

Sol Apartments: Passive House Multifamily Building Strategies

Project: Sol Apartments
Troy, NY

Owner: Rosenblum Companies
300 Great Oaks Blvd
Albany, NY 12203

Report Date: August 5, 2026

Summary

Overview of Investigation

This report was created as part of NYSERDA's Early Design Support program which aims to assist design firms in integrating carbon-neutral features into the initial stages of multifamily building projects. The program seeks to create buildings that are not only clean and resilient but also aesthetically pleasing and functional, providing occupants with healthy, safe, comfortable, and resilient living spaces. By offering direct funding to design firms, the initiative encourages the design of projects that achieve carbon-neutral performance, demonstrate cost-effectiveness, and serve as scalable models for future sustainable building designs.

This report was prepared by Sustainable Comfort, Inc. with assistance from ownership and design team members. It is geared toward a professional audience of developers, architects, as well as general contractors and mechanical, electrical, plumbing, and structural engineers. The goal is to communicate findings of early design studies from the Sol Apartments project, in a format that can be accessed by other teams to support their sustainable development through scalability and replicability.

The team studied the building envelope and system selections needed to meet Passive House building energy targets from Phius and compared the Passive House building envelope to a base building with a HERS rating and energy code baseline comparison. The team evaluated different methods for reducing thermal bridges through THERM modeling and improving air sealing through architectural detailing. A domestic hot water delivery system investigation was performed along with researching drain water heat recovery applicability to the project. Embodied carbon research was performed to understand the carbon impact of design decisions. The non-energy co-benefits and passive survivability of high-performance design was also researched. Wrapping up the study was a review of potential building control systems.

Outcomes and Recommendations

NYSERDA's Early-Stage Design Support funding provided a valuable opportunity to research and further understand the design decisions related to achieving a high-performing, sustainable, healthy space that helps build a strong community. Through this process, the team evaluated Passive House enclosure strategies, thermal bridge reduction methods, air sealing approaches, geothermal and VRF heating and cooling systems, domestic hot water system options, drain water heat recovery feasibility, embodied carbon reduction opportunities, and building resiliency strategies. The funding proved instrumental in advancing the goal of creating an all-electric building that reduces embodied carbon while providing a comfortable, resilient, and affordable living environment for residents.

The team found that although Passive House design typically requires a more robust building envelope, increased airtightness, reduced thermal bridges, and system efficiency improvements over base building code, the building is projected to use less energy overall, reducing both the operational carbon footprint and energy demand of the community. Energy modeling showed the dwelling units performing approximately 36% better than ENERGY STAR® allowable maximums before photovoltaic offsets, while thermal bridge optimization efforts reduced projected heating demand and overall

energy usage. Research also demonstrated that embodied carbon reductions can often be achieved through relatively simple material substitutions, such as lower-carbon concrete mixes, thin brick veneer systems, and careful insulation selection when cost and availability allow. Additionally, the investigation reinforced the value of Passive House strategies in improving occupant comfort, indoor air quality, durability, acoustic performance, and passive survivability during power interruptions and extreme weather events.

Beyond informing the Sol Apartments project specifically, the Early Design Support process expanded Sustainable Comfort, Inc.'s internal knowledge and capacity to deliver future carbon-neutral multifamily projects. The work refined workflows related to WUFI energy modeling, THERM thermal bridge analysis, embodied carbon evaluation, and early-stage system optimization while also leading to the development of reusable air sealing guidance and detailing strategies that can be applied to future projects. The project team hopes to utilize these findings to support broader adoption of scalable, resilient, and low-carbon multifamily development throughout the Northeast and encourages other teams to explore and employ these strategies and benefits in their own projects.

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Introduction

Project Description

The proposed project site, 1818 Fifth Avenue, Troy, NY, incorporates a 0.55-acre parcel located within Census Tract 407, a NYS Draft Disadvantaged Community and DEC Potential Environmental Justice area. The site currently consists of a vacant, 2,976 square foot, single-story suburban-style bank branch built in 1972 with a canopy over two drive-through lanes and asphalt pavement parking. The property has fronts on Fifth Avenue [west] and Union [east] with access to both. It is bound by commercial office buildings to the south and by a church and a five-story building to the north.



Aerial Map prepared by Bohler

The project proposes replacing the vacant bank branch and parking lot with a new construction, four-story, certified Passive House multifamily building consisting of 71 predominantly studio apartments and communal amenities including resident coworking space, entertainment lounge with community kitchen, pet spa, package center, and conditioned indoor bicycle storage. The location is transit-oriented and highly walkable, and the proposed design pays respect to the historic context in the neighborhood.



Project Rendering by REVEAL Architecture | Design

Project Team

Manager

Rosenblum Development is one of the largest fully integrated real estate development and management companies in the Capital Region of New York. Rosenblum's commercial real estate portfolio encompasses over 1.8 million square feet of award-winning office, industrial, retail, self-storage [ValuSpace®], and urban mixed-use/multifamily properties as well as the company's own flexible workplace brands, Hone Coworks and Launchbox Flexible Warehouse Suites. Environmental stewardship is a driving principle of Rosenblum's real estate practice, realized by pursuing more efficient, resilient buildings ["performance"] in walkable, transit-oriented locations ["place"] with amenities that empower tenants to be more sustainable ["practice"]. Rosenblum's high-performance projects include the first all-electric midrise multifamily building [[Industrie Apartments](#)] and first net-zero warehouse [[Launchbox](#)] in the Albany area. The company also has an ongoing energy efficiency and decarbonization program for legacy properties; in 2024, six of its office buildings received ENERGY STAR® certification. To date, Rosenblum has 2.3 megawatts of rooftop solar PV deployed or in development.

Architecture

REVEAL Architecture | Design is a visionary architecture firm that thrives on collaboration and innovation. They believe that great design emerges from the synergy of diverse perspectives and expertise, engaging clients, stakeholders, and a multidisciplinary team to co-create functional, inspiring, and inclusive environments. Leading the design efforts is Shawn Corp, the Saratoga Springs, New York based company's Principal and project architect. Among his vast portfolio of work, Shawn was the lead architect in the design of Rosenblum's first two multifamily projects, The News Apartments and Vicina, also located in downtown Troy, NY. His discipline in balancing space optimization, first-class architectural aesthetics, historic sensitivity, and sustainability considerations, without sacrificing a luxury living experience, has proven itself invaluable, earning these project numerous accolades. More importantly, Shawns' efforts provide meaningfully beautiful contributions to the city's skyline and housing stock.

Passive House Consultant and NYSERDA Primary Energy Consultant

Sustainable Comfort, Inc. [SCI] is a green building and energy efficiency consulting firm with headquarters in Worcester, MA, an office in downtown Syracuse, NY, and inspectors located throughout the Northeast. SCI specializes in green building practices, including the oversight and administration of Passive House, Net-Zero Energy, ENERGY STAR® Homes, LEED for Homes, Enterprise Green Communities, HERS Rating, and State Incentive Programs. As qualified consultants and raters, they help teams design and execute successful, sustainable projects.

As a NYSERDA Primary Energy Consultant, SCI provides technical guidance to project owners and developers participating in NYSERDA's New Construction initiatives. Expertise includes energy modeling and analysis, and advanced clean energy building facilitation. Notably, SCI collaborated with The Rosenblum Companies on the Building 150 project, serving as both Certified Passive House Consultant and NYSERDA Primary Energy Consultant emphasizing both companies' commitments to sustainable development and energy efficiency. As an approved NYSERDA EDS Partner SCI facilitated the work described in this report.

MEP Engineer

M/E Engineering, P.C. is a full-service firm specializing in mechanical, electrical, and plumbing (MEP) design, with a focus on sustainable solutions across sectors like healthcare, education, and government. Founded in 1991 and based in New York, the firm emphasizes innovation, client relationships, and design excellence. M/E's robust background in sustainable MEP design has brought them to the design table for numerous Phius, ENERGY STAR® and NYSERDA-supported projects in the past.

Structural Engineer

Artisan Engineering, P.C. is a Vermont-based structural engineering firm specializing in creative, client-focused solutions for residential, commercial, and institutional projects. With expertise in a range of materials and structural systems, the firm emphasizes collaboration, responsiveness, and well-coordinated, cost-effective designs.

Sustainability Goals

The Sol Apartments project will create a high-performing, sustainable, healthy space that helps build a strong community. The goal is to build an all-electric building that reduces embodied carbon and provides a comfortable and resilient space for residents at an affordable price. The client believes this is the right way to build and sees a market benefit in low carbon buildings.

To reduce the building's carbon footprint, the team plans to utilize the results of embodied carbon studies to make product selections that reduce the carbon footprint where feasible. Additionally, the project will utilize smart building controls to monitor energy use and ultimately find and address larger, unnecessary energy usage areas.

Creating a high-performing and healthy building is important to all stakeholders. To support that goal, the Sol Apartments project has decided to pursue Passive House certification through Phius to create an air-tight building envelope with superior acoustic performance, excellent thermal performance and improved indoor air quality. This will reduce the overall energy demand and create exceptional occupant comfort.

Providing affordable space is a key goal of the project. To do this the bulk of the units will be studio apartments. Additionally, 30% of the apartments in Sol will be available at rents affordable to individuals earning 65% of the area average media income for the Albany-Schenectady-Troy MSA, including young professionals with typical entry level salaries in regionally significant industries.

Passive House Design

About Passive House

As described by the Passive House Institute US [Phius], Passive House is a building design standard that focuses on creating highly energy-efficient structures that require less energy to heat and cool. These buildings are designed with comfort in mind and maintain comfortable indoor temperatures year-round in hot and cold environments, without relying heavily on heating or cooling systems.

The five fundamental principles that are central to Passive House design and construction are:

1. Super-insulated envelopes
2. Airtight construction
3. High-performance glazing
4. Thermal bridge free detailing
5. Heat recovery ventilation

Passive House Benefits

Durability

Proven and applied building science strategies result in increased durability, reducing repairs and maintenance. Third party inspections ensure the building is constructed according to plans.

Health and Wellness

The well-insulated building envelope and triple pane windows, coupled with continuous fresh and filtered air provide the ultimate experience of comfort to occupants. Benefits include noise reduction, superior thermal comfort and the best in indoor air quality.

Cost

The climate specific and optimized energy balance of Passive House design reduces utility costs and the overall cost of ownership over the life of the building while also shielding against fluctuating energy costs and eventual time of use utility costs.

Passive Survivability

With added insulation and airtight construction, indoor temperatures remain comfortable longer during power outages or extreme weather.

Energy Independence

Energy costs will continue to rise and fluctuations will persist due to regulations and disruptions like COVID-19. Lower building energy needs minimize utility cost impacts, while PV integration enhances energy independence.

People spend 90% of their time in buildings and increasingly more time in their own homes, with that, the benefits of Passive House clearly impact the day-to-day lives of the home's occupants. Noise, thermal comfort, and indoor air-quality have significant impact on our overall health, wellness, and productivity while lower maintenance and utility costs and a resilient home reduce stress.

Passive House Institute US [Phius]

Passive House institute US, abbreviated Phius, is a non-profit Passive House organization committed to advanced energy performance, aiming to reduce heating and cooling energy use significantly compared to typical buildings. According to Phius their certified projects are proven to use "40-60% percent less energy than code-built buildings". Their new construction, certification standard program, CORE, requires robust energy modeling to inform low energy usage and emphasizes small mechanical equipment to serve the building.

