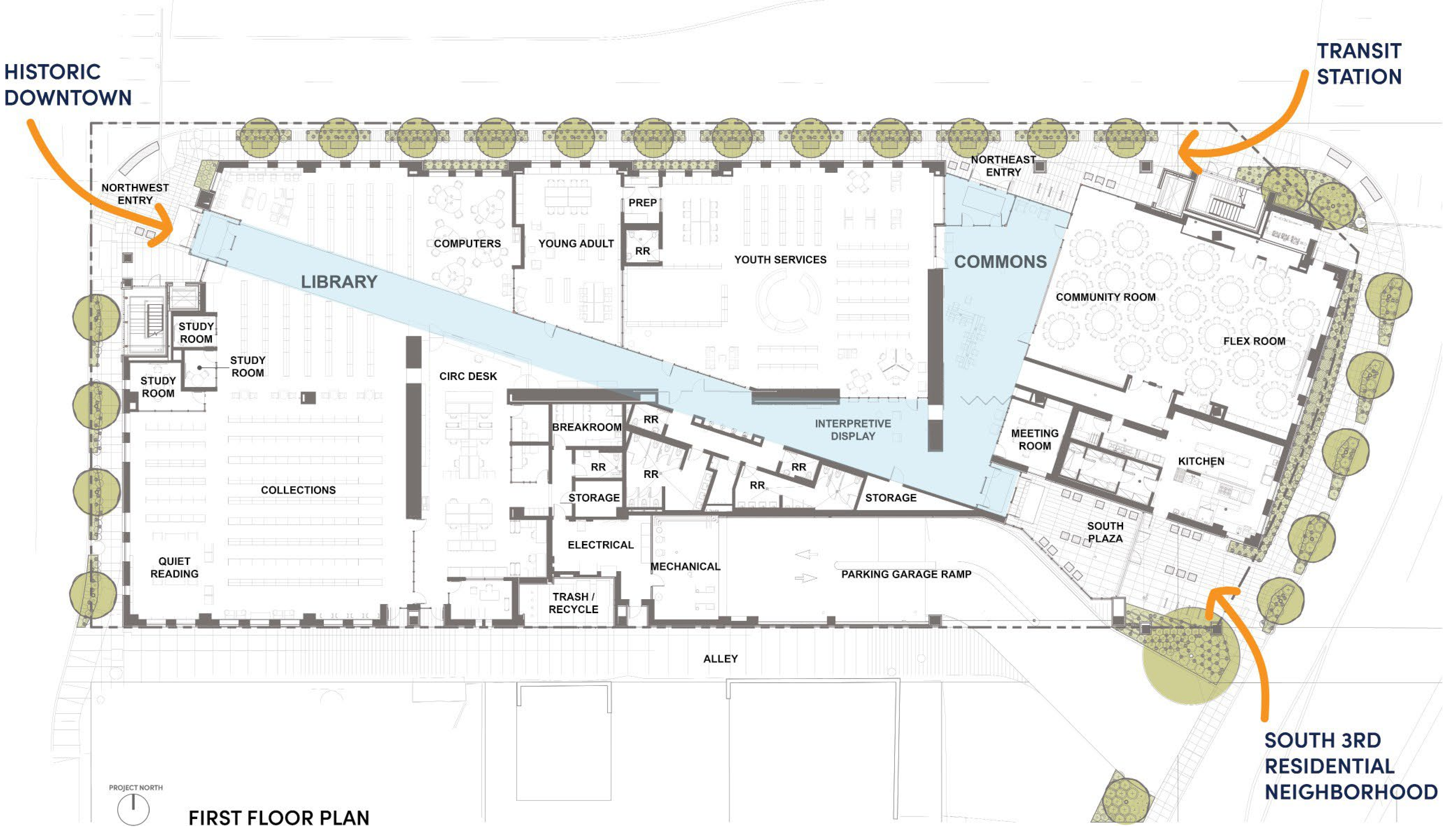


Organization

Low Energy Use
An anticipated Energy Use Intensity of 12 kBtu/SF/yr would be 82% more efficient than the average existing Library in Washington State.

76 EV Charging Stations
With capacity for 200 stations, the garage will be the largest public charging facility in the United States.

Native and Resilient Plantings
Reduces the need for irrigation.

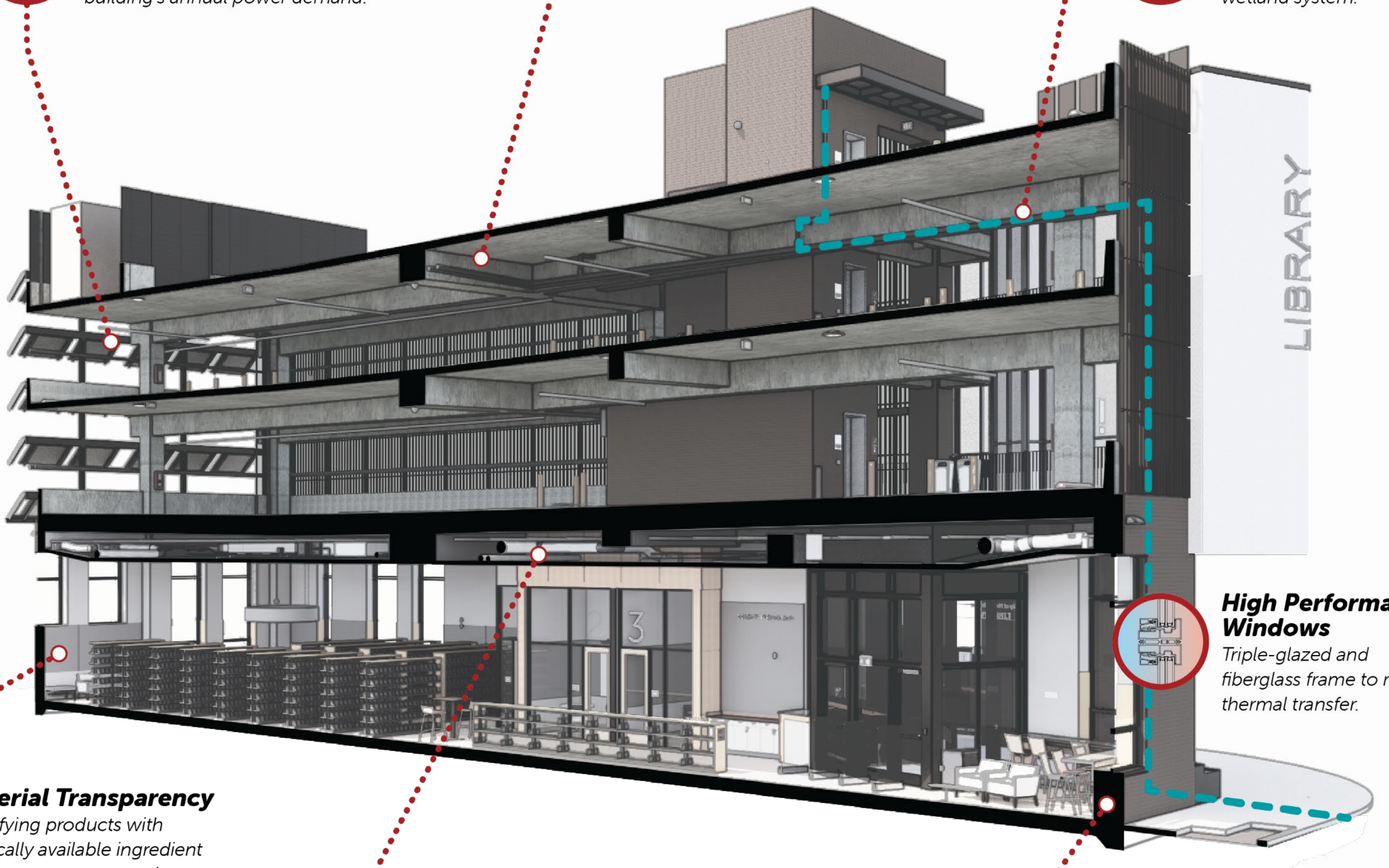
PV Solar Array
A 129kW solar array on the roof and south facade would supply 19-21% of the building's annual power demand.

Low Carbon Materials
Including concrete mix designs to reduce the embodied carbon emissions of typical construction by over 30%, and carbon-negative carpet.

Stormwater Management
Underground modular wetland system.

- **Low Energy Use**
- **PV Solar Array**
- **Low Carbon Concrete Mixes**
- **Daylighting**
- **High Efficiency Air-to-Water Heat Pump**
- **Native and Resilient Plantings**
- **On-site Stormwater Treatment And Permeable Pavers**
- **Naturally Ventilated Parking Garage**
- **Passive House Certification**
  - **Super Insulated Envelope**
  - **Air-Tight Construction**
  - **High-Performance Windows**
  - **Thermal-Bridge-Free Detailing**
  - **Heat Recovery Ventilation**
- **Proximity to Transit**
- **EV Charging Hub**
- **All-Electric Building and Commercial Kitchen (Kitchen ouside of Passive House boundary)**
- **Electric Bike Charging**
- **Material Transparency**

Naturally Ventilated Garage
Eliminates the energy required for mechanical ventilation.



High Performance Windows
Triple-glazed and fiberglass frame to reduce thermal transfer.

Material Transparency
Specifying products with publically available ingredient disclosures to promote human and environmental health.

Heat Recovery Ventilation
Reduces energy demand by exchanging heat between exhaust and intake air.

Super Insulated Envelope
Reduces energy demand and maintains a comfortable interior environment year round.

Sustainable Strategies

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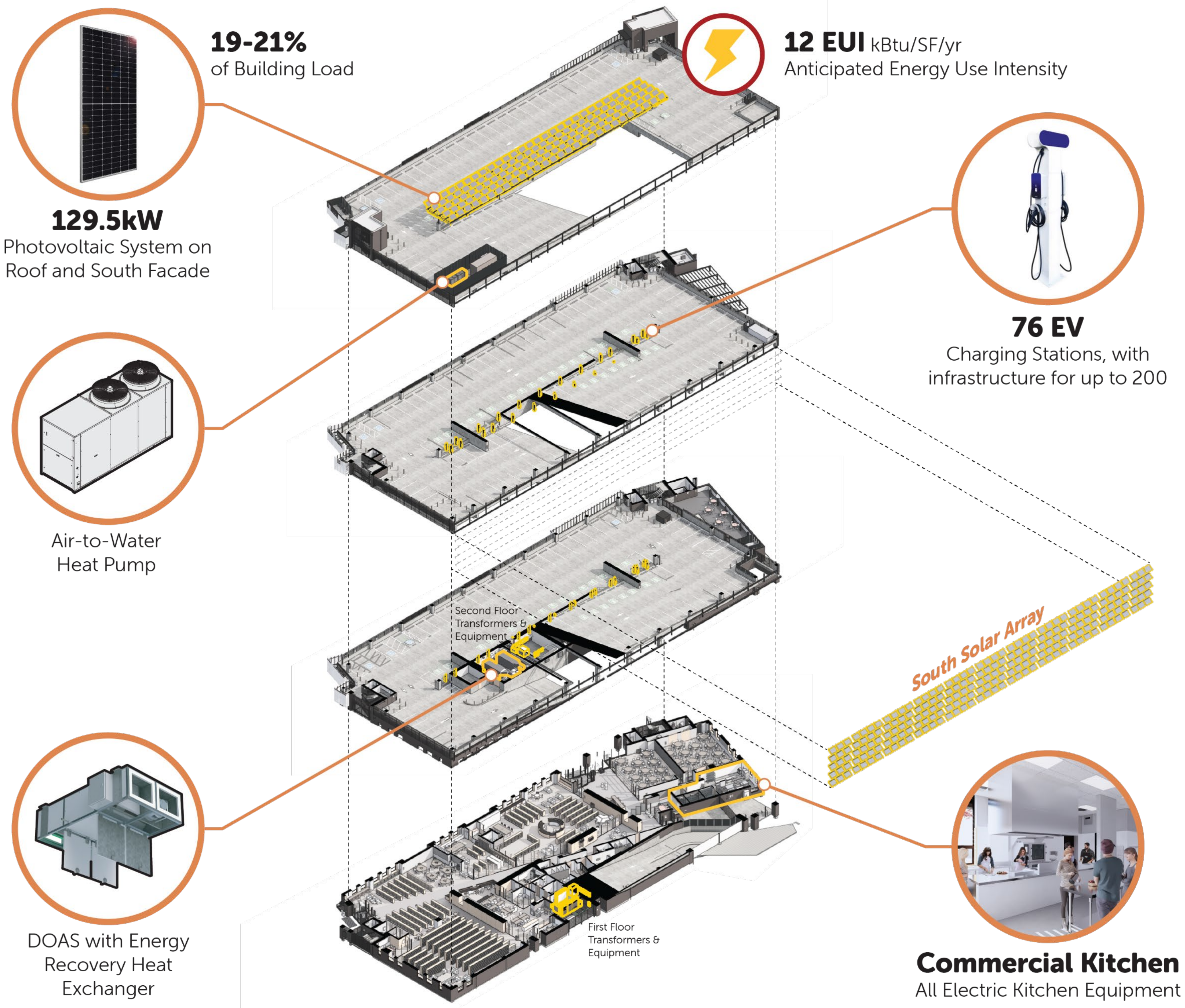
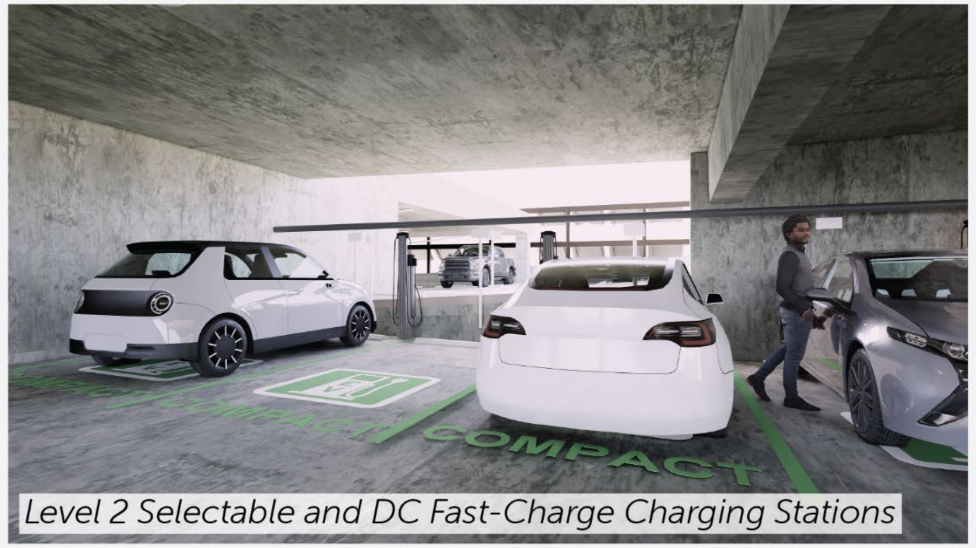



Rooftop Solar Array


Level 2 Selectable and DC Fast-Charge Charging Stations


Electric Bike Charging Lockers

All Electric Building

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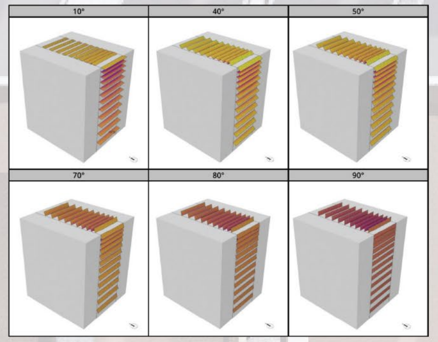
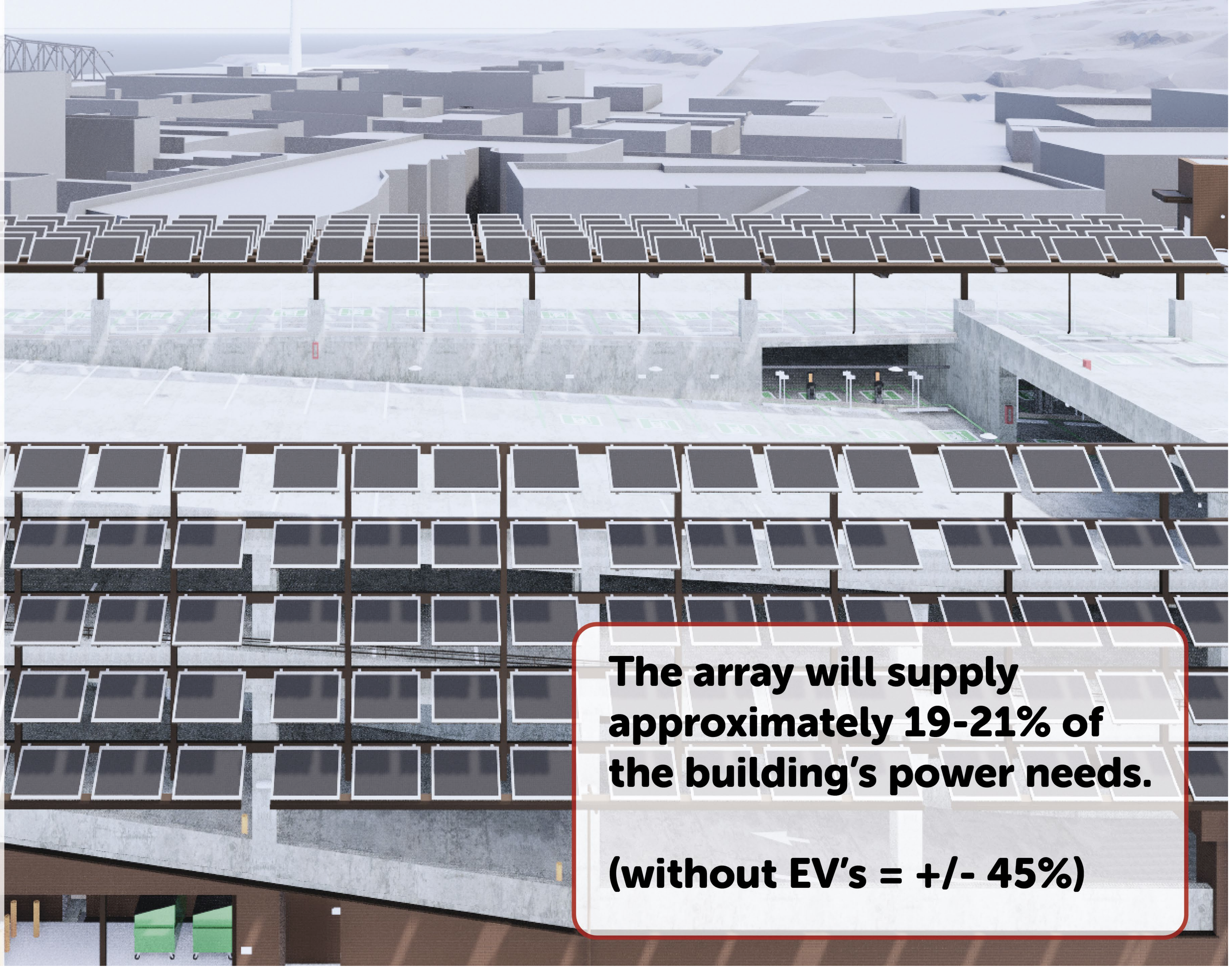
129.5 kW

= 4 1/4 TENNIS COURTS
(Or 13 1/2 Pickelball Courts!)

Total infrastructure area
Photovoltaic System on Roof and South Facade



Tilt angle simulations

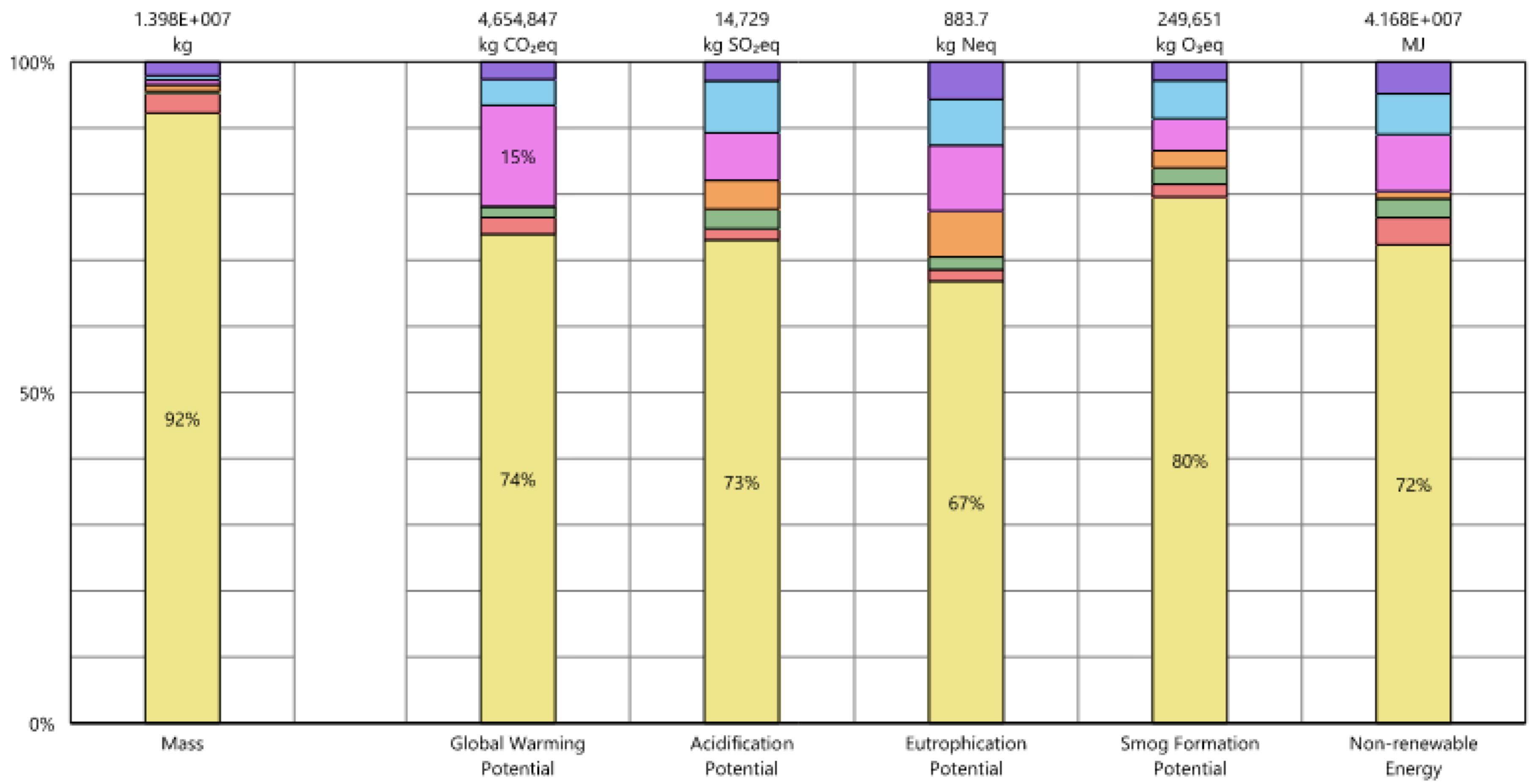


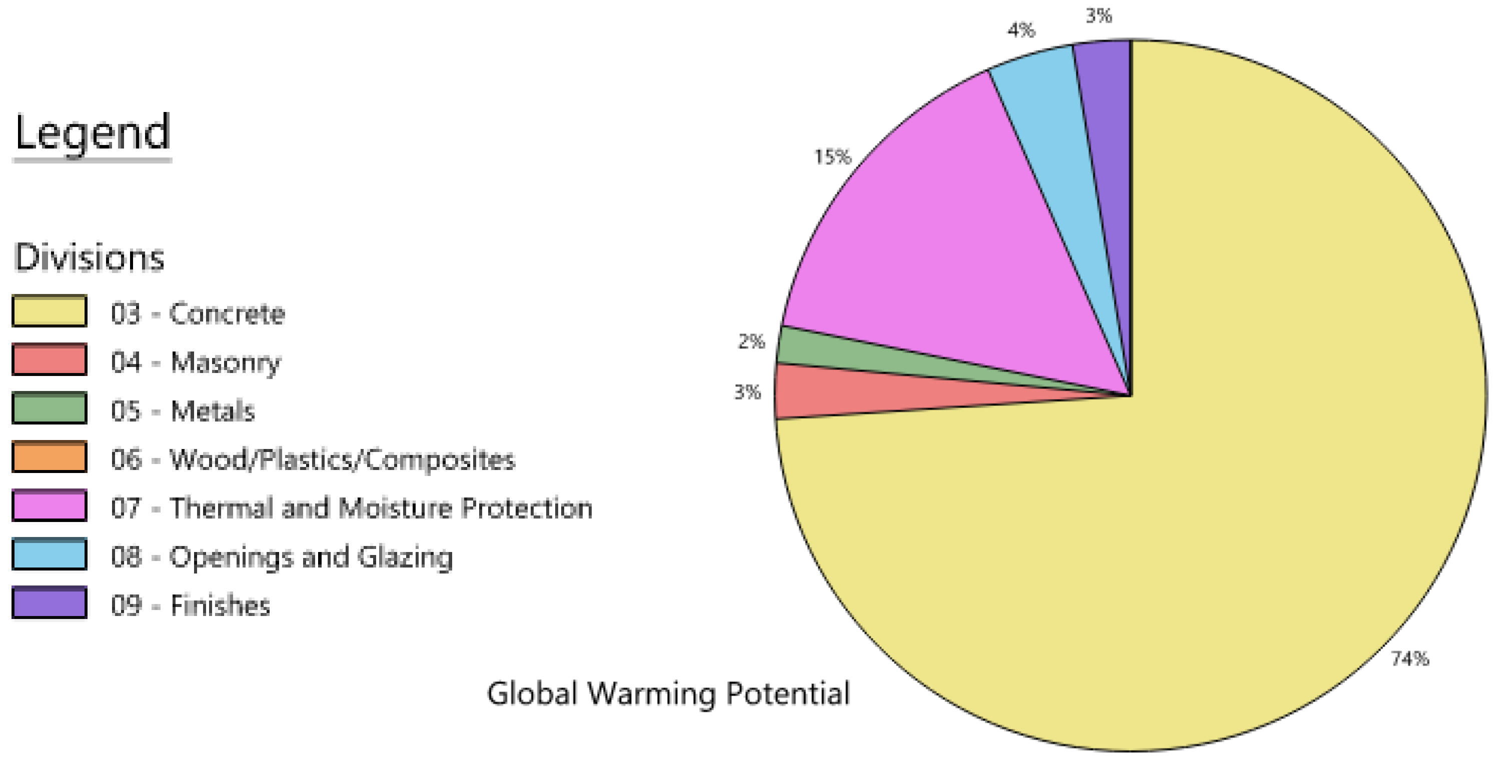
The array will supply approximately 19-21% of the building's power needs.

(without EV's = +/- 45%)

On-Site Solar

Results per Division





Global Warming Potential

Type 1L in all mixes

CONCRETE

CONCRETE WORK SHALL CONFORM TO ALL REQUIREMENTS OF IBC CHAPTER 19.

CONCRETE MIXTURES
CONCRETE MIXTURES SHALL CONFORM TO THE FOLLOWING REQUIREMENTS:

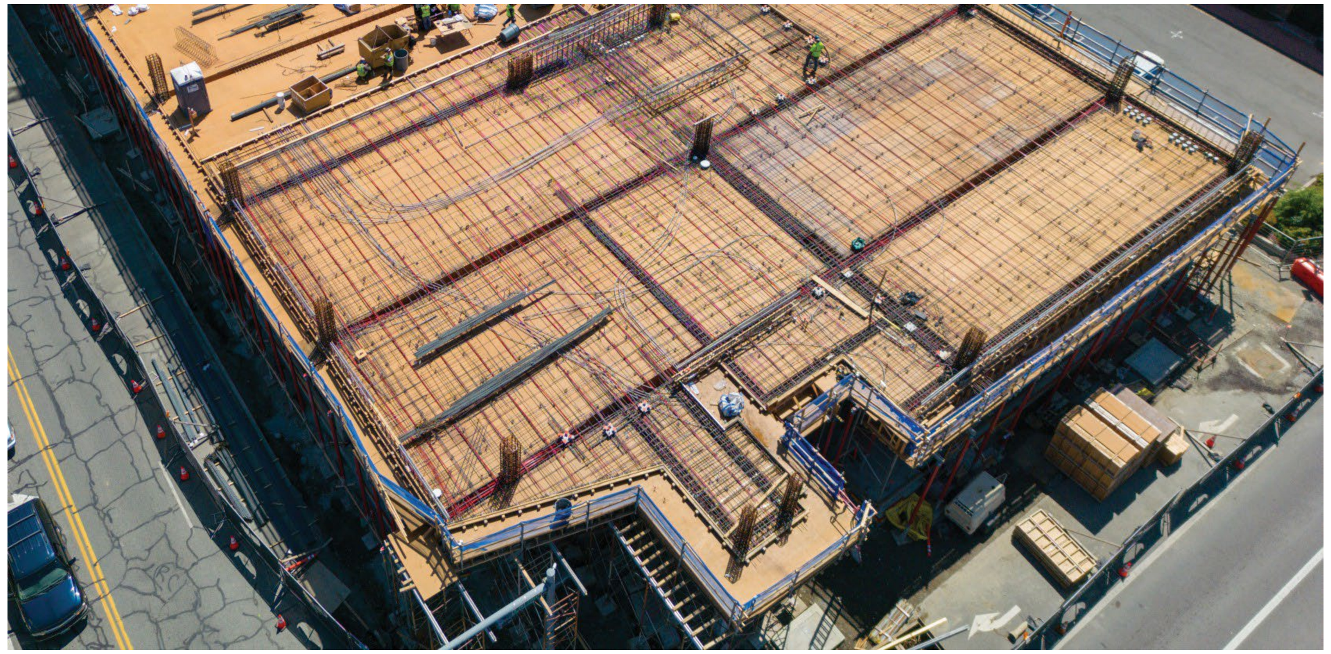
CONCRETE MIXTURES

f'_c (PSI)	TEST AGE (DAYS)	EXPOSURE CLASS F	S	W	C	MAX W/C RATIO	USE	NOTES
3,500	56	F1	S0	W0	C1	-	CURBS AND PADS	3
4,000	56	F0	S1	W0	C1	-	FOUNDATIONS, UNO	5
4,000	56	F0	S1	W0	C1	0.45	WALLS (UNO), VEHICLE BARRIERS	4
4,000	56	F0	S1	W1	C1	0.45	INTERIOR SLAB-ON-GRADE, ELEVATOR PIT WALLS	2
4,000	56	F1	S1	W1	C1	0.45	EXTERIOR SLAB-ON-GRADE	4
5,000	56	F0	S1	W0	C1	-	MAT FOUNDATIONS	5
5,000	56	F0	S1	W0	C1	-	PRECAST STAIRS	-
6,000	56	F1	S0	W0	C1	0.40	ELEVATED SLABS AND BEAMS, UNO	1, 2
6,000	56	F2	S0	W1	C1	0.45	ELEVATED SLABS AND BEAMS AT TOP LEVEL, TOP RAMP	1, 2
6,000	56	F0	S0	W0	C1	-	COLUMNS, SHEAR WALLS	2

1. FOR POST-TENSIONED SLABS AND BEAMS, CONCRETE SHRINKAGE SHALL BE A MAXIMUM OF 0.035 PERCENT, OR A MAXIMUM ALLOWABLE WATER CONTENT OF 255 Lb/CY.
2. PROVIDE A MINIMUM OF 10% SUPPLEMENTARY CEMENITIOUS MATERIALS (SCM).
3. PROVIDE A MINIMUM OF 20% SUPPLEMENTARY CEMENITIOUS MATERIALS.
4. PROVIDE A MINIMUM OF 25% SUPPLEMENTARY CEMENITIOUS MATERIALS.
5. PROVIDE A MINIMUM OF 30% SUPPLEMENTARY CEMENITIOUS MATERIALS.