The ownership team decided to pursue the goal of certifying the Sol Apartments project under Phius CORE 2021 to gain the environmental and occupancy benefits of Passive House design. Those benefits include healthier indoor air quality, balanced controlled ventilation, increased durability and longevity of all assemblies, and reduced noise from outside.

The certification program also requires a high level of oversight via a third-party verifier, and layers in additional benefits such as indoor air quality through the EPA Indoor AirPlus program. Phius goes beyond just energy efficiency to address multiple aspects of sustainable building design.

The Phius Design Certification Process

Certification through Phius is an iterative process which requires multiple rounds of review of the project's relevant drawings, specifications, and building energy model. On average, multifamily projects of similar size and complexity to this project require roughly four rounds of review by Phius before design certification is awarded. Review timelines get shorter as the cycle progresses due to less new information to examine. The initial review by Phius takes eight weeks while following reviews take six weeks for round two, four weeks for round three, and then two weeks for round four and subsequent rounds.

SCI collaborated with the project architect to develop a design schedule that included adequate time between each review cycle for design revisions. More time, roughly one month, was allocated for addressing feedback from Phius's earlier rounds and less time, roughly two weeks, was allocated for later rounds, assuming revisions would be more minor. This schedule proved helpful in aligning team expectations and obtaining four rounds of feedback from Phius prior to construction start. A similar approach of integrating Phius review cycles into the timeline was used for the Lincoln School Apartments. To learn more, visit <https://www.nyserda.ny.gov/All-Programs/Multifamily-Buildings-of-Excellence/Early-Design-Support-Program/Lincoln-Schools>.

Phius Modeling

Criteria Targets

The Phius CORE certification process requires submitting for Phius review, a whole-building energy model that confirms a building's energy usage, peak heating and cooling loads, and annual heating and cooling demands, does not exceed established targets. The targets, generated by a calculator from Phius, are based on climate location, occupant quantity, interior conditioned floor area, and enclosure area. Targets for this project are shown in the calculator image below which is in climate zone 5.

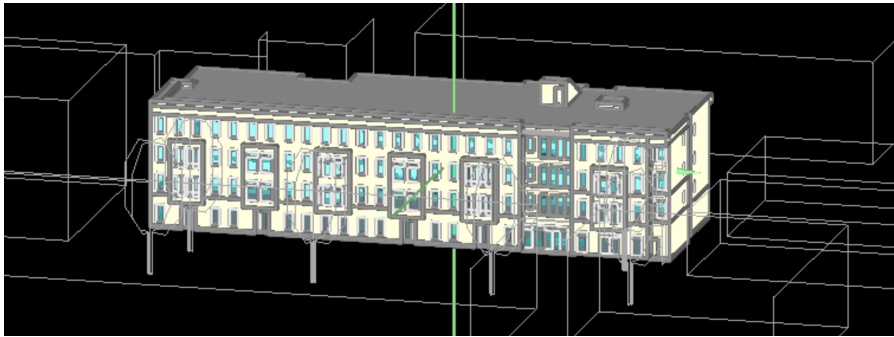
In the image, there is no target listed for whole-building airtightness. This is a pass/fail item and is the same for all modeled projects, except buildings that are both greater than or equal to five stories and of non-combustible construction. To meet the airtightness requirement, the air leakage of the enclosure shall be limited to less than or equal to 0.06 CFM₅₀ per square foot of gross enclosure surface area.

Phius 2021 Performance Criteria Calculator v3.3		
UNITS:	IMPERIAL (IP) ▾	
BUILDING FUNCTION:	RESIDENTIAL ▾	
PROJECT TYPE:	NEW CONSTRUCTION ▾	
STATE/ PROVINCE	NEW YORK ▾	
CITY	ALBANY COUNTY AP ▾	
Envelope Area (ft²)	56,417.3	
iCFA (ft²)	48,061.4	
Dwelling Units (Count)	71	
Total Bedrooms (Count)	17	
Space Conditioning Criteria		
Annual Heating Demand	6.2	kBtu/ft ² yr
Annual Cooling Demand	5.9	kBtu/ft ² yr
Peak Heating Load	4.7	Btu/ft ² hr
Peak Cooling Load	2.4	Btu/ft ² hr
Source Energy Criteria		
Phius CORE	7250	kWh/person.yr

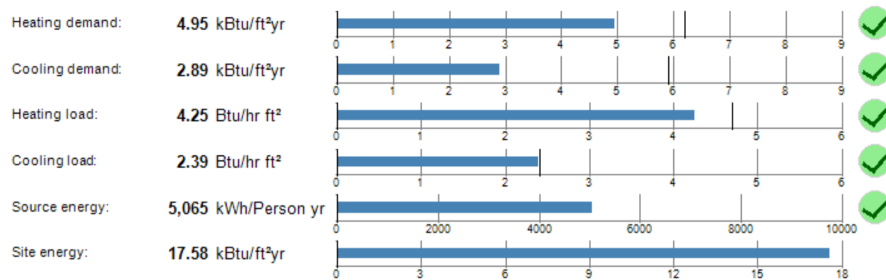
Results

As the CPHC on the project, SCI created a whole-building energy model in WUFI, Phius's selected energy modeling software. Based on the schematic drawings, SCI performed modeling calculations, like thermal bridge calculations discussed later in this report. Available information, such as 3D building form, surrounding shading, insulation types, and mechanical systems, was entered into the WUFI model. Modeling results guided envelope and system decisions, with refinements made based on Phius feedback and final design updates.

Below is an image from WUFI of the simulated building with site shading from trees and neighboring structures [outlined forms]. Along with the image are the results from the last round of WUFI energy modeling on a whole-project basis. Leaning on past WUFI modeling experience of projects with similar massing and occupancy densities, Passive House principles such as continuous and robust insulation, envelope airtightness, reduced thermal bridging, optimized high-performance windows, and energy recovery ventilation were implemented, and all targets were met based on the assembly and system selections listed later in this report.



Building and site
shading image
from WUFI



WUFI
modeling
results

Assembly and System Design Selections

Below is a summary of the various design selection inputs from the CD Stage WUFI energy modeling. As the design progressed, some of these selections changed, so additional details regarding adjustments, the selection process, and considerations for Passive House projects are included.

Exterior Assembly Design

- Slab: R-5 continuous under slab insulation via 1" XPS
 - Design progression:
 - Early schematic design proposed the Geo-Joist foundation [estimated R-11], combining XPS insulation with structural support to allow shallower foundations and reduced soil excavation. During the construction documents phase the team discovered that the average R-value of the Geo-Joist system would be closer to R-30 minimum due to the minimum XPS material thickness.
 - Geo-Joist was eliminated as an option as an average R-value above R-10 prevents additional ground cooling, which benefits multifamily buildings like this one with high internal heat gains from equipment and appliances. Additionally, site contractors did not support the belief that using the Geo-Joist system would reduce the amount of soil excavation.
 - Foam glass insulation, specifically Glavel, was considered, requiring 6" for R-10 thermal value while replacing an equal amount of sub-slab crushed stone. As WUFI modeling became more detailed, the cooling load target was exceeded with R-10 sub-slab insulation. It was determined that more ground cooling was required to offset the internal heating gains of the efficient unit

layout. With limited data on using less than 6" of Glavel, the team opted for 1" XPS, achieving an R-5 sub-slab value.

- Slab edge insulation: 4' vertically installed rigid insulation at R-10, connecting with exterior above-grade wall insulation for thermal bridge-free transition.
 - Since there is no gap between where the foundation insulation meets the above grade wall insulation [also known as 'continuous'], the thermal bridge is not present at this specific connection or 'transition'.
- Walls: R-29 effective assembly R-value comprised of 2.5" R-12 Zip-R insulated sheathing outboard of 2x6 studs 16" on-center with R-21 mineral wool cavity and interior gypsum wall board.
 - Design progression:
 - During schematic design, the team explored wood fiber insulation but opted for an alternative due to cost and availability concerns. While uncertainty prevented its use in this project, improving availability makes it a viable option for future projects as teams seek to reduce the embodied carbon content of their buildings.
 - 2.5" of exterior polyiso insulation [R-15] was considered, but WUFI modeling showed the extra ½" [R-3] had little impact. A side-by-side comparison below shows minimal change in cooling load [tightest criteria] and overall energy use.

Results with 2.5" of exterior polyiso		Results with 2" of exterior polyiso	
Heating demand:	4.63 kBtu/ft²yr	Heating demand:	4.81 kBtu/ft²yr
Cooling demand:	5.61 kBtu/ft²yr	Cooling demand:	5.55 kBtu/ft²yr
Heating load:	4.07 Btu/hr ft²	Heating load:	4.14 Btu/hr ft²
Cooling load:	2.35 Btu/hr ft²	Cooling load:	2.35 Btu/hr ft²
Source energy:	7,131 kWh/Person yr	Source energy:	7,139 kWh/Person yr

- The team ultimately choose to proceed with Zip-R due to availability and ease of installation.
- Roof: Flat/low slope with 9" of R-6/inch polyiso insulation R-40 effective assembly R-value.
 - As a result of metal fasteners penetrating the insulation, the effective R-value is lower than the specified value of R-54 [9" x R-6/inch]. A Phius calculator derates the R-value based on fastener type, size, and spacing. Mechanical fasteners will be used in only the first inboard layer while subsequent will be adhered so only the R-value of the first layer is impacted.
- Detailing: Exterior deck and canopy connections are outboard of continuous exterior insulation resulting in no thermal bridging at structural connections.
- Building Air Tightness: Building testing max of 0.06 CFM₅₀/sf of enclosure.
 - Final airtightness to be field tested. The maximum value is used for modeling.

- Windows / Glass Doors: Triple Pane Casement and Fixed, U-0.15 to U- 0.16 whole window U-value and 0.10 to 0.17 whole window SHGC.
 - Early energy models utilized a mid-range SHGC [~ 0.27 whole window]. With the higher internal heat gains, the added gains from the windows caused a failing cooling load. The SHGC was reduced to minimize the amount of cooling energy used.
- Windows / Glazed Door Condensation Risk Analysis – All selected fenestration complies.
 - The Phius Condensation Risk Assessment Tool (images below) calculates the maximum required window frame U-value to eliminate condensation risk. This calculation is based on the climate of the project site, fenestration type and risk factor.

CONDENSATION RISK

ISO 13788: Low Thermal Inertia Elements

Input Data: Class 2 typical	Fenestration Type	Any other type of fenestrat	
	Input humidity class here	2. Dwellings / Office	
	Frame U-Value	0.49	BTU/hr.ft ² .F
	Safety Factor	15%	
Result:	Risk acceptably low?	YES (Pass)	

Input Data: Class 2 typical	Fenestration Type	Exterior Door with ADA, egi	
	Input humidity class here	2. Dwellings / Office	
	Whole Door U-Value	0.49	BTU/hr.ft ² .F
	Safety Factor	15%	
Result:	Risk acceptably low?	YES (Pass)	

- Window / Glazed Door Comfort Requirements
 - The Phius Window Comfort Tool (image below) calculates the maximum required whole window U-value for thermal comfort. These calculations are based on the climate of the project and total height of the window/door. Glazing in regularly occupied spaces such as dwelling units, community rooms, offices, lobbies with seating, etc. must comply with comfort requirements. Meeting Phius' comfort requirements reduces the occurrence and intensity of convection currents that form when the interior surface of the window is cold compared to the rest of the space. Air immediately adjacent to the window is cooled and drops, creating the sensation of a draft. The taller the window, the more significant the impact which is why requirements are window-height dependent.
 - ADA doors, like the one mentioned above, are exempt from the comfort requirement. Additionally, doors and sidelights at vestibules, stairwells, hallways which are transient only need to comply with condensation risk requirements.
 - Phius Comfort Requirements calculator results for 8ft tall glazed fenestration.