Whole Building Life Cycle Analysis

			Baseline	Pushing Better than Baseline			
			Type I/II Cement	Type 1L Cement			
Location	Strength (psi)	Project Volume (m3)	28 day GWP (kg CO2e per m3)	28 day GWP lowest of range (kg CO2e per m3)	28 day %Reduction from Baseline lowest of range	56 day GWP lowest of range (kg CO2e per m3)	56 day %Reduction from Baseline lowest of range
Curbs and Pads (plus roof slab)	3,000	37.18	13,609.37	9,714.00	-29%	8,727.84	-36%
Retaining Walls, non-structural walls, vehicle barriers	4,000	59.55	26,948.06	17,891.53	-34%	14,569.41	-46%
Slab on Grade	4,000	20.56	9,303.93	6,177.13	-34%	5,030.15	-46%
Foundations, UNO	4,000	338.00	152,950.98	98,162.37	-36%	80,803.60	-47%
Mat Foundations	5,000	1,019.08	565,115.55	364,520.23	-35%	295,959.38	-48%
Precast Stairs	5,000	15.17	8,412.44	5,956.88	-29%	4,877.02	-42%
Post-Tensioned Slabs and Beams	6,000	2,037.51	1,190,111.84	898,676.05	-24%	853,512.77	-28%
Columns, Shear Walls	6,000	758.72	443,169.93	334,646.03	-24%	317,828.28	-28%
					-31%		**-40%**



Concrete Carbon Reduction

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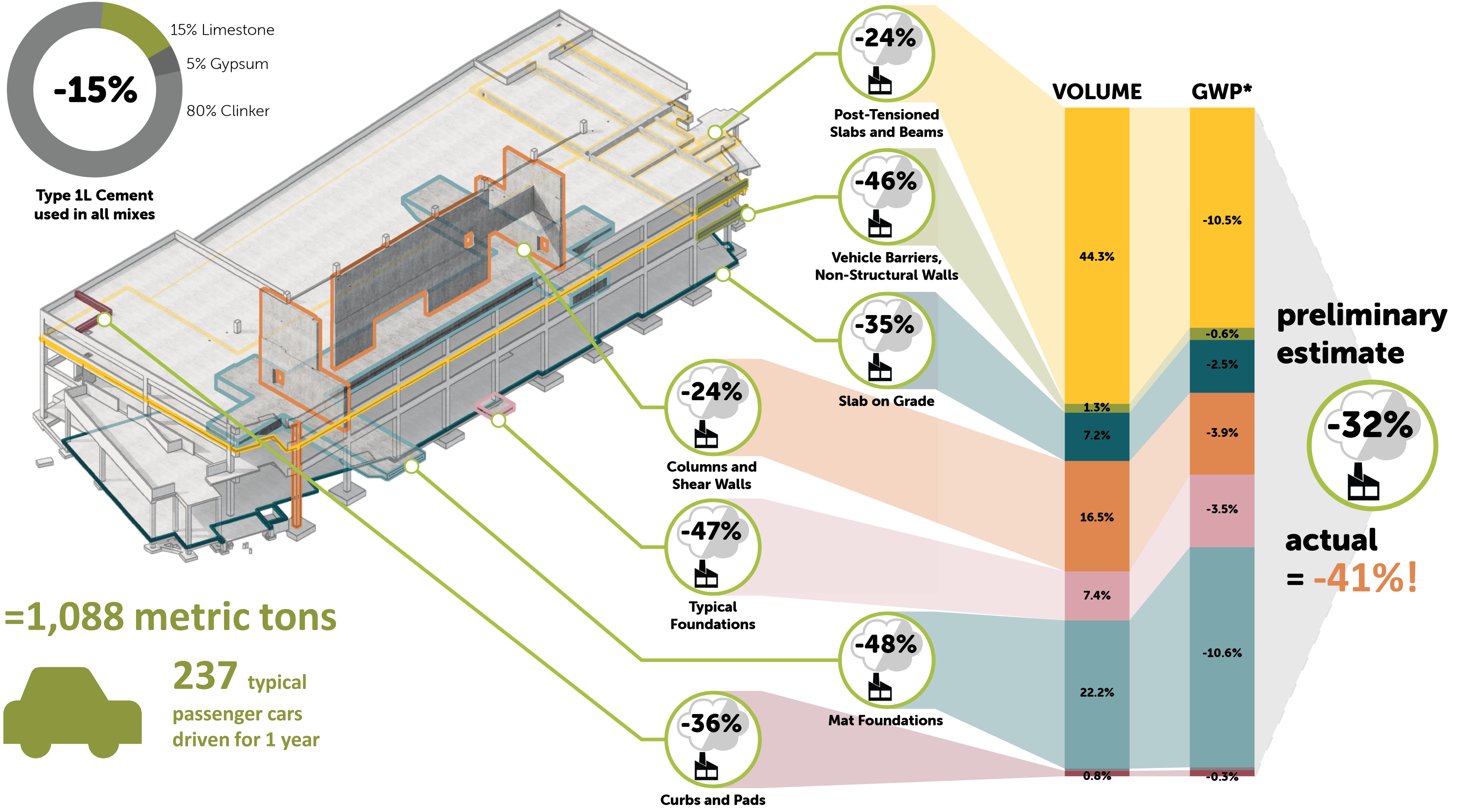
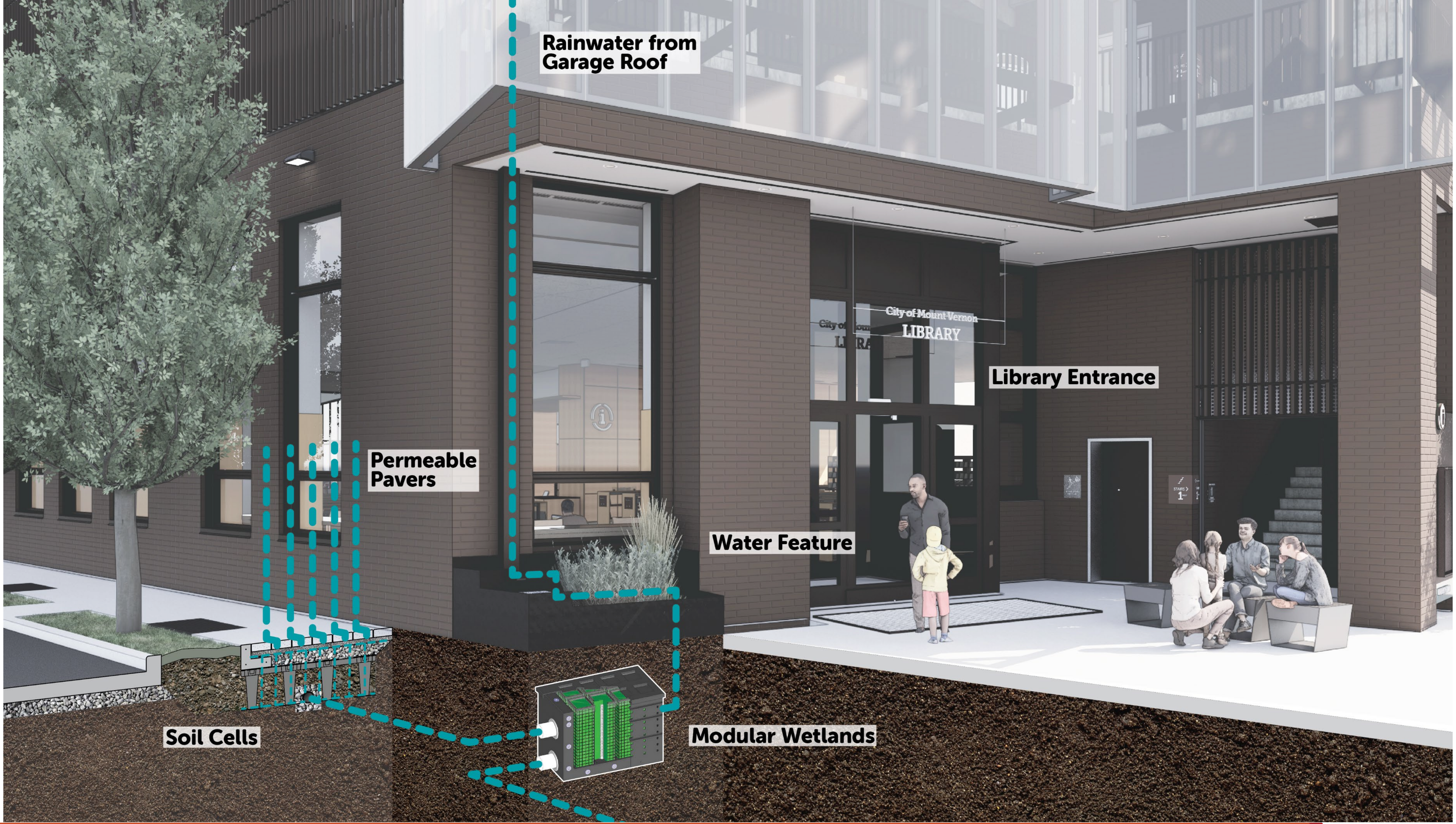
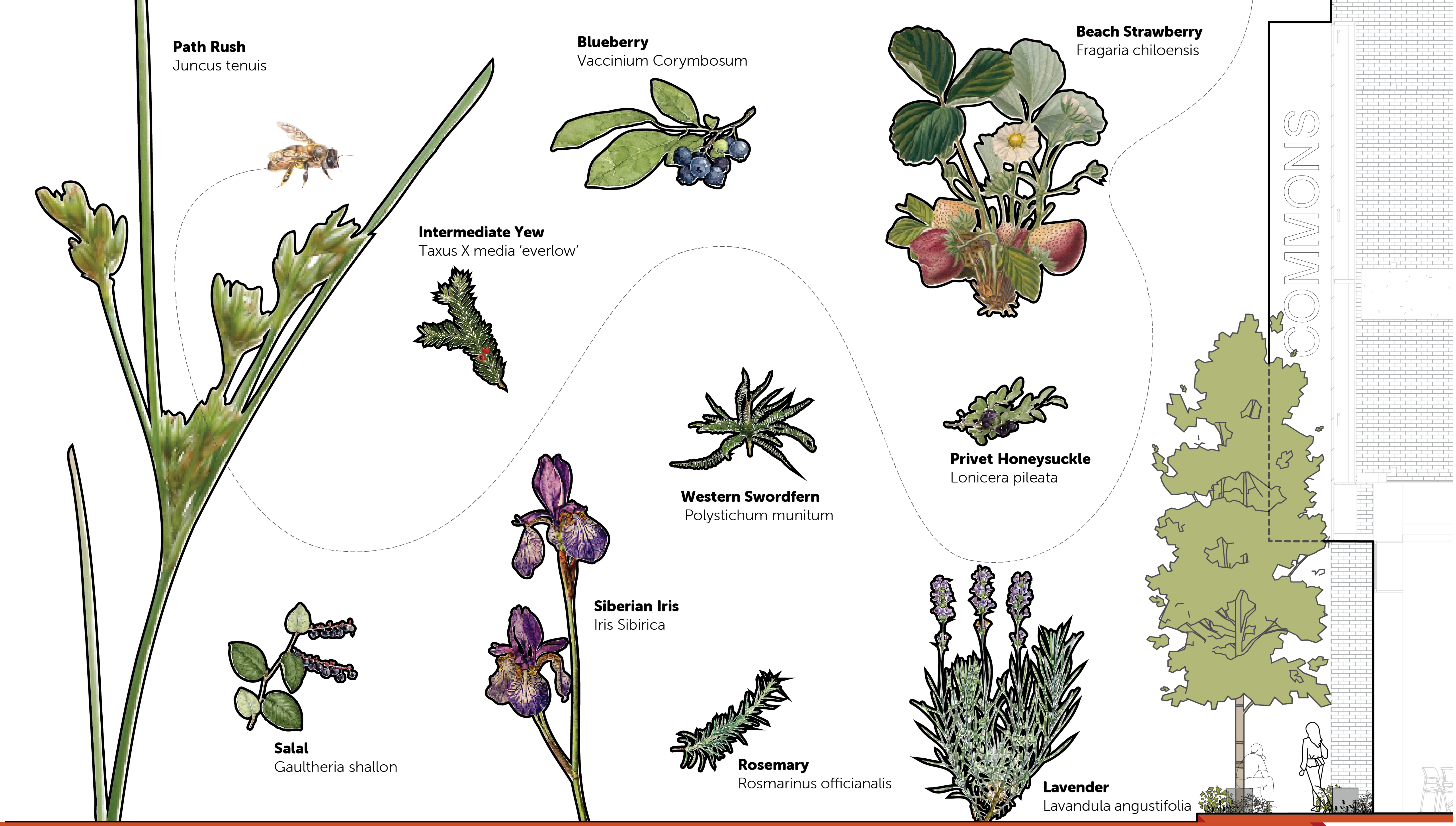


Concrete Carbon Reduction



Stormwater Treatment



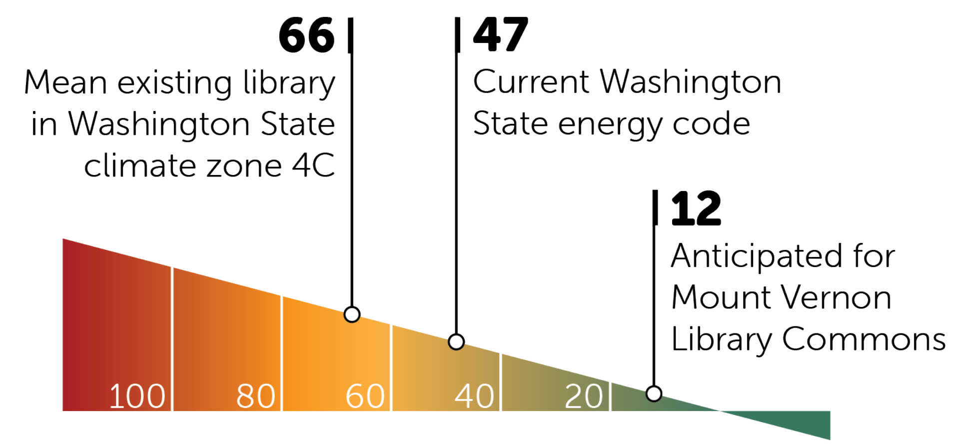
Native and Resilient Plants

STRATEGIES:

- **Super Insulated Envelope**
- **High-Performance Glazing**
- **Heat Recovery Ventilation**
- **Thermal-Bridge-Free Detailing**
- **Air-tight Construction**