COMFORT REQUIREMENTS

Applies to vertical fenestration in all project types.

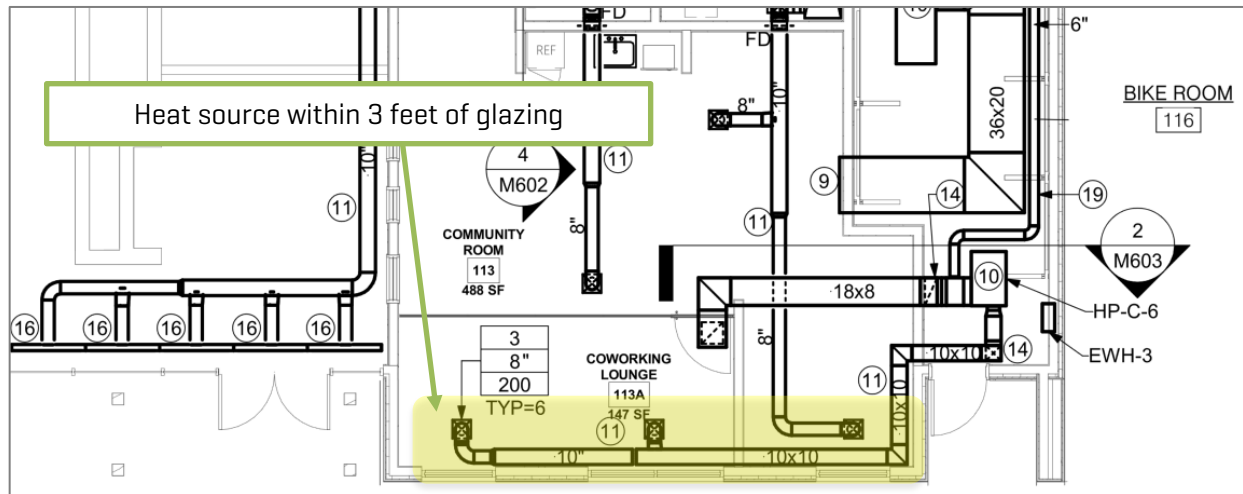
For stacked windows, include the full height of all mullied windows.

Windows >16' in height have the same U-value requirement as 16' tall windows.

Window Vertical Height	8.0	ft
Required Whole Window U-value*	0.19	BTU/hr.ft ² .F

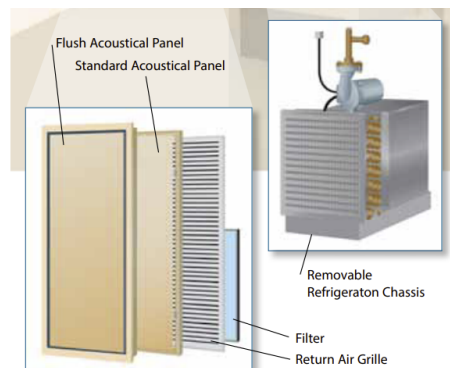
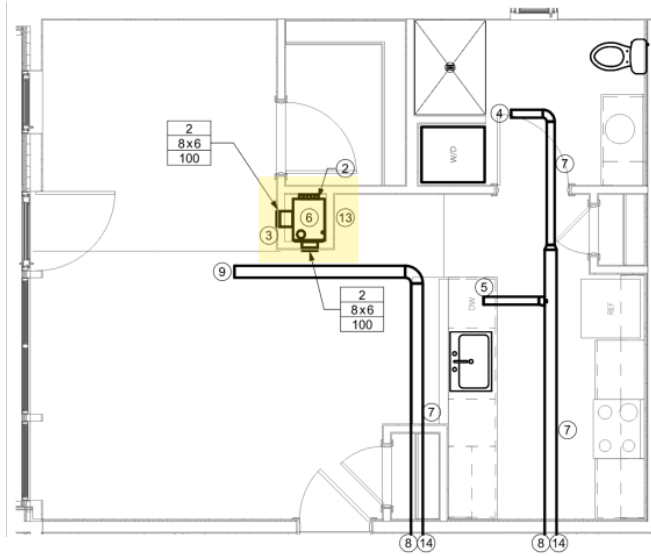
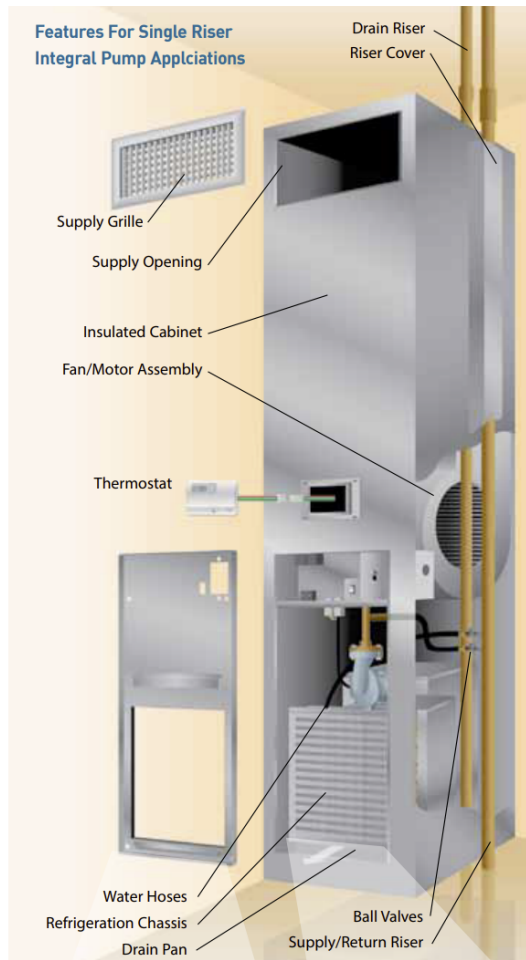
* Uninstalled whole window U-Value used. Do not include frame-to-wall psi-value for compliance.

- Although most of the windows met the requirement, with lower U-values, the taller storefront glazing in the coworking lounge and community room did not. As shown in the plan section below, an active heat source was added within 3 feet of the glazing to meet the comfort requirement.



Mechanical Design

- Heating & Cooling – Geothermal Ground Source Heat Pumps by Whalen and WaterFurnace
 - Residential Units [Whalen] – Vertical units eliminate unnecessary ducts in compact floor plans. See figures below from Whalen showing the equipment and floor plan.
 - Whalen Whisperline Heat Pump Configuration – Units can be installed in a mechanical chase or closet and provide conditioned air without ductwork.



Images from Whisperline® Water-Source and Geothermal Heat Pumps

- Common Areas – Ducted WaterFurnace combined with ventilation ducting.
 - Blended Efficiency: Heating: COP 3.19, Cooling: COP 4.40
 - Phius provides a calculator that blends the efficiency of all heat pump conditioning equipment utilized in the building. It uses a ratio based on capacity and quantity to calculate a weighted average of the equipment performance. Since this is a ground source heat pump fed system, it reduces efficiency based on average losses for the energy used by the field pumps.
- Early feasibility models utilized Variable Refrigerant Flow (VRF) heat pump equipment. Due to refrigerant concerns and an expectation of improved efficiency, the team moved to geothermal. Later in design, the group considered a change back to VRF due to geothermal funding concerns. The mechanical engineer provided the following information from another project to support the belief that geothermal would be a better solution. Ultimately, the team stayed with geothermal.
 - To use a similar project, Pan American Square as a comparison, there was a 21% decrease in load when we reviewed the idea of converting from VRF to geothermal. Conversely, we expect a 21% increase in the building loads at 1818 by going the other direction. We supplied two (2) 1200A feeds to the building for 1818: 1200A for the apartments, and 1200A for the house loads. The house loads included 25% future growth [typical for most designs], and the apartment loads did not [given that there is no realistic possibility of adding more apartments]. Here's how it broke out:

● House Loads: ● 347kVA [963A] ● + 25% future ● 434kVA [1205A]	● Apartment Loads: ● 426kVA [1181A] ● + 0% future ● 426kVA [1181A]
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- We can fit the VRFs onto the 1200A house panel, but we will lose our designed futureproofing, which we would not advise. Or, we need to increase to a 1600A switchboard to accommodate the VRF and the future capacity. The 1200A apartment panels will also need to increase to 1600A switchgear construction to accommodate the VRF.
 - Something else to note: The VRF system will also push our total load from 860kVA to 1040kVA. National Grid's transformers are available in 1000kVA and 1500kVA sizes. If National Grid determines that they want to use a 1500kVA transformer [they may or may not, since we are so close to 1000kVA], we will want to confirm with them that they can still provide the 208/120V building voltage that we need. In the past, Grid has sometimes told us that they only have 1500kVA transformers in the 480/277V variety, but it hasn't been consistent.
- Ventilation – Energy Recovery Ventilation (ERV), Indoor Semi Central Swegon Gold & Pro Casa.
 - Efficiency: ~81.5% SRE, ~0.65 humidity recovery
 - Power Consumption: <0.8 W/CFM [Final input determined in post-construction testing. See Electrical Design – Ventilation System note.]

- Temperature controlled bypass is utilized to reduce internal gains. See the results comparison below with a reduction in the cooling demand and source energy usage.

Results without Bypass	Results with Bypass
Heating demand: 4.81 kBtu/ft ² yr	Heating demand: 4.81 kBtu/ft ² yr
Cooling demand: 5.55 kBtu/ft ² yr	Cooling demand: 3 kBtu/ft ² yr
Heating load: 4.14 Btu/hr ft ²	Heating load: 4.14 Btu/hr ft ²
Cooling load: 2.35 Btu/hr ft ²	Cooling load: 2.35 Btu/hr ft ²
Source energy: 7,139 kWh/Person yr	Source energy: 6,938 kWh/Person yr

- Filter: Minimum MERV 8 filters required on supply and exhaust.
- Common Area Ventilation Rate: 890 CFM [total] continuous.
- CFM Rates in Units:
 - To meet Phius and corequisite programs, the minimum continuous requirements are as follows:
 - Exhaust: 20 CFM minimum to bathrooms, 25 CFM minimum to kitchens
 - Supply: 15 CFM minimum per person, and each bedroom must have dedicated supply air. 18 CFM is recommended.
 - For this project, these requirements meant the following supply/exhaust rates:
 - Studio: 45 CFM continuous
 - 1 Bedroom: 45 CFM continuous
- ERV Location and Ducting Requirements:
 - Outdoor air intake and exhaust ducts within conditioned space should be kept as short as possible to reduce thermal losses. Duct length is measured from inner side of exterior wall to the outside of ventilation unit.
 - Duct Insulation: R-8 insulation on all supply and exhaust ductwork between ERV and outside. Air sealed, class 1 vapor retarder shall be installed over all air permeable insulation [such as fiberglass duct wrap] on ventilation ducts connected to outside.
 - OA inlet to meet manufacturer recommended distance between intake and exhaust. Inlets at least 4' above the ground and not obstructed by snow, plantings, outdoor equipment.
 - Range hood is recirculating type and room exhaust for kitchen is tied into the ERV. The register must be a minimum of 6' [stretched-string distance] from the cooktop, MERV 3 or washable mesh filter for trapping grease, and recirculation hood over range.
 - Dryers: No ventilation required as in-unit ventless dryers will be provided.

Plumbing Design

- Domestic Hot Water
 - Water Heaters: Lync by Watts Heat Pump Water Heater, 3.6 COP. See the 'Domestic Hot Water Investigation & Evaluation' section for additional system information.
 - Hot Water Distribution
 - Unit distribution - manifold design
 - Central and unit piping is kept as short as possible and with the smallest possible diameters to keep the internal heat gains down.
 - Construction documents were revised to reduce the amount of central circulation piping by having apartment supply lines come off the main supply earlier.
 - Per DOE Zero Energy Ready Homes, to minimize water wasted while waiting for hot water and water heating energy, the hot water distribution system is designed to store no more than 1.8 gallons of water in any piping/manifold between the hot water source and any hot water fixture. The 1.8-gallon storage limit is measured from the point where the branch feeding the furthest fixture branches off the recirculation loop, to the fixture itself.
 - Plumbing Fixtures
 - No specific requirements for toilets, however, Phius encourages the use of all WaterSense labeled fixtures for toilets.
 - WaterSense labeled fixtures are required for lavatory faucets and showerheads to comply with DOE Zero Energy Ready Homes prerequisite program.
 - Pipe Insulation on all water pipes. This is required to minimize the amount of cooling needed and comply with DOE Zero Energy Ready guidelines.
- Radon control system required per EPA Indoor AirPlus program.

Electrical Design

- Lighting: 100% of fixtures to be high efficiency LED for all interior and exterior fixtures.
 - The electricity use of common area lighting is calculated by inputting the square footage and space use type into a Phius calculator. The calculator was produced with recommended lighting power density (Watts/SF) usage from Building America B10 Analysis – New Construction, 2011-01-26 workbook.
 - Based on Phius guidance, all common area lighting is modeled at a 10% lighting power density reduction to represent occupancy sensors.
 - Unit lighting electrical use is calculated via the same calculator, and on a square foot basis, but by RESNET protocol.
- Efficient ENERGY STAR® or equivalent appliances including refrigerators, dishwashers, and washer/dryer units.
 - In addition to having an impact on the overall source and site energy use, the energy usage of appliances, especially refrigerators, has a sizable impact on the building's cooling load due to internal heat gains. Below is a comparison of modeling results with two different refrigerators. As shown in the table, the more efficient, lower kWh/year refrigerator on the right side of the table keeps the cooling load lower.

Refrigerator using 380 kWh/year	Refrigerator using 350 kWh/year
Heating demand: 5.02 kBtu/ft ² yr	Heating demand: 5.09 kBtu/ft ² yr
Cooling demand: 3.34 kBtu/ft ² yr	Cooling demand: 3.29 kBtu/ft ² yr
Heating load: 4.13 Btu/hr ft ²	Heating load: 4.13 Btu/hr ft ²
Cooling load: 2.38 Btu/hr ft ²	Cooling load: 2.36 Btu/hr ft ²
Source energy: 5,535 kWh/Person yr	Source energy: 5,487 kWh/Person yr

- Community room kitchen and package room: Compact undercounter refrigerator.
- Ventilation System: For final power consumption, electrical contractor shall perform electrical wattage measurement on installed ventilation systems and be witnessed by the Phius Verifier.

PV and EV Design

- Solar PV
 - Modeled at 90,000 kWh/yr with 60 kW sized system [based on 2024 projection]. Aries Power provided a PV design and estimated the yearly production on year one. This level of production is more than enough to stay below the Phius Source Energy Target.
 - Based on WUFI modeling estimates, this amount of PV results in approximately a 24% reduction in both source and site energy.
- Electric Vehicle [EV] Charging Infrastructure – 15 parking spots
 - Infrastructure for the current and future charging of electric vehicles [EVs] is required for all residential buildings where parking spaces are planned to meet Phius and DOE Zero Energy Ready requirements
 - For Phius CORE 2021, the number of EV Ready and EV Capable Spaces required depends on the number of parking spaces provided in the project. The table below from Phius shows the quantity requirements.

Total # of Parking Spaces	Minimum number of EV Ready Spaces	Minimum number of EV Capable Spaces
1	1	-
2-10	2	-
11-15	2	3
16-20	2	4
21-25	2	5
26+	2	20% of total

- Based on the table above, 15 parking spaces require [2] EV Ready and [3] EV Capable spaces.
- The project team is currently planning to provide [2] EV Ready and [4] EV Capable spaces.

Energy Modeling

The Sol Apartments project has committed to comply with the ENERGY STAR® Multifamily New Construction (MFNC) Program. Compliance with this program is ultimately required to gain the Phius CORE 2021 certification the team is seeking. The project has been reviewed for compliance, which includes an energy model of each apartment. A fundamental requirement of the EPA ENERGY STAR® MFNC V1.1 is full compliance with the program checklists, which will be verified through the design and construction process.

Methodology and Findings

Our evaluation of this project included generating HERS (Home Energy Rating System) Indexes for each unit type based on the ENERGY STAR® Version 1.1 program using Ekotrope energy modeling software. The table below shows the results for a sample of the units, assuming the mandatory measures are met during construction.

The ENERGY STAR® MFV1.1 Target Index is the maximum HERS score allowable to meet ENERGY STAR® Version 1.1. The Modeled Pre-PV HERS Index is the index of the actual design for the building and the Post-PV HERS Index includes the offset from the Solar PV System.

For more information about HERS ratings, visit the RESNET HERS Index website [<https://www.hersindex.com/hers-index/what-is-the-hers-index/>]. To perform a HERS rating, a certified Home Energy Rater assesses the energy efficiency of a home, assigning it a relative performance score. The lower the number, the more energy-efficient the home. A typical home built to 2006 energy efficiency standards scores 100 on the HERS® Index.

Summary of HERS Scores

UNIT TYPE	UNIT MODELED	ENERGY STAR			SOLAR			
		HERS INDEX [PRE-PV]	ENERGY STAR MFV1.1 TARGET INDEX	% BETTER THAN ENERGY STAR	HERS INDEX [POST PV]	NYSERDA TIER 4 POST-PV TARGET INDEX	SOLAR SIZE [KW]	KWH/YR SOLAR PRODUCTION
Studio1st	107	48	73	34%	35	43	0.86	1,158
Micro4th	415	52	81	36%	38	48	0.86	1,158
1Bed4th	417	43	70	39%	33	42	0.86	1,158
Total Project Solar Size							60	81,060

Based on the Ekotrope modeling results, the units are roughly 36% better than ENERGY STAR® allowable maximum before solar [PV] offsets.

Energy Code vs. Passive House Compliance Comparison

Purpose

This report offers a comparison based on preliminary modeling between the 2018 IECC and the features necessary for full Passive House certification using the Phius CORE 2021 Standard. The goal is to provide the owner with a clearer understanding of the key differences so the potential cost implications of opting for Passive House certification versus adhering to the baseline code requirements may be assessed.

Energy Modeling Inputs

Climate Zone 5, Group R-2

Envelope Requirements

Component	Base Code	Phius CORE 2021
Slab	R-15 for 36" perimeter +R-5 full slab	R-10 full slab
Foundation Walls	R-7.5 ci	R-16 Slab Edge/ 4' vertical
Above Grade Walls	R-13 Cavity + R-7.5 Continuous OR R-20 Cavity + R-3.8 Continuous	R-21 Cavity + R-12 Continuous R-29 Effective Assembly
Windows	U-0.38 Fixed U-0.45 Operable	U-0.15 Fixed U-0.17 Casement
Doors	R-4.75 Opaque	R-2.44 Opaque
Roof	R-30 Continuous [insulation above roof deck] R-49 Other	R-35

Findings

At the time of this report, the monetary cost difference of the envelope requirements listed above was not available. However, based on material thickness, it's presumed the insulation for the Phius CORE 2021 pathway would be a cost increase. That cost increase should be offset by the operational cost savings of a more efficient building envelope.

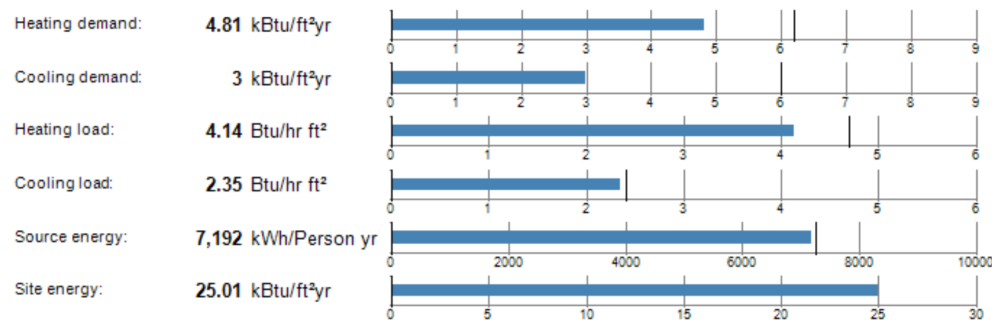
A brief WUFI modeling study [next page] compares base code and Phius CORE 2021 envelope values, showing higher heating, cooling, and energy use in the base code scenarios. The results highlight the energy benefits of Passive House design.

It is also important to note the non-energy benefits of the increased insulation R-values. Occupant advantages like a more comfortable interior environment every day and during occasional power outages should be recognized. These benefits are discussed in detail within the 'Passive Survivability Research' section of this report.

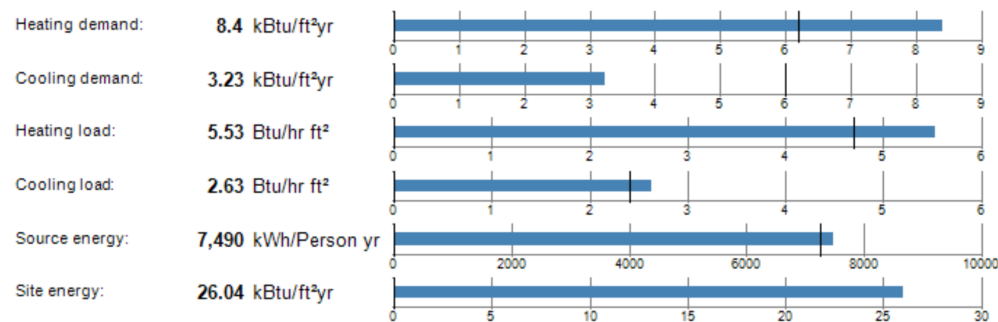
WUFI Modeling Study

Below are the WUFI energy model performance results for different enclosure scenarios. The same thermal bridge allowances, and mechanical, electrical, and plumbing systems are used in each model and any PV is excluded. The only changes are the envelope thermal values and airtightness.