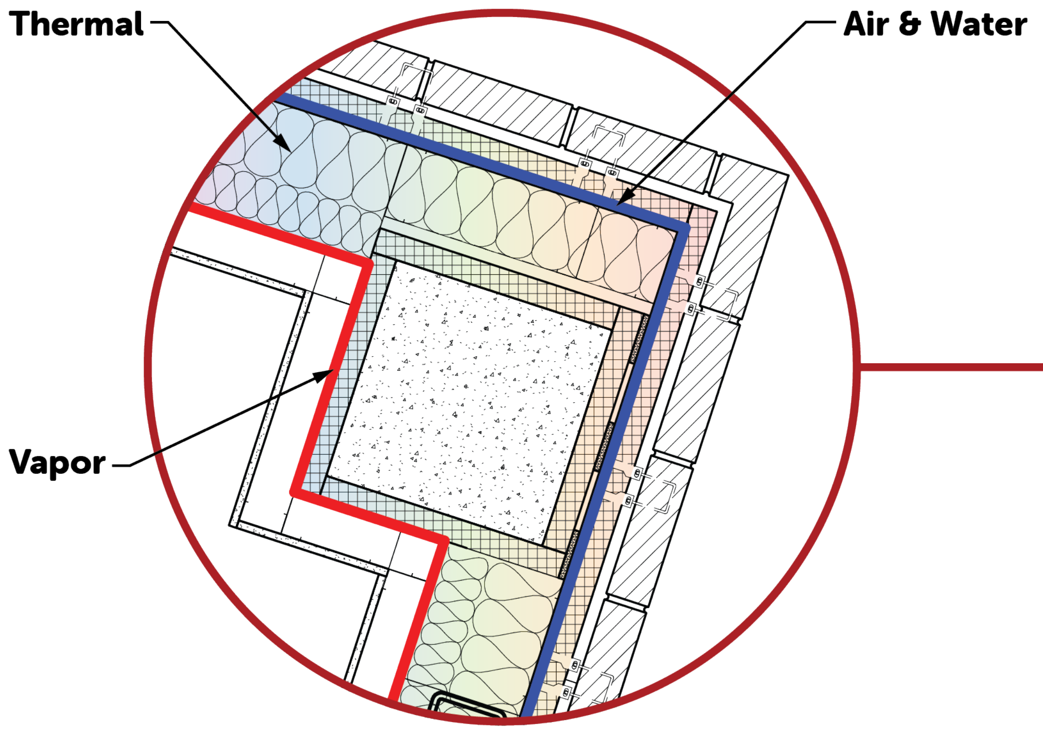
BENEFITS:

- **Low Energy Use 12 EUI***
- **Comfortable Interior Environment Year Round**
- **Improved Indoor Air Quality**
- **Quiet Acoustics**

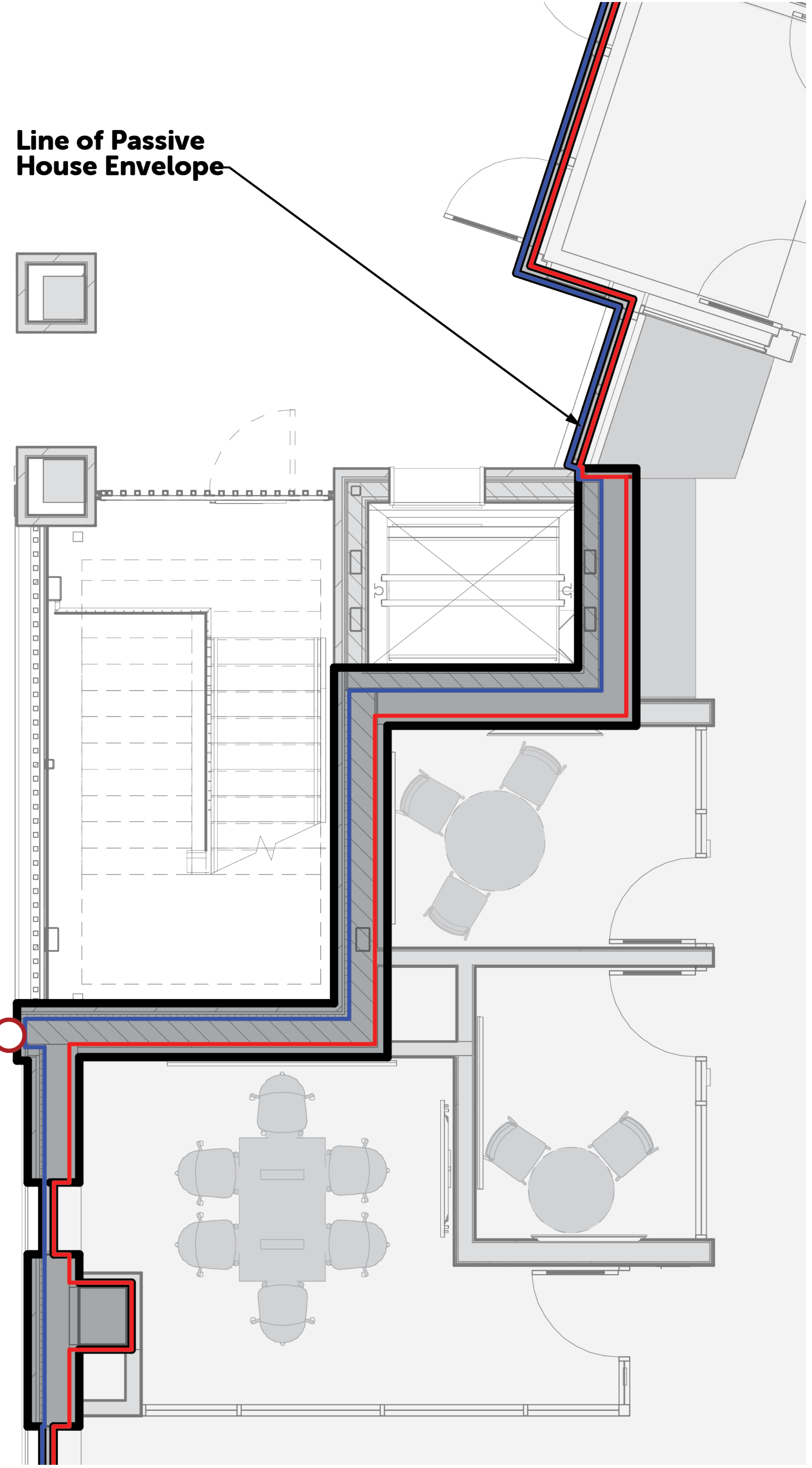


* **EUI** kBtu/SF/yr
Energy Use Intensity

Less than 1/5 the energy use of the mean existing library in Washington State climate zone 4C (66 EUI)



Continuous Control Layers



4x better than Washington State Code required EUI for libraries

Phius Certification

Phius 2018+ Certified

27,910 iCFA

Blower Door Test

CFM50 = 0.055
ACH50 = 0.380

4x better than Washington State Code

Designed to LEED Silver Targets
(certification waived)

Preliminary WUFI and Therm Modeling

PHIUS+ 2018 and PHIUS 2021

Climate Location: Mount Vernon, Washington
Envelope Area: 72,468 sf
iCFA: 27,910 sf
Total Occupancy: 113

	PHIUS+ 2018	PHIUS 2021
Annual Heating Demand (kBtu/sf)	8.5	7.6
Annual Cooling Demand (kBtu/sf)	5.5	3.6
Peak Heating Load (Btu/hr-sf)	6.6	4.2
Peak Cooling Load (Btu/hr-sf)	2.7	1.4
Source Energy (kBtu/sf)	34.8	24.5
Other		- Updated energy emission factors - All-electric or electric-ready - EV charging

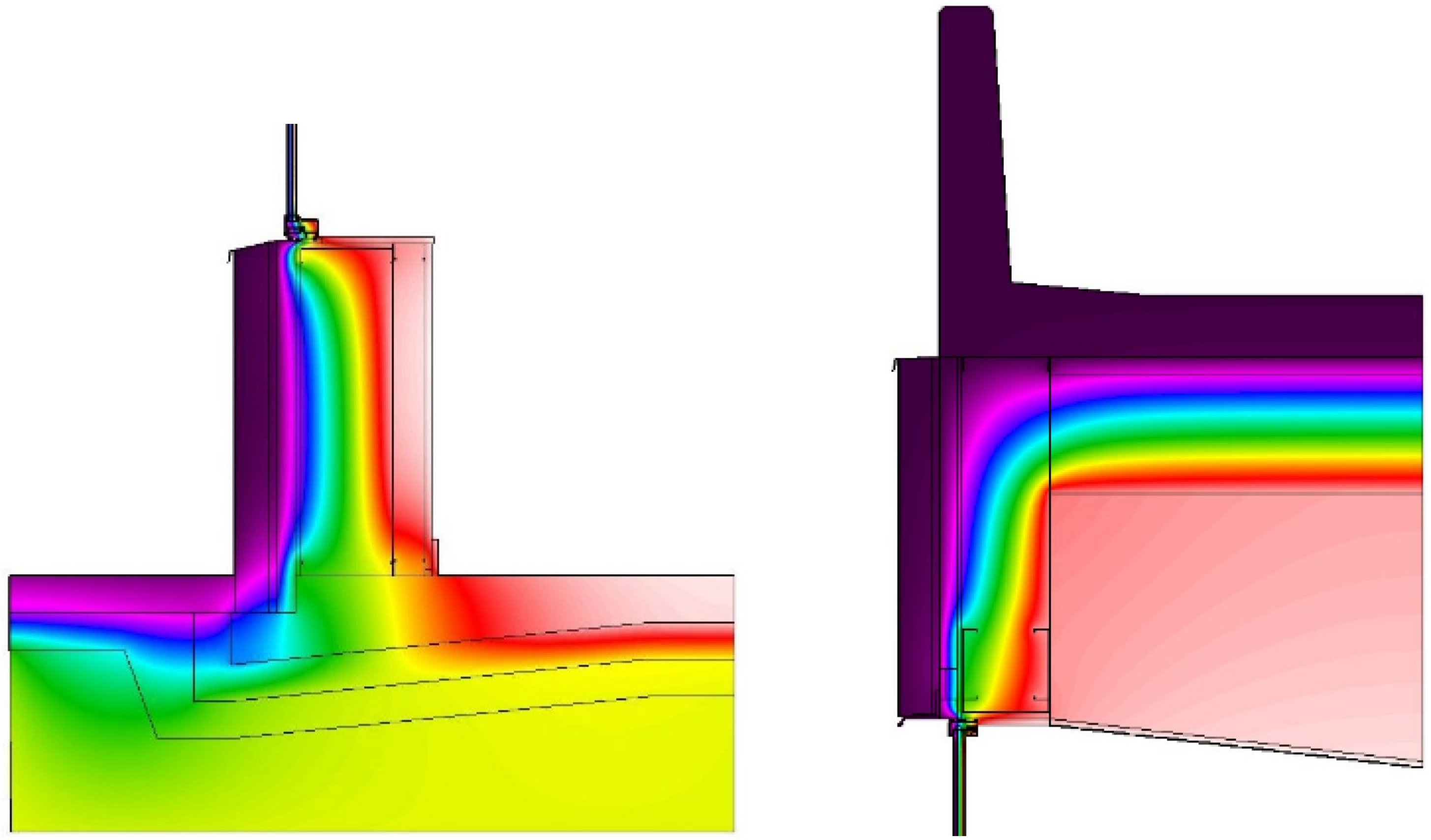
WUFI Passive Results

Heating demand is at least 83% above PHIUS criteria

Cooling demand is at least meets PHIUS criteria

Source energy is at least 146% above PHIUS criteria

Category	EUI
Annual Heating Demand (kBtu/sf)	15.55
Annual Cooling Demand (kBtu/sf)	1.65
Peak Heating Load (kBtu/hr-sf)	4.76
Peak Cooling Load (kBtu/hr-sf)	1.7
Source Energy (kBtu/sf)	85.49
Site Energy (kBtu/sf)	30.53



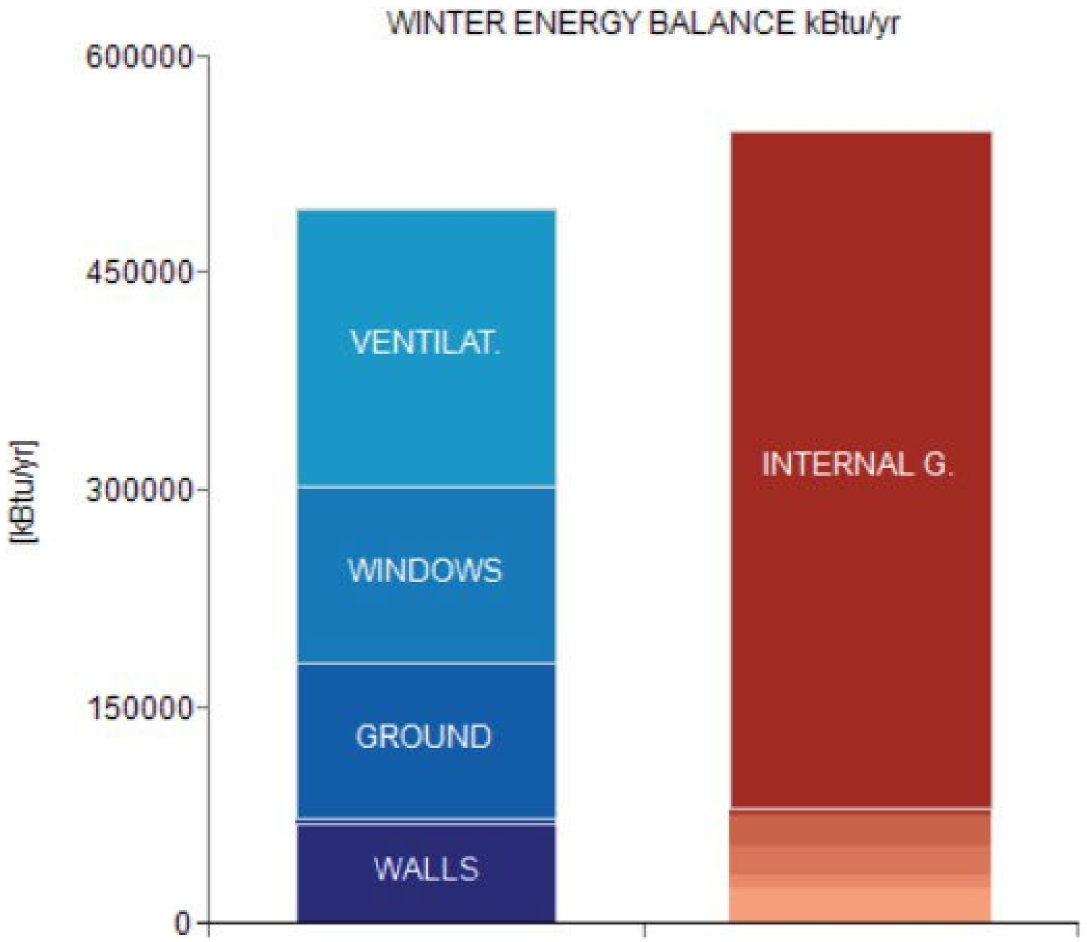
Initial recommendations and refinements to comply:

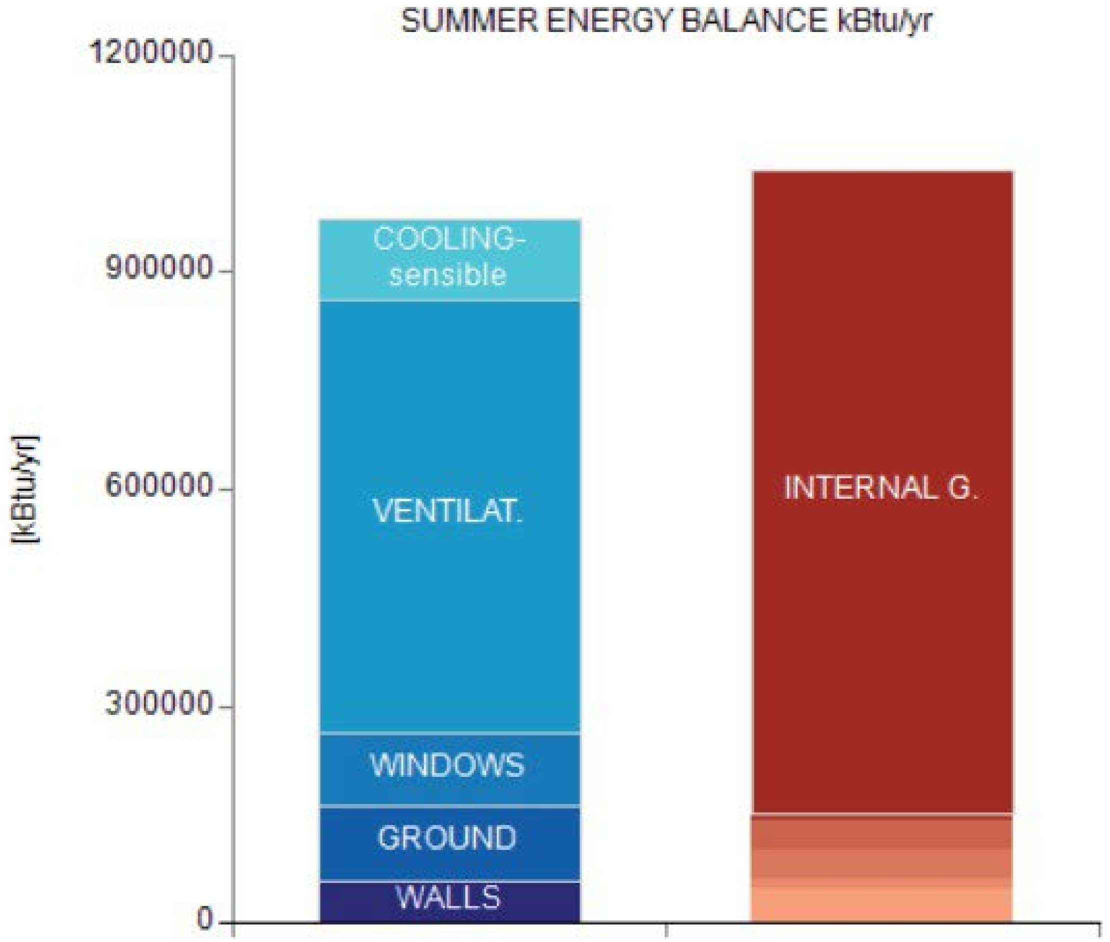
- Recommend providing a high efficiency ERV (90% sensible recovery)
- Adding insulation can help reduce heading demand
- Incorporate natural ventilation in the summer to reduce the cooling demand
- Revise ventilation rates to minimize heating and ensure compliance with ASHRAE 62.1
- Revise equipment using Energy Saving mode operation
- Ensure that the Commercial Kitchen is not considered with site energy
- Include PV solar panel renewable energy

WUFI Passive Results

Current design meets the PHIUS+ 2018 criteria.