Phius CORE 2021 Modeling Results



Base Code Modeling Results (with Phius envelope airtightness of 0.06 CFM₅₀ /SF)



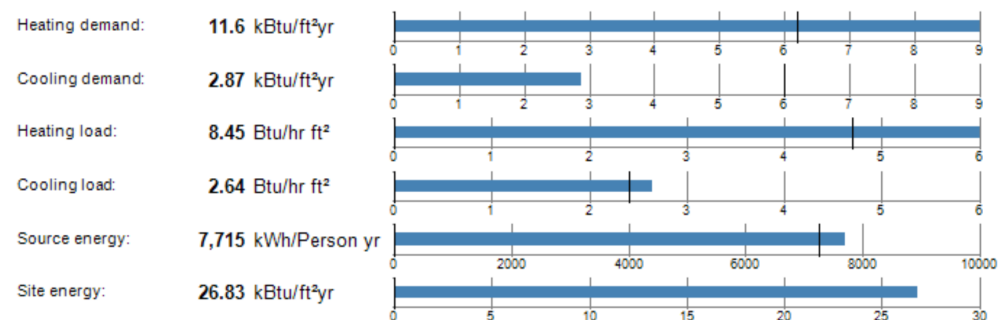
Annual Site Energy Increase:

~4% or
15,491.14
kWh/yr

Annual Utility Cost Savings:

~\$2,875
based on an
estimated
\$0.19/kWh
electric rate

Base Code Modeling Results (with code baseline airtightness of 0.30 CFM₅₀ /SF)



Annual Site Energy Increase:

~7% or
25,599.51
kWh/yr

Annual Utility Cost Savings:

~\$4,750
based on an
estimated
\$0.19 /kWh
electric rate

Thermal Bridge Modeling

About THERM Modeling

THERM modeling is a process used to analyze thermal bridging in Phius buildings. Thermal bridges are areas in a building where heat flows more easily due to material conductivity or design features, such as at window frames, balconies, or wall intersections. Since Phius prioritizes high energy efficiency and durability, minimizing thermal bridges is essential to reduce heat loss and improve overall building performance.

THERM, a software developed by Lawrence Berkeley National Laboratory [LBNL], is used to simulate and quantify heat flow through building assemblies using a two-dimensional model. It helps designers identify where thermal bridges occur and evaluate different insulation strategies to mitigate energy loss.

How THERM Relates to Phius Certification

For Phius CORE 2021 certification, Phius requires linear thermal transmittance [psi-value or Ψ] calculations to represent additional heat loss due to a thermal bridge for critical junctions.

Each of the following details were identified as potential thermal bridges and modeled in THERM to simulate heat flow [see following images from THERM with isotherm temperature lines]. Relevant data [temperature gradients, heat transfer rates] is extracted from the THERM models. Then the psi-value is calculated using established formulas in a spreadsheet style calculator from Phius. For Phius, psi-values are measured in Btu/hr.ft.°F, showing the heat energy lost per foot between two thermal elements due to thermal bridging.

Based on the results, connection details were adjusted to reduce the thermal bridge, and another round of modeling and calculations were performed to determine the new psi-value. The larger the psi-value, the larger the thermal bridge. The final psi-values, if greater than 0.006 Btu/hr.ft.°F, must be entered into the WUFI model to accurately represent the reduced thermal performance of the building envelope.

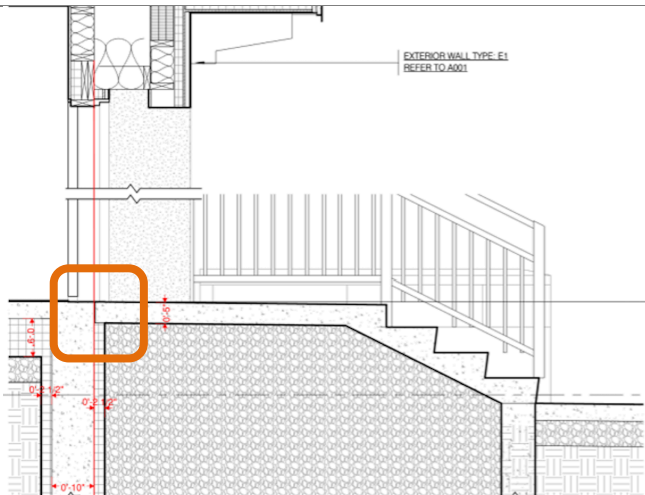
Findings

The following sections show the thermal bridge modeling and calculation results for specific details. Also illustrated are the design revisions and new results. In a quick comparison of the thermal bridges outlined on the pages to follow, the revised designs reduced the heating demand by 11,054.13 kBtu per year, the source energy use by 1,672 kWh per year and the site energy usage by 2,883.69 kBtu per year. One can see that small changes to the design can have a larger impact on the heat transfer and overall building performance.

Continuous Concrete Stoop

Original Design

Note the area of concern highlighted in **orange**. With no thermal break between the concrete foundation wall and exterior concrete landing, it's suspected that the colder exterior concrete will steal heat energy from the interior components.



Detail from Drawing Set

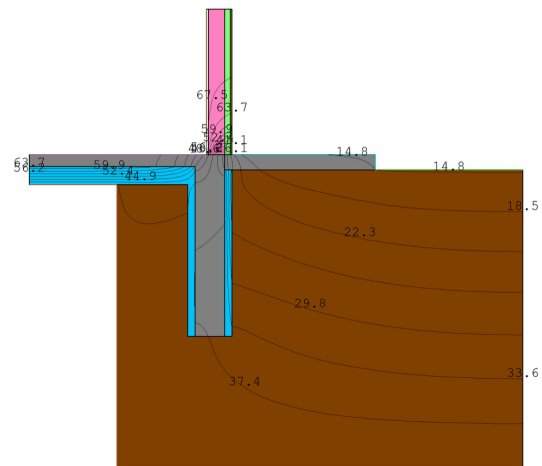


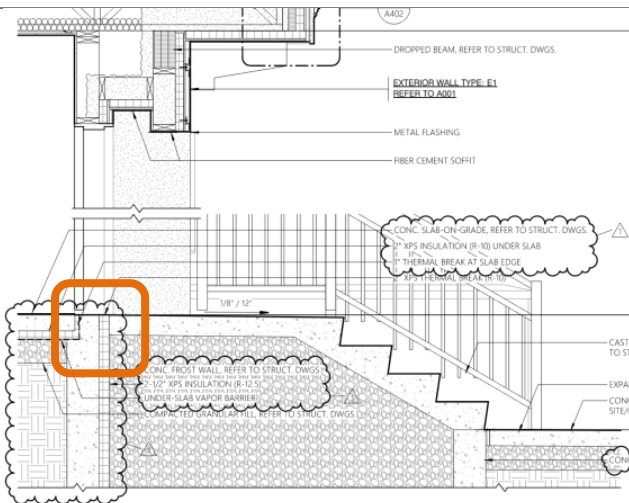
Image of THERM Model

2D model		U (btu/hr.s.f.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
	Interior	0.0596	54	108.00	28.97	4.51%
	Exterior	0.0156	54	412.13	28.93	4.51%
Component		U (btu/hr.s.f.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Component A	Interior	0.0438	27	68.63	6.76	0.00%
Slab	Exterior	0.0438	27.00	68.63	6.76	0.00%
Component B	Interior	0.0283	54	58	7.39	0.00%
Wall	Exterior	0.0283	54.00	58.00	7.39	0.00%
Psi		PsidT (btu/hr.ft)	dT (F)	Psi (btu/hr.ft.F)	Psi for WUFI (btu/hr.ft.F)	
	Interior	14.82	54.00	0.274	0.274	
	Exterior	14.78	54.00	0.274		

Psi Value Calculation & Results [larger **green** box]

Revised Design

Note the area of revision highlighted in **orange**.



Detail from Drawing Set

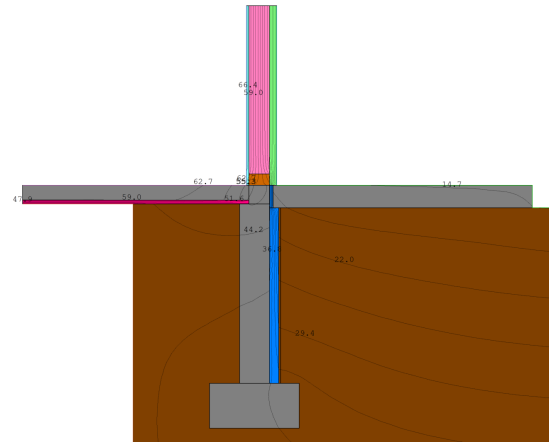


Image of THERM Model

2D model		U (btu/hr.sq.ft)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
	Interior	0.0687	54	108.00	33.39	3.39%
	Exterior	0.0144	54	516.13	33.44	3.39%

Component		U (btu/hr.sq.ft)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Component A	Interior	0.0273	54	53.00	6.51	0.00%
Wall	Exterior	0.0273	54.00	53.00	6.51	0.00%
Component B	Interior	0.1600	27	68.125	24.53	0.00%
4in Slab 1in XPS	Exterior	0.1600	27.00	68.13	24.53	0.00%

Psi	PsidT (btu/hr.ft)	dT (F)	Psi	Psi for WUFI (btu/hr.ft.F)
Interior	2.35	54.00	0.044	0.044
Exterior	2.41	54.00	0.045	

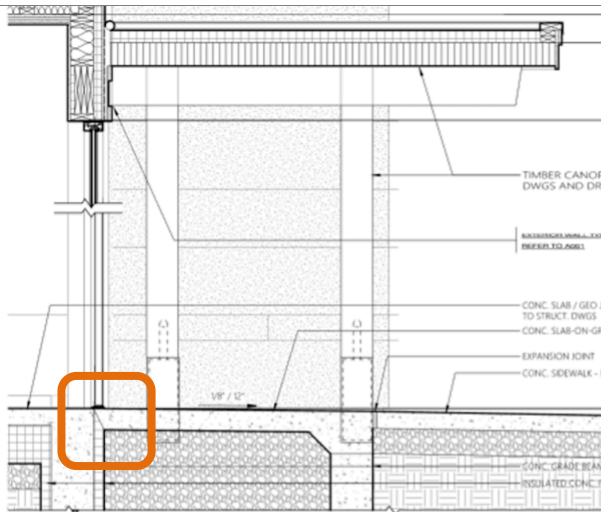
Psi Value Calculation & Results [larger **green** box]

Result: Adding a small amount of insulation or thermal break between the two pieces of concrete resulted in 0.23 Btu/hr.ft.°F energy savings.

Door Installation at Storefront Entry

Original Design

Note the area of concern highlighted in **orange**. Although this detail shows a thermal break between the concrete foundation wall and exterior concrete landing, it's suspected that the thickness of the break should be increased to reduce the amount of heat energy transfer.