Category	EUI	Status
Annual Heating Demand (kBtu/sf)	1.04	Pass
Annual Cooling Demand (kBtu/sf)	4.02	Pass
Peak Heating Load (kBtu/hr-sf)	4.37	Pass
Peak Cooling Load (kBtu/hr-sf)	1.62	Pass
Source Energy (kBtu/sf)	31.69	Pass
Site Energy (kBtu/sf)	11.32	n/a





A3	A3 #	Title	Proposer	Date/Rev.	Collaborators	Status	Approved By:
fsi ENGINEERS	M-1	Mechanical System Options	S. Boucher	6/23/2021	G. Smith	Submitted for review	O. Jarvegren

Section 1 - Definition & Background Information

This A3 presents three options for heating and cooling at the Mt. Vernon Library.

Section 2 - The Dedicated Outdoor Air Unit (DOAS) Unit

2018 Washington State Energy Code (WSEC) Section C403.6 requires outdoor air to be provided to office buildings by a dedicated outdoor air system (DOAS) with energy recovery, unless the overall system includes a high-efficiency VAV system. Code-compliant options for this project are:

1) DOAS with Energy Recovery - Outdoor air is preconditioned from an exhausted airstream. In some cases, additional cooling or heating is required to precondition the air.

2) High Efficiency VAV System - Complies with 2018 WSEC Section C403.6.1. Air is supplied through a central air handling unit to zones which are controlled by variable air volume boxes (VAVs). A complex control system is required to modulate airflow in each space.

Options 1 to 3 below include DOAS with heat recovery for ventilation. The purpose of a DOAS system is to deliver conditioned outdoor air directly to each occupied zone. A DOAS unit is centrally located and is typically smaller than a similar conventional HVAC unit. DOAS handles outdoor air only. It has 15-25% the volume of a conventional system, so DOAS ducts are much smaller.

Recommendation: FSi's recommendation is to proceed with a DOAS with energy recovery. The high efficiency VAV system is far more complex to design and operate than a DOAS unit with energy recovery.

Section 3 - Option descriptions

Option 1 - DOAS with heat recovery and mini split systems.
Options 1 includes a DOAS unit with ventilation all components housed in one cabinet, typically placed on the roof, including a fixed plate heat recovery section with supplemental direct expansion cooling and electric heat. Supply and return fans move ventilation air to and from the unit to each space. Outdoor air is heated to room temperature (approx. 70 degrees) in the winter and can be cooled to room temperature in the summer.

Space heating and cooling is provided with indoor air handling units, wall or ceiling mounted fan coil units connected to several condensing units via copper piping. Each indoor unit will have a corresponding outdoor unit. The condensing units are located in an outdoor location free from obstructions allowing airflow over the units to allow for heating or cooling.

Option 2 - DOAS with heat recovery and VRF
Options 2 includes a DOAS unit with ventilation all components housed in one cabinet, typically placed on the roof, including a fixed plate heat recovery section with supplemental direct expansion cooling and electric heat. Supply and return fans move ventilation air to and from the unit to each space. Outdoor air is heated to room temperature (approx 70 degrees) in the winter and can be cooled to room temperature in the summer.

Space heating and cooling is provided with indoor air handling units, wall, or ceiling mounted fan coil units connected to a VRF condenser located in an outdoor location. This is essentially a large condensing unit with multiple compressors. The condensing unit is connected to each indoor unit through refrigerant piping. Using a series of valves the condensing unit sends refrigerant to each zone requiring conditioning. The VRF system also has the benefit of energy recovery between zones. The system can move heat from one room that is calling for cooling and route it to a room calling for heating.

Option 3 - DOAS with heat recovery and Air to Water Heat Pump
Option 3 includes a DOAS unit with all components housed in one cabinet, typically placed on the roof, including a fixed plate heat recovery section with supplemental direct expansion cooling and electric heat. Because this option includes hydronic heating and cooling the DOAS air can be tempered by the air to water heat pump. Supply and return fans move ventilation air to and from the unit to each space. Outdoor air is heated to room temperature (approx. 70 degrees) in the winter and can be cooled to room temperature in the summer.

Space heating and cooling is provided by an air to water heat pump. The air to water heat pump is usually located in an outdoor location then piped into a mechanical room. This system works similar to a condensing unit but instead uses water supplied by pumps to move hot or cold water to different zones that are conditioned by fan coil units. An air to water heat pump is a very efficient system that also requires a back up electric boiler on very cold days.

Section 4 - Energy and Cost Metric Comparisons

Option 1, DOAS with heat recovery and mini split systems - lowest energy efficiency and first cost of the three options.

Option 2, DOAS with heat recovery and VRF - medium energy efficiency and medium first cost of the three options.

Option 3, DOAS with heat recovery and air to water heat pump - highest energy efficiency and highest first cost of the three options.

Section 5 - Key considerations

Below is a comparison of each option and how it ranks in relevant categories.

Category	DOAS + Mini Split	DOAS + VRF	DOAS + Air to Water Heat Pump
First Cost	Lower	Medium	Higher
Maintenance Cost	Medium	Lower	Higher
Energy Efficiency	Lower	Medium	Higher
Complexity	Lower	Medium	Higher
Expandability	Lower	Higher	Higher

Section 6 - Advantages & Disadvantages

System	Advantages	Disadvantages
Option 1 DOAS with heat recovery and mini split systems	• Lowest first cost • Simple system to operate • Easy to maintain, maintenance can be performed by most service technicians • Controls can be stand alone and simple to install • Simultaneous heating and cooling	• Lowest energy efficiency • No free cooling (only partial cooling with outdoor air) • Multiple components leading to multiple possible points of failure • Large amount of copper piping presents possibility for refrigerant leaks. Additional monitoring will be required to ensure refrigerant does not accumulate in spaces if a leak is present.
Option 2 DOAS with VRF	• Simple system to operate • Higher energy efficiency with potential for heat recovery • Controls can be stand alone and simple to install • Simultaneous heating and cooling • Ability to heat and cool DOAS unit with central system • Smaller footprint than option 1	• Maintenance can only be performed by licensed service technicians • No free cooling (only partial cooling with outdoor air) • Large amount of refrigerant required for the system • Large amount of copper piping presents possibility for refrigerant leaks. Additional monitoring will be required to ensure refrigerant does not accumulate in spaces if a leak is present.
Option 3 DOAS with Air to Water Heat Pump	• Highest energy efficiency • Lowest carbon footprint • Can be used for domestic water heating • Hydronic systems have proved to be reliable with proper maintenance • Ability to heat and cool DOAS unit with central system • Ability to customize controls to suit the building an occupants • Best thermal comfort control for occupants • Best system modulation	• Highest first cost • More complex system requiring knowledgeable service techs • Outdoor units are required to defrost with colder temps, requiring more equipment • Additional electric back up boiler required • Hydronic systems require a mechanical room to house equipment in addition to outdoor units • Larger footprint of mechanical equipment

Preliminary System Options Analysis

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Section 6 - Advantages & Disadvantages		
System	Advantages	Disadvantages
Option 1 DOAS with heat recovery and mini split systems	• Lowest first cost • Simple system to operate • Easy to maintain, maintenance can be performed by most service technicians • Controls can be stand alone and simple to install • Simultaneous heating and cooling	• Lowest energy efficiency • No free cooling (only partial cooling with outdoor air) • Multiple components leading to multiple possible points of failure • Large amount of copper piping presents possibility for refrigerant leaks. Additional monitoring will be required to ensure refrigerant does not accumulate in spaces if a leak is present.
Option 2 DOAS with VRF	• Simple system to operate • Higher energy efficiency with potential for heat recovery • Controls can be stand alone and simple to install • Simultaneous heating and cooling • Ability to heat and cool DOAS unit with central system • Smaller footprint than option 1	• Maintenance can only be performed by licensed service technicians • No free cooling (only partial cooling with outdoor air) • Large amount of refrigerant required for the system • Large amount of copper piping presents possibility for refrigerant leaks. Additional monitoring will be required to ensure refrigerant does not accumulate in spaces if a leak is present.
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Highest First Cost

Highest Efficiency

Lowest Carbon Footprint

Owner's Choice

Systems Options Analysis

2-pipe versus 4-pipe

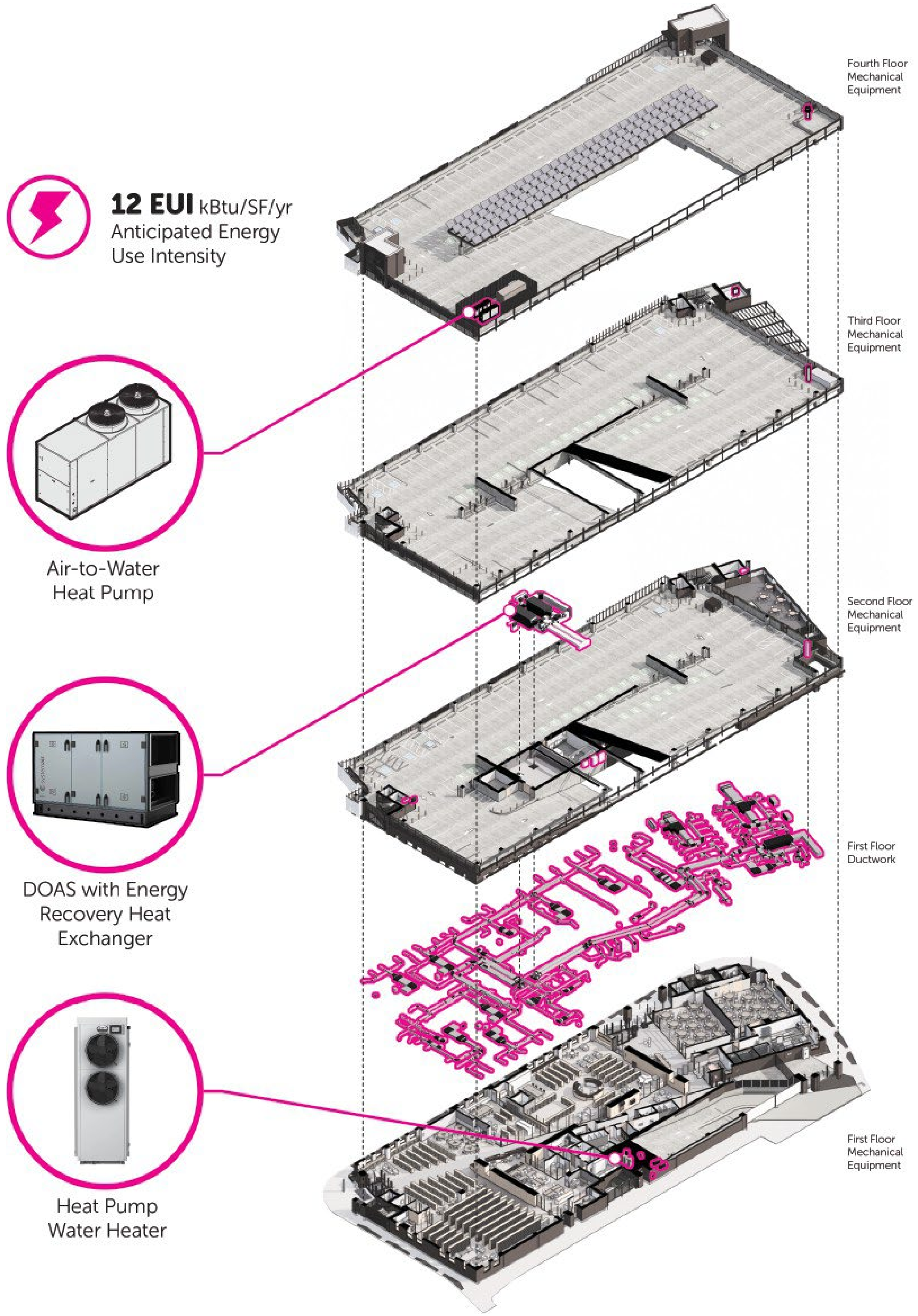
System	Advantages	Disadvantages
2-pipe system	• Lower first cost	• No simultaneous heating and cooling except with economizers • Limited heat recovery in economizer mode which does not fit well with Passive House criteria for heat recovery.
4-pipe system	• Improved energy efficiency: in simultaneous heating and cooling mode, heat will be transferred between spaces as needed. • Better thermal comfort: mechanical cooling can be provided in any room at anytime.	• First cost estimated to be $250,000 to $300,000 higher than a 2-pipe system. Payback will be 100+ years • Slightly higher maintenance cost because of larger quantities of valves and pumps.

Owner Choice

Lower First Cost ($250,000-$300,000 less)

Not as great an energy savings

Not as great a carbon reduction



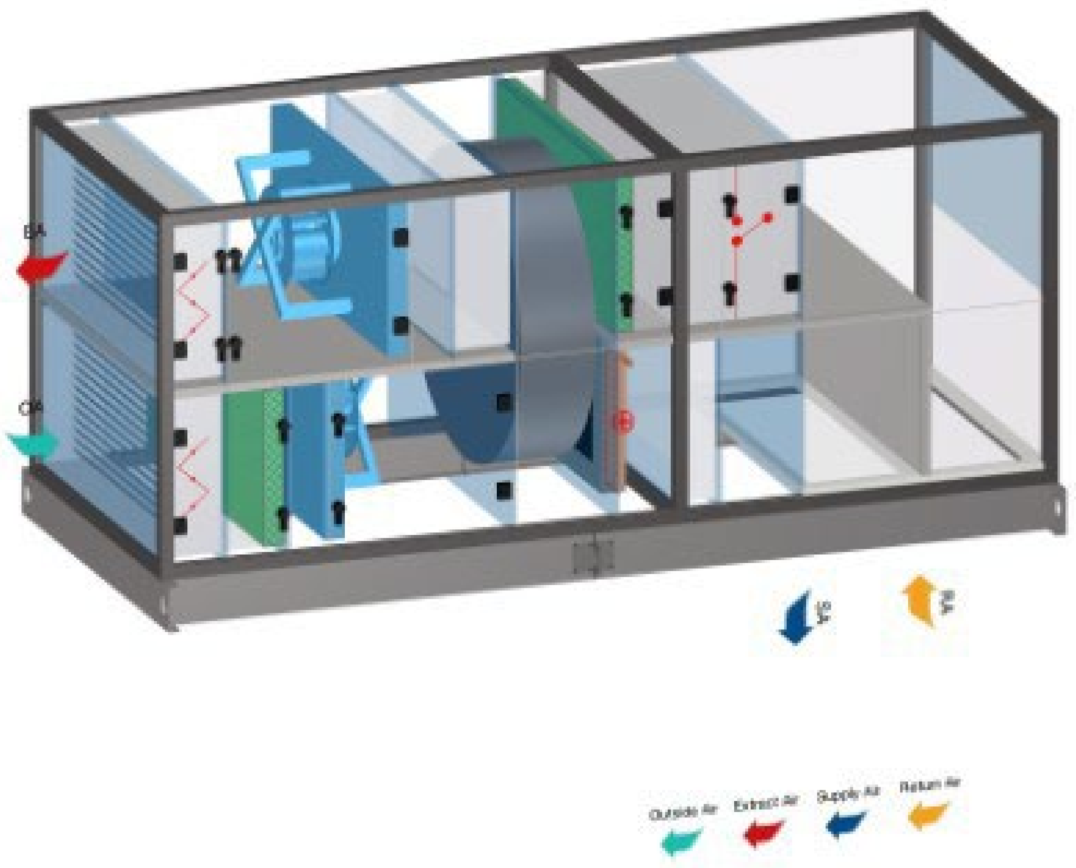
- Heating & Cooling: Air-to-Water Heat Pumps and FCU's
- Ventilation: DOAS with Heat Recovery
- Domestic HW: Electric Heat Pump Water Heater

Mechanical Systems

TECHNICAL REPORT

Configuration Name: Geniox-4
Configuration Tag: DOAS-1

PRODUCT VIEW



TECHNICAL REPORT (cont.)

Configuration Name: Geniox-4
Configuration Tag: DOAS-1

ENERGY RECOVERY WHEEL

PARAMETER	UoM	VALUE / DESCRIPTION
Heat Exchanger Type	-	ENTHALPY
Rotor Speed	-	20
Rotor Speed Type	-	Variable
Rotor Profile	-	HIGH PERFORMANCE
Horsepower	hp	0.5

SUMMER

PARAMETER	UoM	SUPPLY	RETURN
Airflow Standard	SCFM	2700	2700
Airflow Actual	ACFM	2700	2700
Air Pressure Drop	in w.c.	0.5	0.6
Air Temperature (In/Out)	F	85/76.8	75/83.2
Relative Humidity (In/Out)	%	39/46.7	48/40.1
Total Capacity	MBH	34.6	
Sensible Effectiveness	%	82.3	
Latent Effectiveness	%	74	
Total Effectiveness	%	79.6	

WINTER

PARAMETER	UoM	SUPPLY	RETURN
Airflow Standard	SCFM	2700	2700
Airflow Actual	ACFM	2700	2700
Air Pressure Drop	in w.c.	0.5	0.6
Air Temperature (In/Out)	F	19/60.3	70/28.8
Relative Humidity (In/Out)	%	30/64.9	54.8/60.5
Total Capacity	MBH	207.7	
Sensible Effectiveness	%	80.9	
Latent Effectiveness	%	83	
Total Effectiveness	%	81.8	

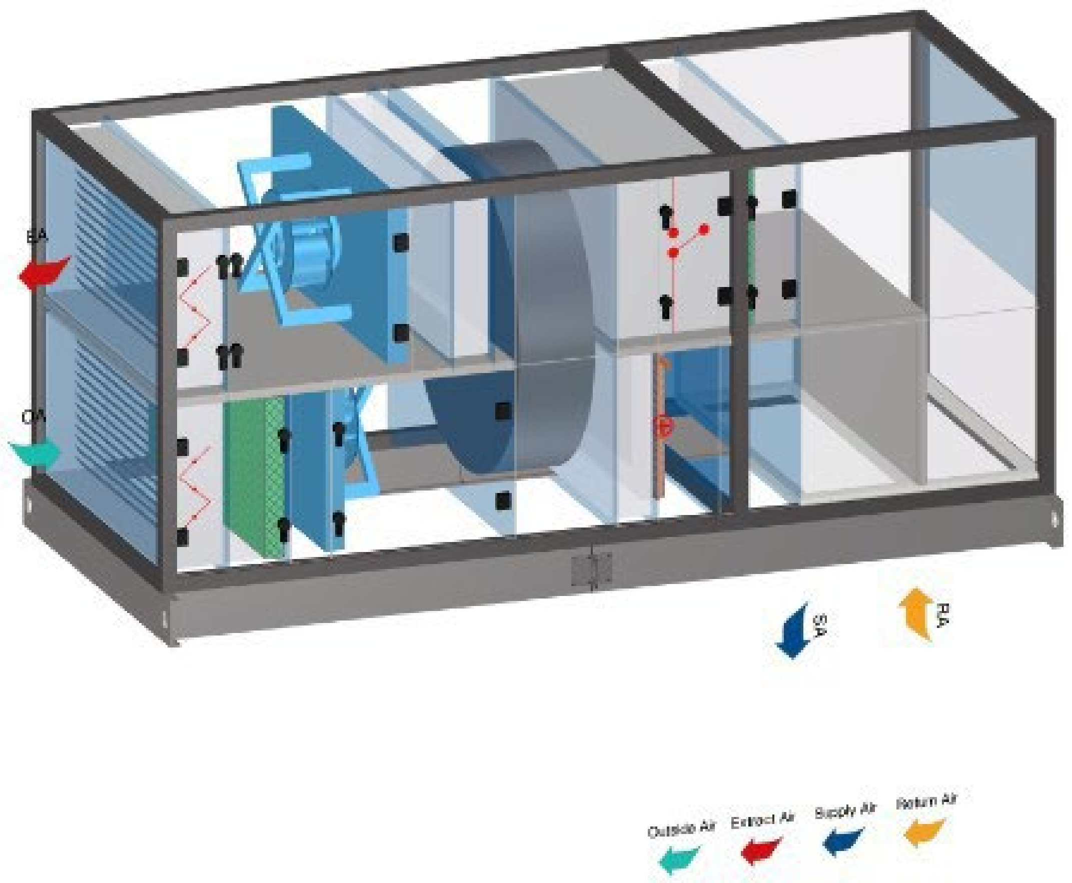
DOAS-1 with Heat Recovery - Library

TECHNICAL REPORT

systemair

Configuration Name: Geniox-5
Configuration Tag: DOAS-2

PRODUCT VIEW



TECHNICAL REPORT (cont.)

systemair

Configuration Name: Geniox-5
Configuration Tag: DOAS-2

ENERGY RECOVERY WHEEL

PARAMETER	UoM	VALUE / DESCRIPTION
Heat Exchanger Type	-	ENTHALPY
Rotor Speed	-	20
Rotor Speed Type	-	Variable
Rotor Profile	-	HIGH PERFORMANCE
Horsepower	hp	0.5

SUMMER

PARAMETER	UoM	SUPPLY	RETURN
Airflow Standard	SCFM	2975	2700
Airflow Actual	ACFM	2975	2700
Air Pressure Drop	in w.c.	0.6	0.6
Air Temperature (In/Out)	F	85/77.3	75/83.4
Relative Humidity (In/Out)	%	39/46.3	48/39.8
Total Capacity	MBH	35.7	
Sensible Effectiveness	%	85	
Latent Effectiveness	%	75.5	
Total Effectiveness	%	81.9	

WINTER

PARAMETER	UoM	SUPPLY	RETURN
Airflow Standard	SCFM	2975	2700
Airflow Actual	ACFM	2975	2700
Air Pressure Drop	in w.c.	0.6	0.6
Air Temperature (In/Out)	F	19/57.8	70/27.3
Relative Humidity (In/Out)	%	30/66.2	54.8/60.2
Total Capacity	MBH	213.7	
Sensible Effectiveness	%	83.8	
Latent Effectiveness	%	84.7	
Total Effectiveness	%	84.2	

DOAS-2 with Heat Recovery - Commons

DOAS Units & Intake/Exhaust Ducts

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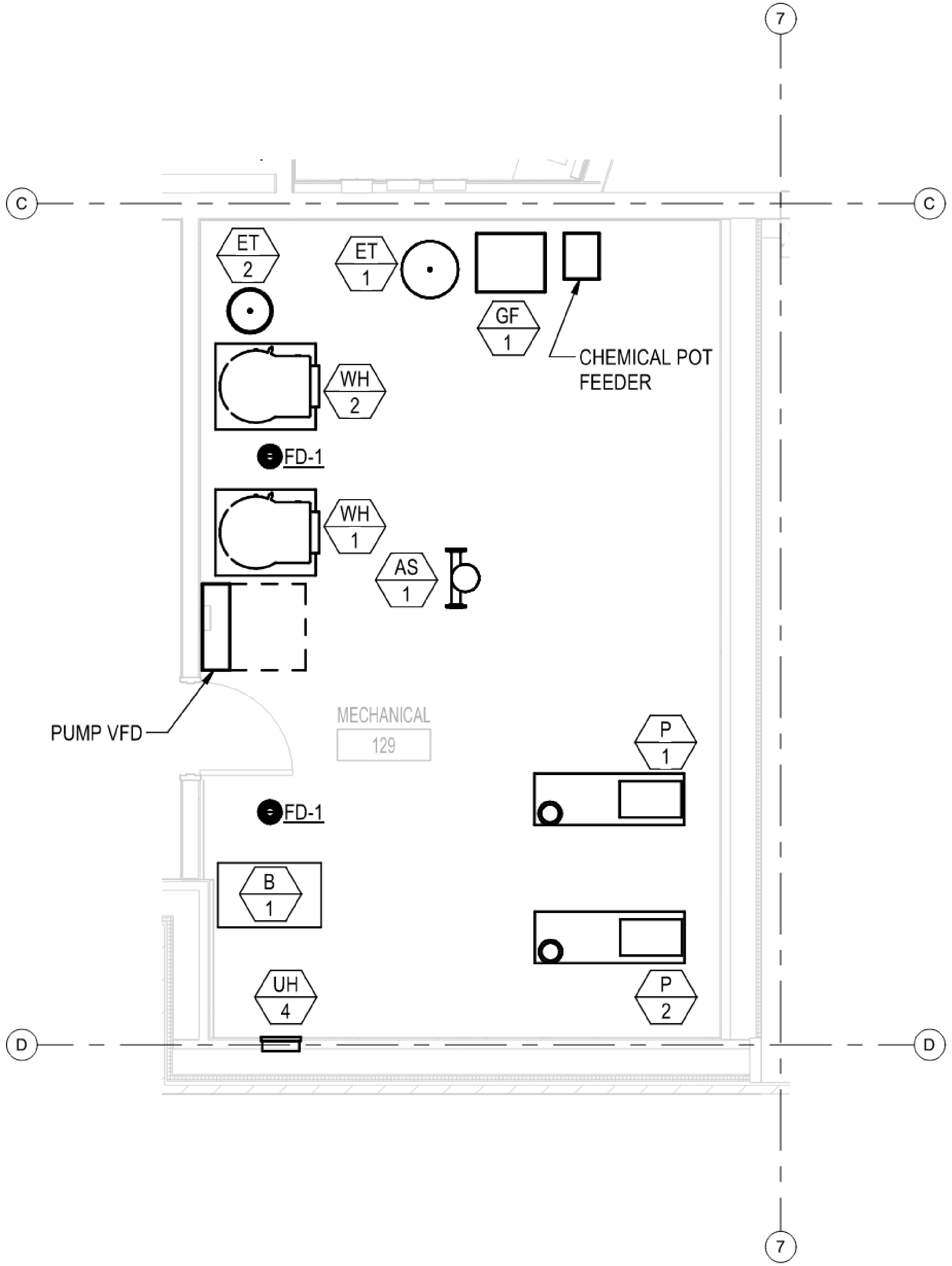
DVM Chiller, Air Cooled Modular Chiller (R-410A)

- Air to Water - HP Efficiency
  - 17 & 65 Degrees Ambient
    - Cooling EER – 15.16 EER
    - Heating COP – 2.011 W/W
  - 21 & 75 Degrees Ambient
    - Cooling EER – 12.95 EER
    - Heating COP – 2.221 W/W
  - 27 & 85 Degrees Ambient
    - Cooling EER – 11.40 EER
    - Heating COP – 2.358 W/W
  - 37 & 90 Degrees Ambient
    - Cooling EER – 10.68 EER
    - Heating COP – 2.724 W/W
  - 47 & 95 Degrees Ambient
    - Cooling EER – 10.01 EER
    - Heating COP – 3.218 W/W
  - IPLV.IP 0.6378 kW/Ton