Detail from Drawing Set

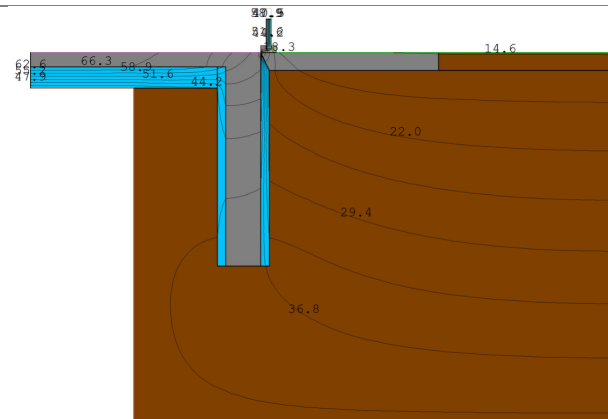


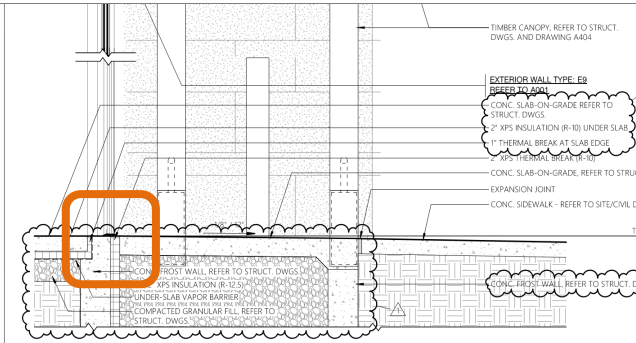
Image of THERM Model

2D model		U (btu/hr.sq.ft)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
	Interior	0.0804	54	77.10	27.89	4.45%
	Exterior	0.0168	54	368.10	27.83	4.45%
Component		U (btu/hr.sq.ft)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Component A	Interior	0.0438	27.00	70.6	6.96	0.00%
Slab	Exterior	0.04	27.00	70.63	6.96	0.00%
Component B	Interior	0.1193	54.00	9.5	5.08	2.78%
Door	Exterior	0.1193	54.00	9.47	5.08	2.78%
Component C	Interior	0.0283	54.00	13.0	1.66	0.00%
Above Grade Wall	Exterior	0.0283	54.00	13.0	1.66	0.00%
Psi		Psi dT (btu/hr.ft)	dT (F)	Psi (btu/hr.ft.F)	Psi for WUFI (btu/hr.ft.F)	
	Interior	14.19	54.00	0.263	0.262	
	Exterior	14.13	54.00	0.262		

Psi Value Calculation & Results [larger **green** box]

Revised Design

Note the area of revision highlighted in **orange**.



Detail from Drawing Set

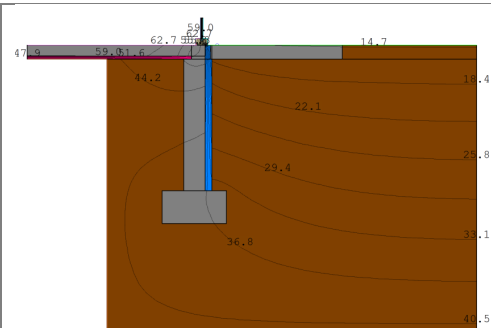


Image of THERM Model

2D model		U (btu/hr.sf.F)	dT (F)	L (in)	UdLT (btu/hr.ft)	error (%)
	Interior	0.1058	54	75.30	35.85	3.60%
	Exterior	0.0166	54	480.86	35.92	3.60%
Component		U (btu/hr.sf.F)	dT (F)	L (in)	UdLT (btu/hr.ft)	error (%)
Component A	Interior	0.1600	27.00	70.6	25.43	0.00%
4" Slab 1" XPS	Exterior	0.16	27.00	70.63	25.43	0.00%
Component B	Interior	0.1512	54.00	9.5	6.45	3.10%
Storefront Glazing	Exterior	0.1573	54.00	9.50	6.72	3.10%
Component C	Interior	0.0273	54.00	5.0	0.61	0.00%
Above Grade Wall	Exterior	0.0273	54.00	5.0	0.61	0.00%
Psi		PsidT (btu/hr.ft)	dT (F)	Psi (btu/hr.ft.F)	Psi for WUFI (btu/hr.ft.F)	
	Interior	3.36	54.00	0.062	0.060	
	Exterior	3.16	54.00	0.058		

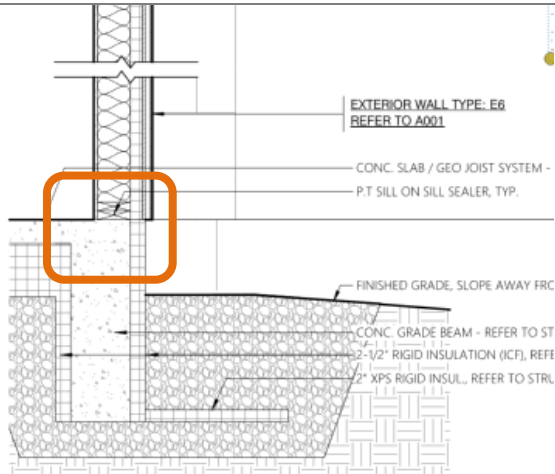
Psi Value Calculation & Results [larger **green** box]

Result: Adding a small amount of insulation or thermal break between the two pieces of concrete resulted in 0.202 Btu/hr.ft.°F energy savings.

General Perimeter Footing

Original Design

Note the area of concern highlighted in **orange**. Most standard foundation connections include a thermal bridge. Early WUFI modeling included an allowance for a foundation thermal bridge based on the detail below. The detail was modeled with a small slab break [rigid insulation] between the stem wall and concrete slab.



Detail from Drawing Set

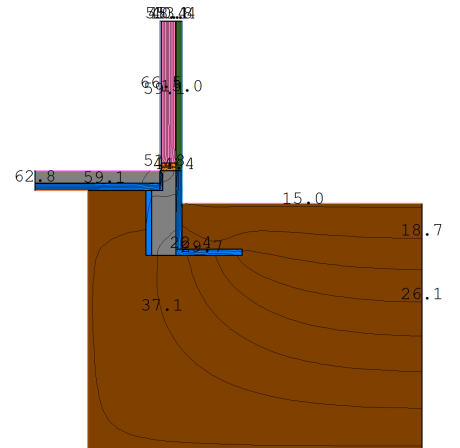


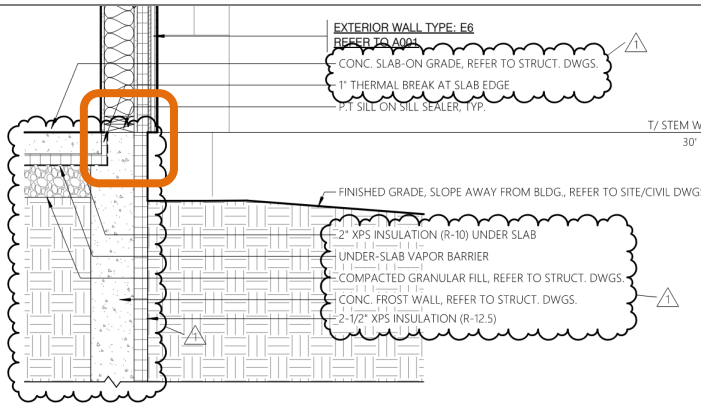
Image of THERM Model

2D model		U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
	Interior	0.0432	54	111.38	21.65	4.49%
	Exterior	0.0111	54	434.00	21.68	4.49%
Component		U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Component A	Interior	0.0255	54	68.00	7.80	0.00%
Wall	Exterior	0.0255	54.00	68.00	7.80	0.00%
Component B	Interior	0.0376	27	60.5	5.12	0.00%
Slab	Exterior	0.0897	27.00	60.50	12.21	0.00%
Psi		Psi dT (btu/hr.ft)	dT (F)	Psi (btu/hr.ft.F)	Psi for WUFI (btu/hr.ft.F)	
	Interior	8.73	54.00	0.162	0.096	
	Exterior	1.66	54.00	0.031		

Psi Value Calculation & Results [larger **green** box]

Revised Design

Note the area of revision highlighted in **orange**. In this revised detail, the slab break shown in the drawings was removed from the THERM model to see if the resulting thermal bridge would be allowable in the WUFI model.



Detail from Drawing Set

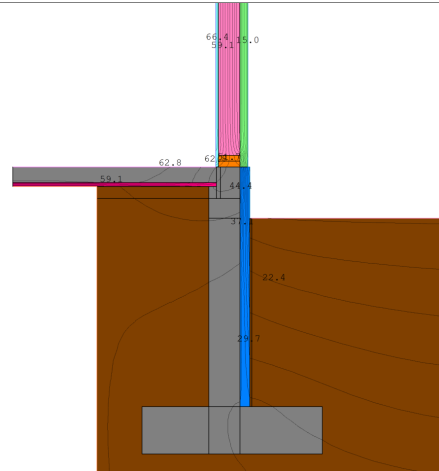


Image of THERM Model

2D model		U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
	Interior	0.0625	54	111.84	31.45	4.85%
	Exterior	0.013	54	536.00	31.36	4.85%
Component		U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Component A	Interior	0.0273	54	65.00	7.99	0.00%
Wall	Exterior	0.0273	54.00	65.00	7.99	0.00%
Component B	Interior	0.1600	27	60	21.60	0.00%
4in Slab_1in XPS	Exterior	0.1600	27.00	60.00	21.60	0.00%
Psi		Psi dT (btu/hr.ft)	dT (F)	Psi (btu/hr.ft.F)	Psi for WUFI (btu/hr.ft.F)	
	Interior	1.87	54.00	0.035	0.034	
	Exterior	1.77	54.00	0.033		

Psi Value Calculation & Results [larger **green** box]

Result: The change in detail resulted in a minor 0.062 Btu/hr.ft.°F energy savings. This is likely since this process is calculating the heat differential. The original detail had higher R-value sub slab insulation. The lower R-value in the revised detail means less heat difference. Ultimately the thermal bridge was allowable in the WUFI model.

Air Sealing

The Importance of Air Sealing

Air sealing is the process of locating and sealing all the areas in a building's envelope where air leakage could occur. This process is a critical component in high performance buildings and can mean the difference between passing and failing an energy program. Utilizing appropriate air sealing techniques is crucial for Phius buildings for several reasons:

- **Energy Efficiency:** Air sealing minimizes uncontrolled air leaks, reducing the need for heating and cooling. This significantly lowers energy consumption and helps meet Phius's strict energy use standards.
- **Thermal Comfort:** Preventing drafts and maintaining consistent indoor temperatures improve occupant comfort by eliminating cold spots and uneven heating or cooling.
- **Moisture Control:** Effective air sealing prevents humid air from infiltrating wall assemblies, reducing the risk of condensation, mold growth, and structural damage.
- **Indoor Air Quality:** With a tight building envelope, ventilation can be precisely controlled using energy recovery ventilators (ERVs), ensuring a steady supply of fresh, filtered air while expelling stale air.
- **Durability:** Preventing air and moisture infiltration protects insulation and building materials, enhancing the longevity and durability of the structure.
- **Reduced Heating and Cooling Loads:** Less air leakage means smaller HVAC systems are needed, which can lower initial installation costs and long-term operational costs.

Proper air sealing is essential for achieving the energy performance, comfort, durability, and indoor air quality goals of Phius-certified buildings.

Air Sealing Guide

Due to the high importance of air sealing in high performance buildings, with Early-Stage Design resources, an air sealing guide for wood framing was developed by SCl as a tool to assist project teams with understanding air sealing. An overview is included below, with the full air sealing guide available through Sustainable Comfort, Inc.