Air to Water Heat Pumps

MODEL CAHP 120

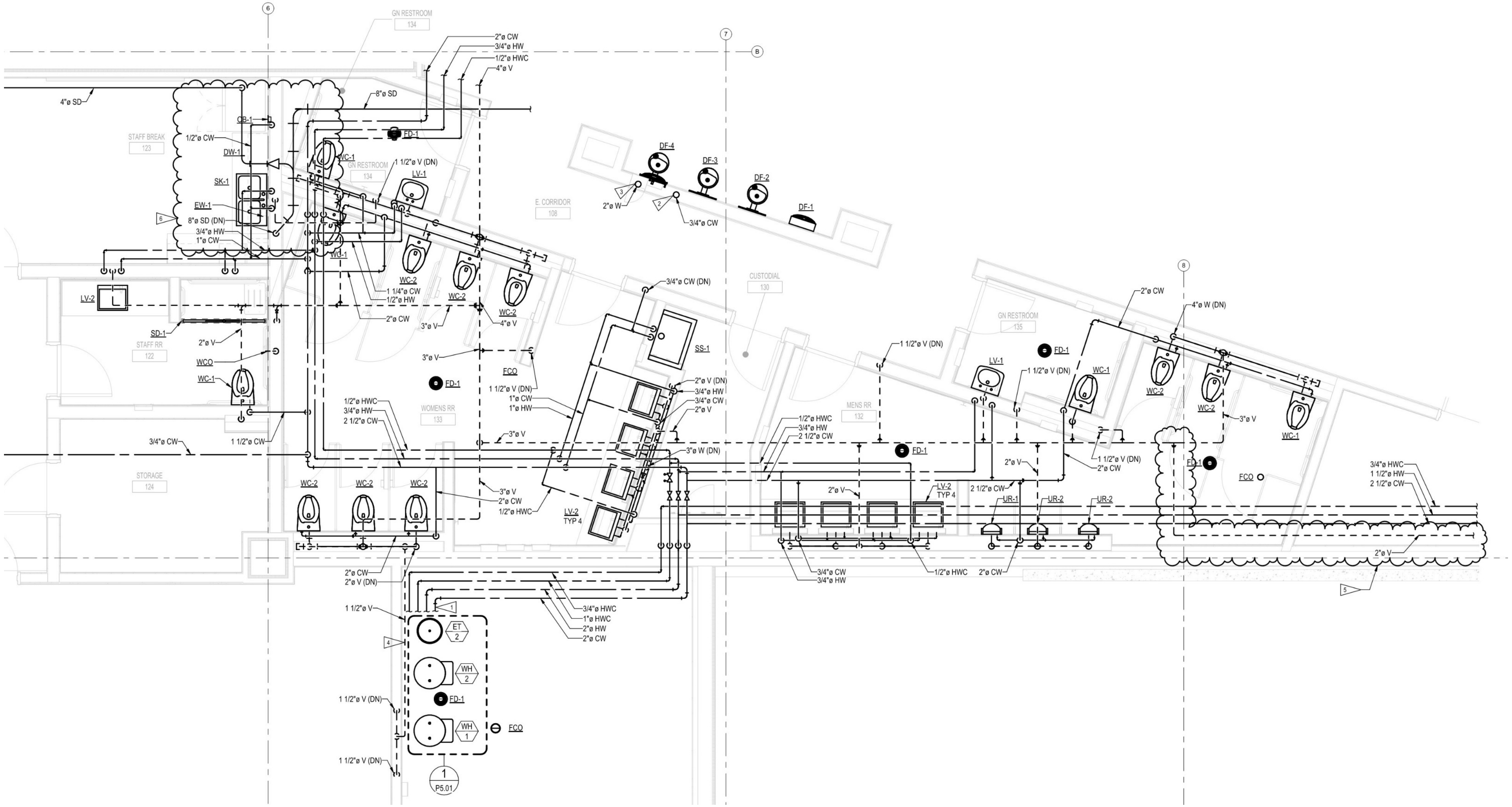
COP = 4.2



Heat Pump Water Heaters / Mechanical Room

MODEL CAHP 120

COP = 4.2



Heat Pump Water Heaters / Consolidated Plumbing

2	Ventilation system airflow testing verification: Where ventilation system has independent ductwork for supply and/or exhaust, branch airflow testing is to be performed by PHIUS+ Verifier.	Design (cfm)	Verified (cfm)	% +/- Design	+/- cfm Design	OK?	Room pressure difference	OK?
2.1	"Design Airflow Rate - Maximum" supply at HRV/ERV	2660	2666			YES		
2.2	"Design Airflow Rate - Maximum" exhaust at HRV/ERV	2350	2413			YES		
2.3	Total supply and exhaust are at least 100% of design values **and** within 10% of each other?			10%		YES		
2.4	S-01 148 BOOK RETURN	25	28	12%	3	YES		
	S-02 124 STORAGE	20	24	20%	4	YES		
	S-03 123 STAFF BREAK	35	40	14%	5	YES		
	S-04 126 OFFICE	25	27	8%	2	YES		
	S-05 121 STAFF WORK	180	173	-4%	-7	YES		
	S-06 125 OFFICE	25	28	12%	3	YES		
	S-07 117 STUDY	50	55	10%	5	YES		
	S-08 118 STUDY	25	30	20%	5	YES		
	S-09 119 STUDY	25	29	16%	4	YES		
	S-10 110 COLLECTION	310	308	-1%	-2	YES		
	S-11 110 COLLECTION	310	302	-3%	-8	YES		
	S-12 110 COLLECTION	310	293	-5%	-17	YES		
	S-13 109 REFERENCE	55	60	9%	5	YES		
	S-14 109 REFERENCE	130	135	4%	5	YES		
	S-15 112 COMPUTERS	250	244	-2%	-6	YES		
	S-16 113 YOUNG ADULT	185	198	7%	13	YES		
	S-17 114 STORAGE	25	29	16%	4	YES		
	S-18 116 YOUTH	225	220	-2%	-5	YES		
	S-19 116 YOUTH	225	230	2%	5	YES		
	S-20 116 YOUTH	225	213	-5%	-12	YES		
	Total of supply branches (for reference only)	2660	2666					
2.5	E-01 121 STAFF WORK	180	184	2%	4	YES		
	E-02 122 STAFF RR	75	82	9%	7	YES		
	E-03 109 REFERENCE	165	170	3%	5	YES		
	E-04 110 COLLECTION	440	452	3%	12	YES		
	E-05 117 STUDY	45	51	13%	6	YES		
	E-06 110 COLLECTION	440	431	-2%	-9	YES		
	E-07 107 W CPRRODPR	225	236	5%	11	YES		
	E-08 113 YOUTH	165	178	8%	13	YES		
	E-09 116 YOUTH SERV	255	254	0%	-1	YES		
	E-10 116 YOUTH SERV	255	269	5%	14	YES		
	E-11 115 GM/FAMILY	100	106	6%	6	YES		
	enter exhaust branch name here							
	Total of exhaust branches (for reference only)	2345	2413					
2.6	"Design Airflow Rate - Typical 24/7 operation" supply at HRV/ERV		2666					
2.7	"Design Airflow Rate - Typical 24/7 operation" exhaust at HRV/ERV		2413					
2.8	Total supply and exhaust are +/- 15% or 15 CFM design values **and** within 10% of each other?			10%		YES		
2.9	Measure power input (Watts) at **typical 24/7** airflow setting		2098					
2.10	Watt/cfm for final input into consultant's energy model		0.79					

Passive house design versus balanced and measure outside air amounts.

Passive house as part of its certification process during construction certification requires that the balanced and measured total outside and exhaust air flow for each system (DOAS-1 & 2) is at least 100% of the design value. Final testing and balancing report show the following values for both systems and airflows.

System	*Air Type*	*Design (CFM)*	*TAB (CFM)*	*% Difference*
DOAS -1	Supply	2,610	2,627	100.6%
DOAS -1	Exhaust	2,350	2,391	101.7.%
DOAS -2	Supply	2,965	2,945	99.3%
DOAS -2	Exhaust	2,710	2,652	98.0%

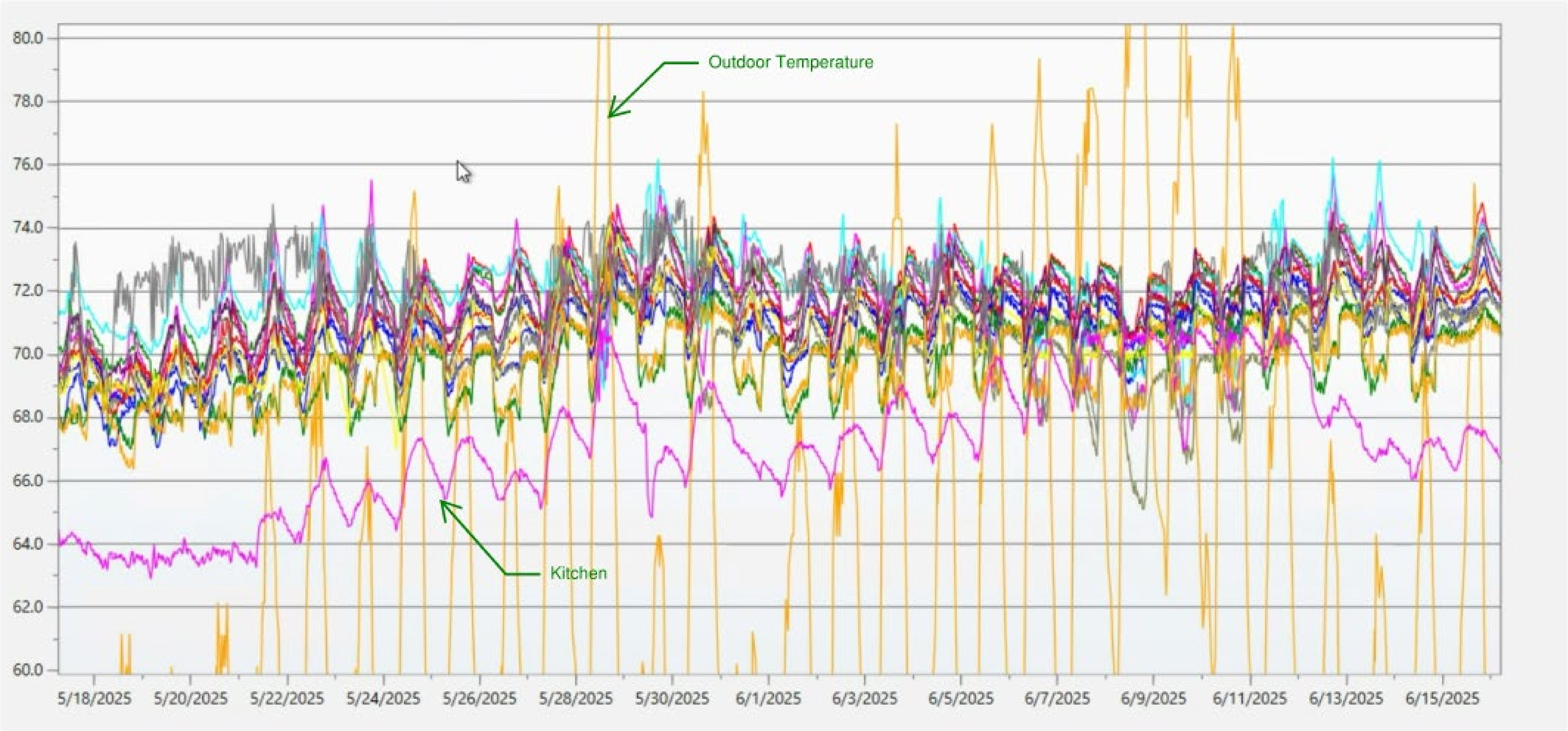
Testing and Balancing – Calibration of testing equipment.

The process of testing and balancing airflow includes the use of capture hoods that measures airflow at each diffuser, register, and grille. These hoods are calibrated from time to time to ensure they provide accurate measurements. The testing and balancing report includes certification of calibration for all testing equipment. Based on these certificates the capture hoods that are used to test air flows for this project show tolerance level between (±) 3% to 7%. Actual calibration show calibration of (±) 1%.

If we factor in calibration into the final TAB values, we find the following final system airflow values.

System	*Air Type*	*Design (CFM)*	*TAB (CFM)*	*% Difference*
DOAS -1	Supply	2,660	2,666	100.02%
DOAS -1	Exhaust	2,350	2,413	102.6%
DOAS -2	Supply	2,935	2,935	100.0%
DOAS -2	Exhaust	2,645	2,660	100.56%

TAB/Commissioning



Indoor Temperatures

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FIELD REPORT – DUCT SEALING AND LEAKAGE

Builder: Lydig
Project: Mount Vernon Library and Community Center
Inspection Date: 1/17/2024
By: Tom Balderston

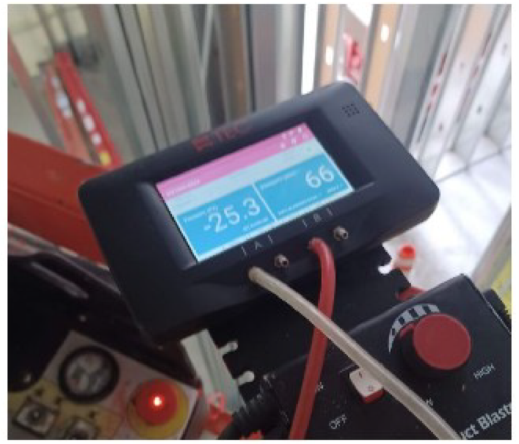
PHIUS certification requires air tight ducts, even if they are 100% inside the passive house envelope to ensure good air flow and distribution. Final test and balancing are required and all registers need to test within 20% of design cfm values. In addition HRV air flows must be at least as high as design and total supply and return air flows must be within 10% of each other. PHIUS will not certify a building that does not meet these standards.

PHIUS does not require pressure testing of all duct systems inside the heated space. Visual inspection to confirm all duct joints are sealed well with mastic is allowed. However, installers need to ensure a quality air tight system so that the required design air flows can be achieved.

On Jan 17 Tom visited the site with the intent to inspect and test a sample of some systems to check for leakage. Ducts are required to be kept masked and sealed to keep them clean during construction and storage on this project to meet both specifications and Indoor Air Plus standards. Between 30% and 50% of the masking at the ends of supply runs and returns was cut, broken, or missing, so we only tested one system as an example, system FCU -2.

*ALL DUCTS MUST BE KEPT MASKED during construction. The masking needs to be repaired or replaced right away where it is broken or cut.

System 2 test:
Using a lift, duct masking on this small system was repaired. A duct blaster was connected to the first supply register, with the reference pressure tap placed in the last register. **At 25 Pascals the leakage rate measured was 66 cfm.**



If duct testing were required , the standard to pass at rough in is 4 cfm per 100 sf or <= 40cfm at 25 Pa. Since this system serves less than 1000 sf, the standard is 40cfm. As is the system is not quite passing the ENERGYSTAR standard.

Visual inspection shows the mastic looks properly applied and complete, so there may be some leakage in the air handler itself, filter openings or cover panels. Thes should be checked and provided with better gaskets if needed. These ducts on system 2 are approved on visual inspection.

System FCU 1 has 1 joint about 10ft north of the air handler that has no mastic at all. This should be completed and thoroughly sealed.

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Systems FCU 3 through FCU 12 were inspected from the floor and the mastic looks good on all joints, except where they appear to be incomplete. Ducts so far complete are approved. Systems FCU 13 and east are incomplete at this time.

RECCOMENDATIONS:

- Continue thorough sealing with mastic on all duct joints. Mastic should be applied "nickel thick" for best durability. Confirm all joints are sealed.
- All ducts must be kept masked and sealed during construction, except while being assembled, and masked at the end of each work period.
- Confirm Air handler cover panels or filter access doors have good gaskets that seal when closed.
- Flex duct should minimize bends or turns that are not needed, and flex should be fully extended and cut as short as possible for the intended run. Flex connections should be made with both mastic and mechanically tightened zip ties.

Systems 2and 3, masking has cuts masking broken open

Duct Air Leakage Testing

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- Thermally isolated unistrut to carry hanging equipment and stud wall framing below Thermal Envelope

Installation Coordination

- HVAC, Lighting, Piping, etc hung from Unistrut

Installation Coordination

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From Vision to Reality

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Modeling vs Safety Factors

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Trust the Science

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First Year of Operation

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Questions?

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Thank You!

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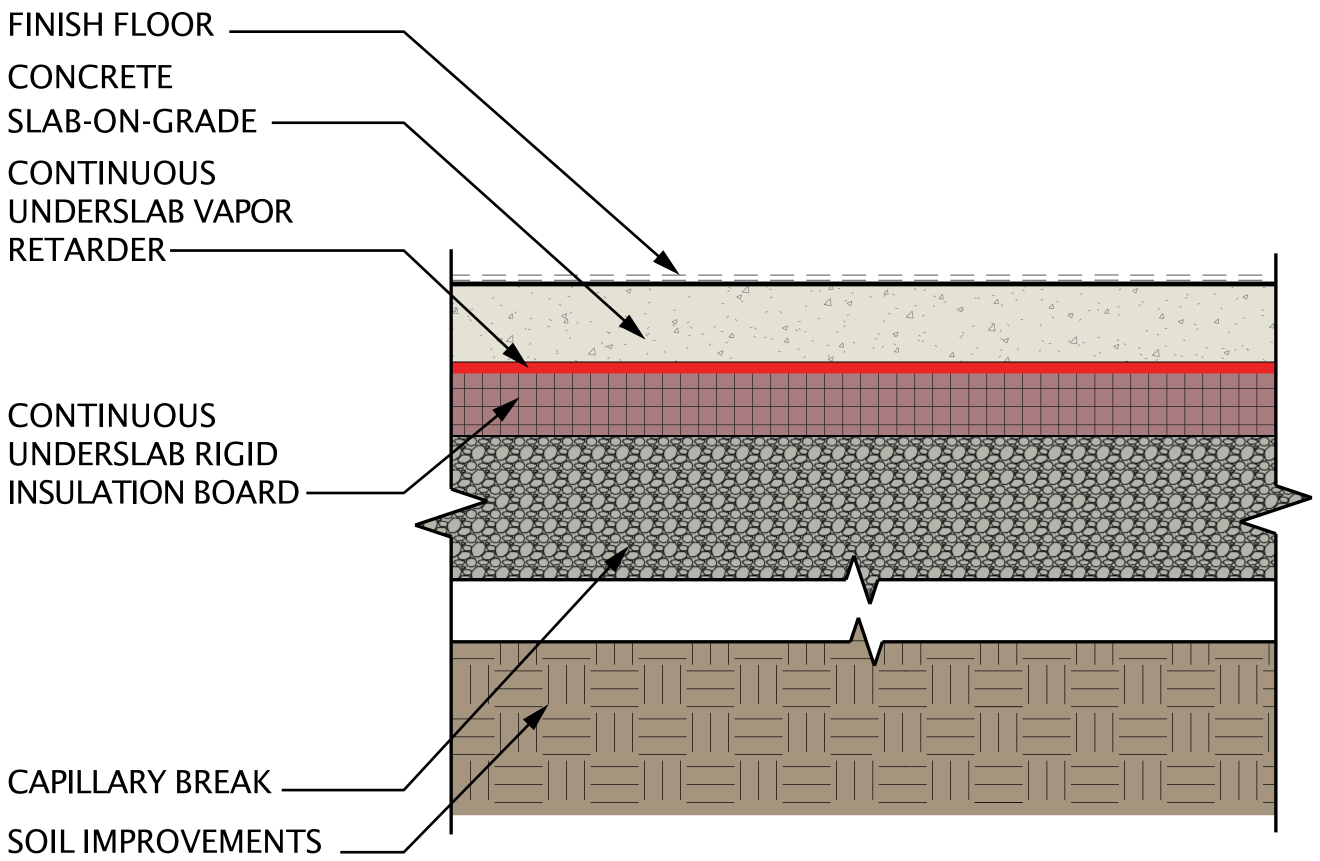
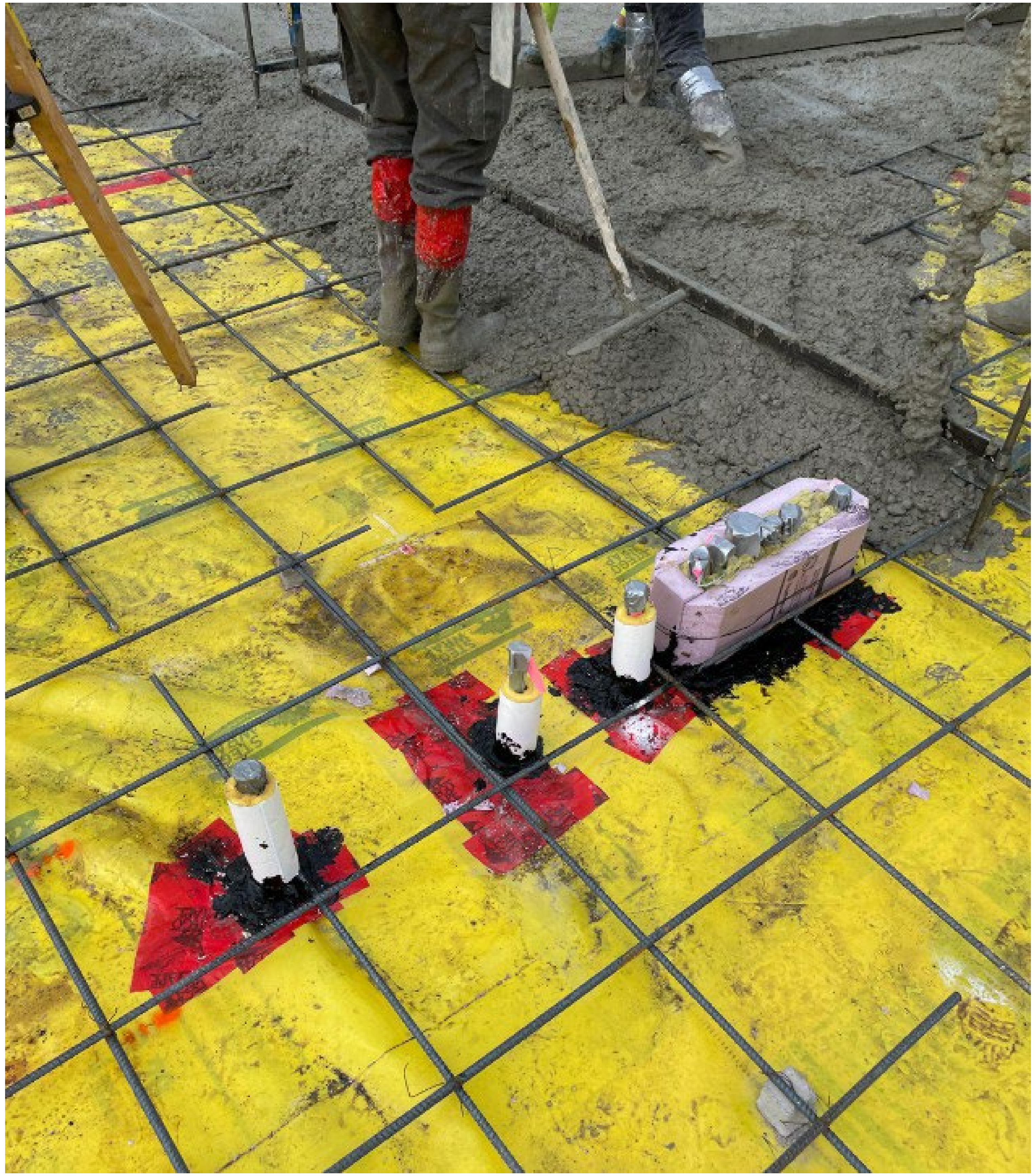
Appendix Slides

TYPICAL PASSIVE HOUSE SLAB-ON-GRADE FLOOR (R-20)





Envelope: Floors

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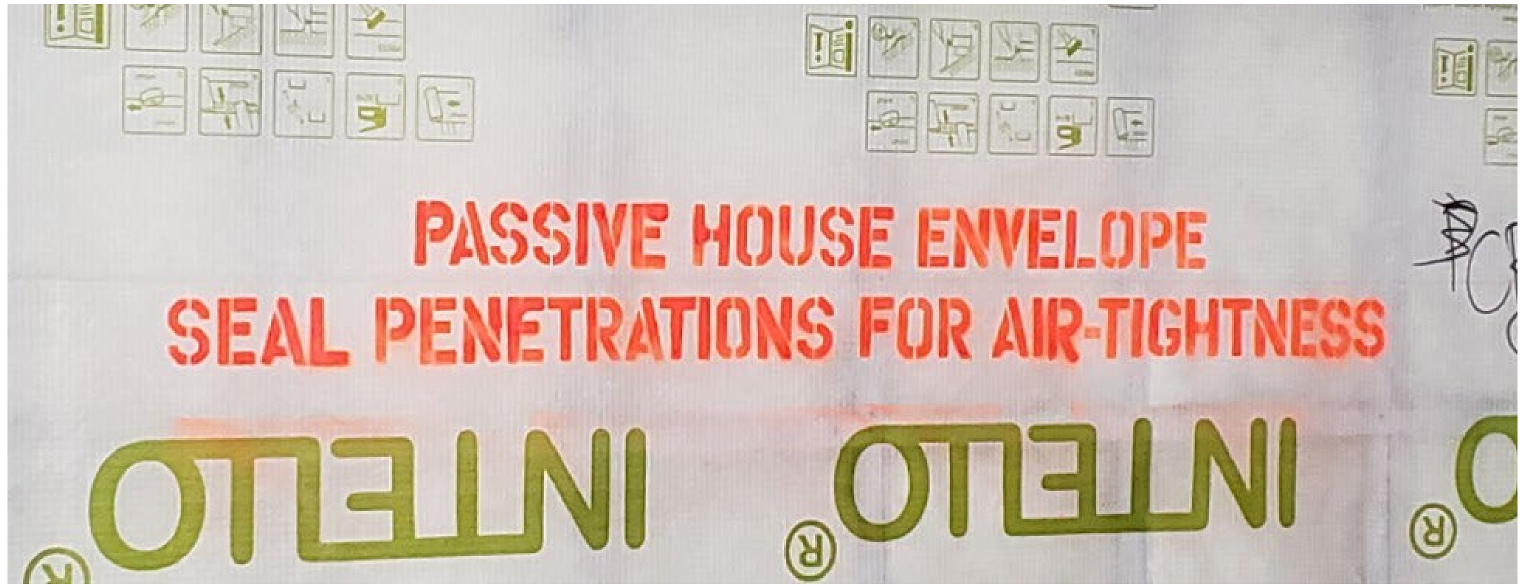
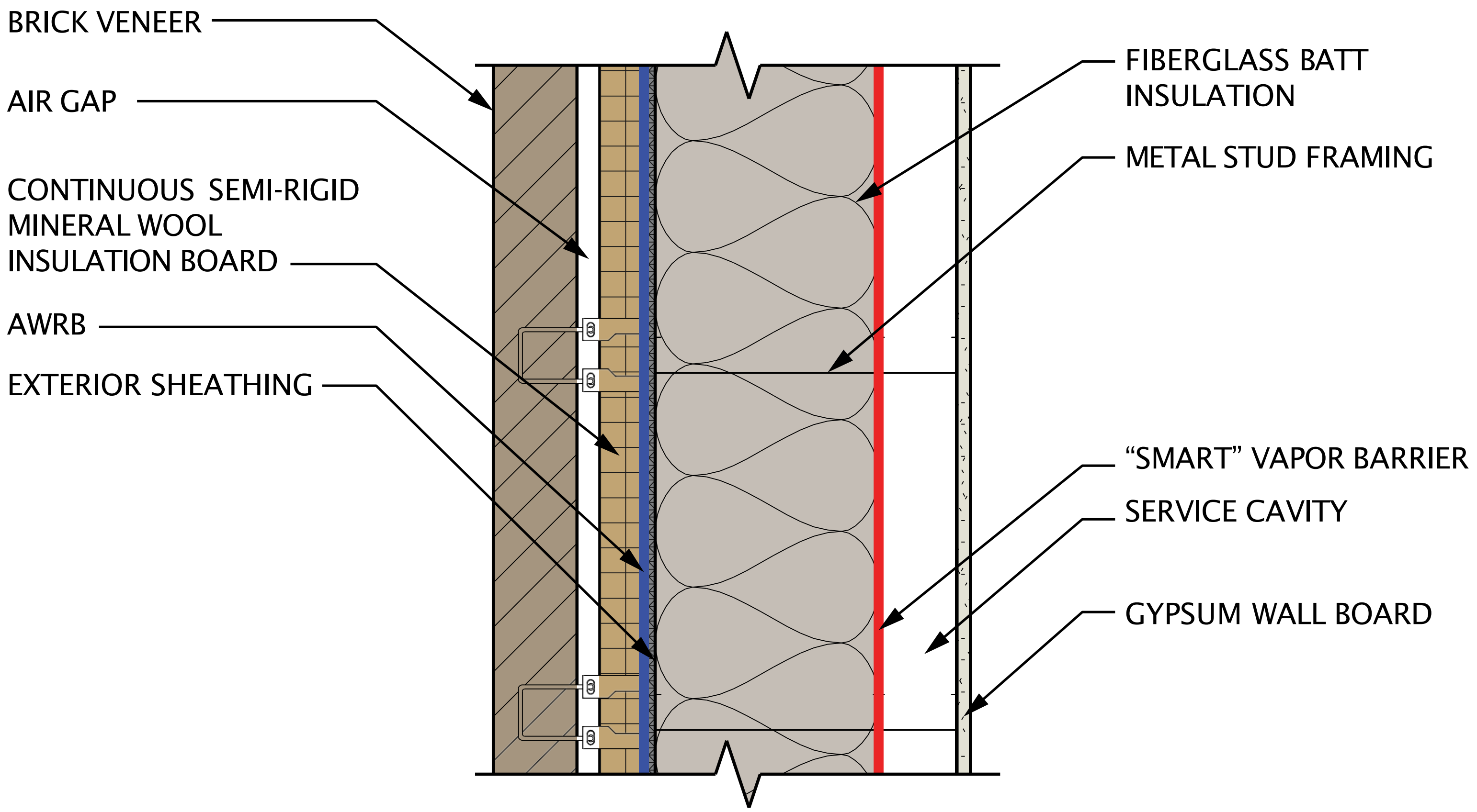


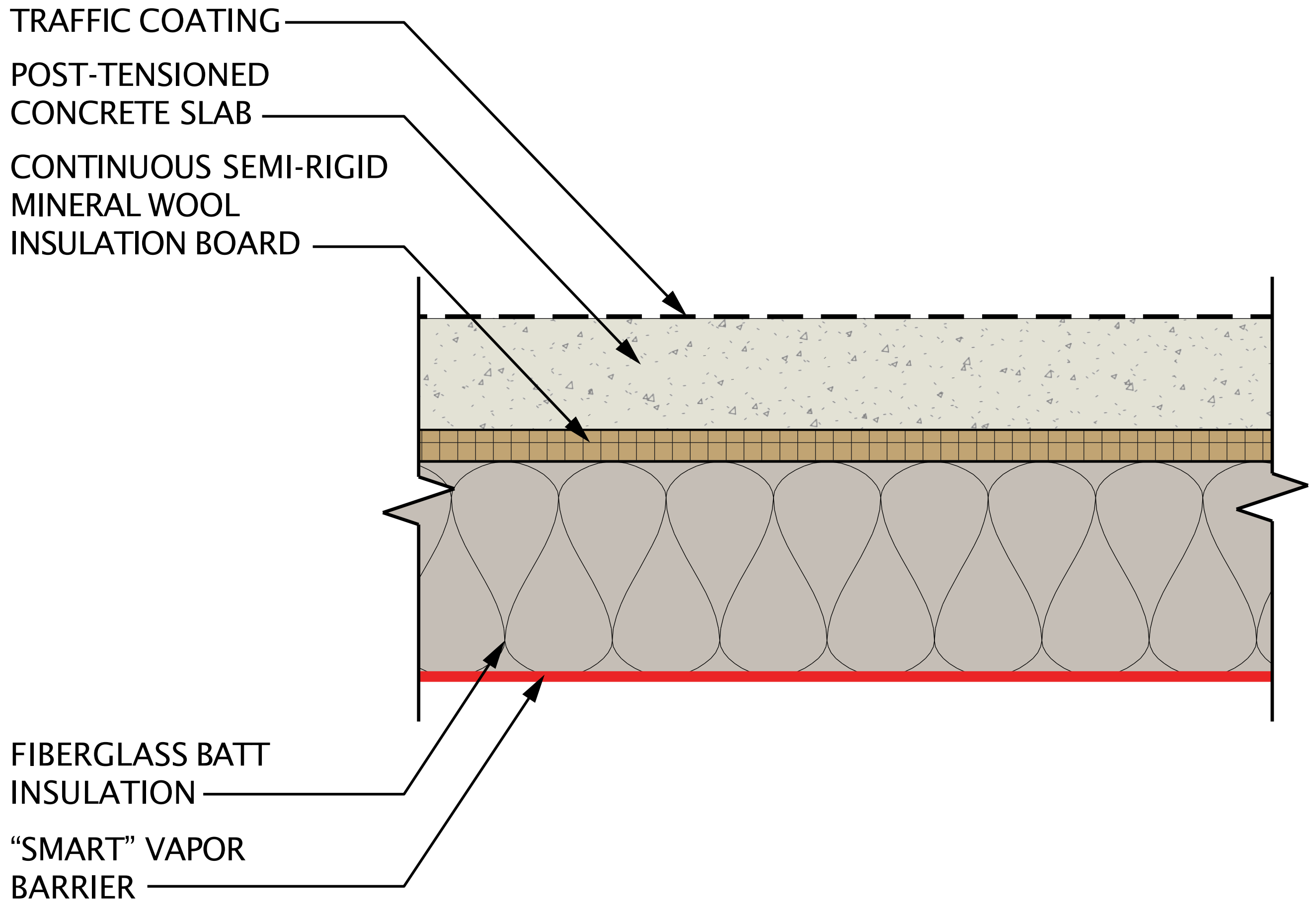
TYPICAL EXTERIOR PASSIVE HOUSE WALL (R-46.6)



- **Rockwool Plant Strike and Shutdown**
- **Revised Interior Batt to Fiberglass**
- **Revised WUFI Model**

Envelope: Walls

TYPICAL PASSIVE HOUSE CEILING AT GARAGE SLAB (R-57.6)



- Two areas where insulation needed to be reduced to fit mechanical
- Revised WUFI Model

Envelope: “Roof”