[Air Sealing Guide - Introduction Excerpt](#)

As the energy consultant, SCl typically conducts inspections and testing to ensure adequate air sealing. We are happy to help with any air sealing questions throughout the construction process. The main caveat to the guide is that it is not comprehensive and cannot guarantee air sealing success. It's important that the contractor is aware of the importance of proper air sealing to ensure code and energy program compliance.

Air Sealing Guide - Overview Excerpt



Air sealing will help improve a building's durability by reducing the air leakage, condensation potential, and thermal losses that lead to high energy bills. Air sealing also improves indoor air quality and comfort, it eliminates drafts, keeps outside air pollutants and pests out, promotes noise reduction and odor control from outside and between adjacent units in multifamily buildings.

Airtightness Boundary (red): When air sealing a building, it is important to target areas where the primary air barrier material terminates to transition to another material or when a penetration is made through the building's envelope, such as the foundation and attic, windows and openings, etc.

Compartmentalization Boundary (green): This boundary separates dwelling units from each other and common spaces, and contributes to the quality of construction. Compartmentalization reduces the stack effect, thereby improving control of indoor airflow. It helps prevent the spread of pests, odor, and noise between apartments.

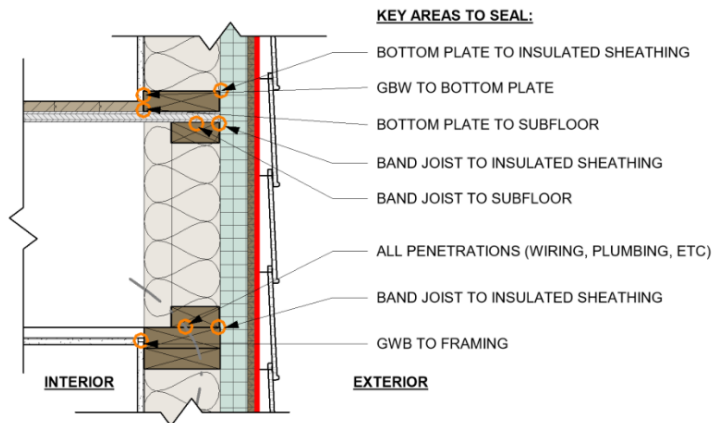
Important Tips

1. Clean out cracks before applying sealant.
2. For gaps smaller than 1/4", use shrink-proof and crack-proof caulk.
3. For gaps larger than 1/4":
 - Use backer rod and caulk instead of foam at window and door openings.
 - Use flexible caulk material instead of foam where applicable.
 - Use expanding foam sparingly (greater negative environment impact and prone to cracking).
4. Use correct sealant for the temperature and conditions.

When working on a project, be sure to get your energy consultant's input to ensure proper air sealing practice. Identify potential leakage areas early by working with your energy consultant to coordinate a mid-point blower door test.

Air Sealing Guide – Band Detail Excerpt

Top/Bottom Plating



When air sealing the top and bottom plates, it is recommended to use caulk, foam gaskets, or other sealants. Before installing drywall, be sure to air seal gaps between the framing and sheathing, as well as any additional cracks in the framing first. Otherwise, it will be difficult to target these areas once the drywall is installed.

AIR SEALING: TOP & BOTTOM PLATES

— AIRTIGHTNESS BOUNDARY



Properly sealing off the bottom plate to subfloor will prevent air leakage. Be sure the air seal is continuous throughout.



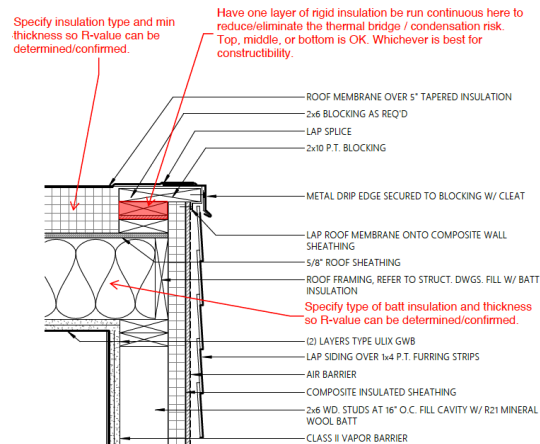
ZIP-R sheathing was not sealed behind the framing, creating an area for air leakage. Fully seal the primary air barrier before installing other building components.

Air Sealing Detail Review

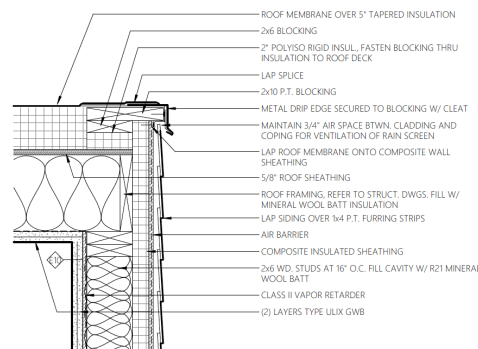
Developing the air sealing guide and examining the critical details in the guide with the project's architect resulted in a comprehensive air sealing details sheet included in the drawing set. Below is an example of the redlined review of a detail, along with the eventual detail from the details sheet in the project's drawing set.

These details are a bit more generic in nature, so they can be applied to several projects, thereby reducing the hours spent on drafting custom details and focusing efforts on more impactful tasks. Additionally, the air sealing guide that was created has been requested by other teams as a reference.

Original “redlined” detail



Revised Detail



Critical air sealing locations and methods were called out in the redlined detail. These locations were also illustrated in the band detail except from the air sealing guide on the previous page. One can see how recommendations were captured in the revised detail that will be used by the field team in construction. Having a clear reference document reduces back-and-forth clarifications between architects, builders, and subcontractors.

The developed air sealing guide bridges the gap between design intent and on-site execution, ensuring that airtightness goals are understood, properly implemented, and verified – ultimately leading to a better-performing, more durable, and energy-efficient building.

Domestic Hot Water Investigation & Evaluation

System Options

Basis of Design

The original basis of design for central domestic hot water generation provided for four locations to service vertical quadrants of the building and apartment units. It included Sunamp Systems heat “battery” type units that utilize phase change material (PCM) technology to heat domestic water for domestic hot water use. Each unit is very compact in size [15”W x 23”D x 34”H] and provides for an integral electric resistance heating element as a back source for heating hot water. The Sunamp Units receive the source heating supply/medium through an exterior air source heat pump (ASHP) system [approximately a 20-ton heat pump].

The building domestic hot water recovery calculations showed the need for an overall hot water demand of 577 gallons per hour. Utilizing Sunamp’s sizing criteria along with their suggested model selection, the design needed [16] Sunamp, Thermino 210i units to meet the daily domestic water demand.

As indicated above, the system was broken into four quadrants with a Sunamps unit for each. This equates to each set of four water heater assemblies to provide 170 gallons per hour of domestic hot water from a recovery standpoint. In turn, domestic hot water distribution will be vertical and avoid long supply and return piping runs on each floor.

Utilizing geothermal heat source as a primary domestic hot water heating source was also researched.

It was determined that the project would most likely feature a combination heating medium using both heat pump and geothermal.

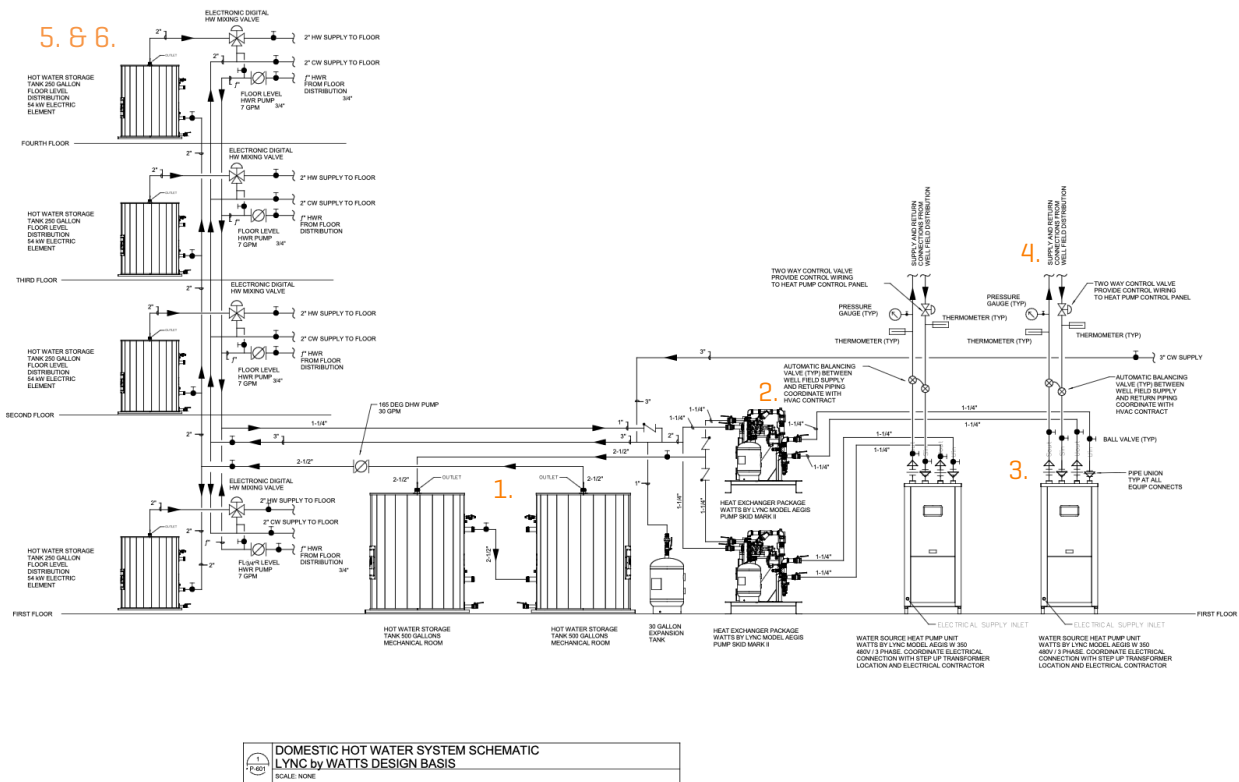
Selected System

Ultimately an internal heat pump system fed by the geothermal well field was selected. The heat pump portion of this system has a COP of 3.6 as opposed to an external system figured in early modeling with an estimated COP of 3.16. With an internal system there’s no reduction in the COP for the exterior climate and there’s the added benefit of more roof space is available for PV.

The final interior piping system design divided the building up into four quadrants, but unlike the original basis of design, these quadrants were based on floor. This resulted in the heat exchangers and pumps located in the larger lower level mechanical room with the geothermal equipment, and a larger water storage tank in a smaller mechanical room of each floor for distribution. Breaking the building up into vertical sections would likely have resulted in unit layouts that were not consistent from floor to floor and more vertical piping than horizontal piping but minimal impact on the overall energy usage.

Selected System Design

Schematic is shown below for the final designed system:



System sequence of operation:

1. Source heating medium from Geothermal field
2. Medium circulated through CO₂-based water source heat pump equipment LYNC Aegis W 350
3. Double wall heat exchanger, LYNC Aegis Mark II HEX pump Skid, delivery temp 165 degrees
4. The potable hot water side of HEX is delivered to [2] 500-gallon DHW storage tanks in the first-floor mechanical room
5. Each floor level is fitted with a 250-gallon DHW storage tank for delivery of domestic hot water. Supply is fed from the main plant described by 1, 2, & 3 above
6. 250-gallon floor-level hot water storage tanks are fitted with electric resistance heating elements for backup heating should the geothermal supply be compromised

The LYNC system equipment, sourced by Geothermal, is all indoors.

Drain Water Heat Recovery

What is Drain Water Heat Recovery

Drain Water Heat Recovery [DWHR] is a system that captures and reuses heat from wastewater - typically from showers, sinks, or dishwashers - before it goes down the drain. This recovered heat is then used to preheat incoming cold water, reducing the energy needed for water heating.

How It Works:

- Heat Transfer: Warm wastewater flows down a vertical copper or stainless-steel drain pipe with a coiled cold-water supply pipe wrapped around it.
- Preheating Incoming Water: As warm drain water flows through, it transfers heat to the cold water in the coil, raising its temperature before it enters the water heater or mixing valve.
- Energy Savings: Since the preheated water enters the water heater at a higher temperature, less energy is needed to heat it to the desired level.

Research and Findings

As part of the Early Stage Design Support, a drain water heat recovery system was researched. This type of system requires a wastewater storage tank, macerator unit, heat exchanger skid, and controls. At maximum sewage flow, the heat output amounts to 2,474 MBH. The large equipment footprint needed was not available in this building, being slab on grade and without a basement area to collect the wastewater in the building.

Embodied Carbon Research

Embodied Carbon and Sol Apartments

According to the EPA, 15% of global greenhouse gas emissions are associated with the production of construction materials.¹ Embodied carbon refers to the greenhouse gas emissions associated with the production [the extraction, transport, and manufacturing] stages of a product's life. To reduce greenhouse gas emissions, project teams like this one have begun to track embodied carbon and look for ways to improve the net emissions [calculated in kg CO₂e] through material choices.

The following represents the project research regarding materials and their expected embodied carbon. Not all final decisions for materials for the project are distinctly called out, however the research was used throughout design and therefore concisely shared here. The team gained critical insights into how material choices impact a building's total carbon footprint. For example, just changing manufacturers when selecting a product as simple as drywall can have a sizable impact on embodied carbon.

Estimates for all proposed and selected materials were not performed, so it's unclear what the overall embodied carbon is. However, knowing the impact certain material choices can have and understanding how to estimate embodied carbon is a step closer to helping reduce the carbon footprint on this and future projects.

Embodied Carbon Calculations

The team utilized 'Builders for Climate Action's- Building Emissions Accounting for Materials (BEAM) estimator to assess the carbon impact of materials. The BEAM tool contains a comprehensive list of materials/products including their carbon footprints. It includes industry averages of emissions for estimates and allows for customization when a specific product with an Environmental Product Declaration (EPD) is known.

The BEAM tool addresses the structure, enclosure, partitions, and primary finishes of the building. It does not include MEP Systems, fasteners, flashing, damp-proofing, sealants, adhesives, appliances, millwork, stairs, paints, stains, surface finishes, or yardwork. It does not capture the full climate impact of the building, just the product stage carbon footprint of the components addressed. Some items, such as MEP Systems, are currently excluded from the tool due to lack of data and may be added to the tool in the future. Even with its limitations, BEAM is still a very helpful tool for understanding the embodied carbon consequences of material choices.

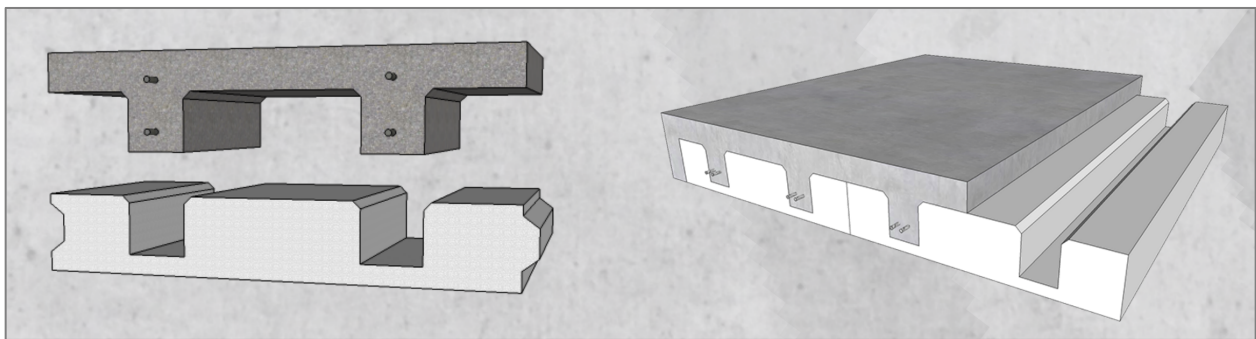
In the pages to follow one will see several images from the BEAM tool, showing how it can compare the overall embodied carbon of different selections in a simple table. Other embodied carbon research and datapoints are based on research of industry resources. These are highlighted with footnotes.

¹ United States Environmental Protection Agency. "C-MORE: Construction Material Opportunities to Reduce Emissions." Accessed January 24, 2025. <https://www.epa.gov/greenerproducts/cmored>.

Footings & Slabs

Geo-Joist

Concrete can be a major source of carbon emissions. The project team considered a Geo-Joist (image below) slab system for the foundation system. Geo-Joist is made from EPS insulation and provides more structural support than typical sub slab insulation, allowing for a reduced slab and/or foundation thickness. With this system the embodied carbon typically created by the slab would be reduced due to the Geo-Joist reducing the concrete slab thickness and weight². The Geo-Joist product did not prove to be a viable option by the end of the design phase of this project due to the substantial amount of XPS insulation used to build the system. More about this is included in the beginning of this report.



Concrete Additives

Additionally, alternative concrete mixes like those that incorporate fly ash can reduce the carbon footprint and were investigated to see if they work structurally and cost-wise. CarbonCure additives were also researched.

In the image below from the BEAM tool, you can see a list of options for different concrete mixes and their respective net emissions for this project. A standard mix with a quantity of 12,640.0 SF would produce 36,943 kg CO₂e. The same quantity of concrete with 20-29% Fly Ash content would only produce 31,847 kg CO₂e, a 5,096 kg savings. The team notated a minimum 20% Fly Ash content in their concrete specifications.

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO ₂ e)
	Concrete - 31-35 MPa, 35-50% Slag, GU / CRMCA [Industry Avg CA]	12,640.0	ft ²	100%	☐	36,720
CONCRETE - <= 2500 psi - N.AMERICA						
	Concrete - 0-2500 psi, Standard mix / NRMCA [Industry Avg US & CA]	12,640.0	ft ²	100%	☒	36,943
	Concrete - 0-2500 psi, 20-29% Fly Ash / NRMCA [Industry Avg US & CA]	12,640.0	ft ²	100%	☐	31,847
	Concrete - 0-2500 psi, 30-39% FA/SL / NRMCA [Industry Avg US & CA]	12,640.0	ft ²	100%	☐	28,899
	Concrete - 0-2500 psi, 40-49% FA/SL mix / NRMCA [Industry Avg US & CA]	12,640.0	ft ²	100%	☐	26,072
	Concrete - 0-2500 psi, >50% SCM mix / NRMCA [Industry Avg US & CA]	12,640.0	ft ²	100%	☐	23,192

² CMI Structural. "Geo-Joist in Northeast | Northeast Geotechnical Designs." Accessed September 8, 2023. <https://www.cmistructural.com/geo-joist>.

Insulation Foam Glass

In the later stages of design, the team decided that a foam glass aggregate product, Glavel [image at right], would provide the required sub slab stabilization and insulation. Typically, rigid plastic insulation is used to insulate under the slab, which has a high level of embodied carbon. By utilizing Glavel, the project could achieve a significant reduction in the amount of required plastic insulating materials.



Foam Glass Gravel offers the physical properties of glass in a lightweight and load-bearing aggregate. With Thermal insulation of R1.7 per compacted inch and compressive strength of 116psi, foam glass gravel is ideal for multiple applications in the construction industry.

The BEAM tool indicates that R-10 of foam glass aggregate from a similar manufacturer, Hasopor, at R 1.7/inch and 12,640 SF would produce 1,286 kg CO₂e. To get the equivalent R-value with a typical EPS foam board at R-4.0/inch, that same square footage would produce 9,881 kg CO₂e. This type of comparison was considered when making material selections along with other factors such as cost, ease of installation, and thermal values.

Although using Glavel would potentially reduce the embodied carbon, it was determined that it would actually increase the cooling load energy use. The project needed to gain some of the ground cooling to offset the internal heat gains and using Glavel would block that cooling. This is discussed in greater detail earlier in this report.

Structural Elements

Wood vs Steel and Concrete

The project team values the impact of materials selection on the embodied carbon and operational carbon of the building and has therefore chosen to construct a low-rise wood frame building. In general, wood-framed buildings tend to have lower embodied carbon than comparable steel and concrete buildings because wood stores carbon and requires less energy-intensive manufacturing, while steel and cement production generate significant greenhouse gas emissions and typically require larger quantities of high-carbon structural material. Limiting the use of steel and concrete can significantly reduce the embodied energy and carbon. To understand the actual carbon footprint of a wood versus steel and concrete building, an engineer would need to calculate the material requirements for each scenario.

BamCore

The team has also investigated the use of an engineered bamboo-wood hybrid structural panel called BamCore, fabricated of responsibly sourced timber bamboo as well as mass timber. While using this product may have reduced embodied carbon totals, the team chose not to use BamCore as the company had not proven financially stable at the time of decision-making in 2023. This product could be considered as an option for future projects if the manufacturer is able to increase its availability.

Exterior Walls

Continuous Exterior Insulation

The project team looked at Gutex (wood fiberboard), Timber HP (wood fiberboard), and polyiso rigid foam for the exterior insulation. In general, wood fiber insulation like Timber HP and Gutex actively store carbon. One can see the net emissions comparison of these materials in the chart to follow from BEAM.

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO ₂ e)
POLYISOCYANURATE FOAM BOARD						
	Polyisocyanurate / Wall Boards / R 6.5/inch / PIMA [Industry Avg US & CA]	29,751.0	ft ²	100%	☐	12,960
	Polyisocyanurate / Wall Boards / DuPont / Thermax / R 6.5/inch	29,751.0	ft ²	100%	☐	7,562
	Polyisocyanurate / Wall Boards / Hunter / Xci / R 6.5/inch	29,751.0	ft ²	100%	☐	7,182
CORK BOARD						
	Cork board insulation / Amorim / Isolamentos / R4/inch	29,751.0	ft ²	100%	☐	-21,612
WOOD FIBER BOARD						
	Wood fiber board / GUTEX / Multi-Therm / R 3.6/inch, 40, 60, 80, 100, 120, 140, 160, 180, 200 mm	29,751.0	ft ²	100%	☐	-13,725
	Wood fiber board / Steico / Special Dry / R 3.6/inch, 40, 120, 140, 160, 180, 200 mm	29,751.0	ft ²	100%	☐	-21,776
	Wood fiber board / Pavatex / Pavatherm / R 3.4/inch	29,751.0	ft ²	100%	☐	-26,163
	Wood fiber board / R 2.7/inch / NAFA [Industry Avg US & CA]	29,751.0	ft ²	100%	☒	-32,645

The team decided on all-in-one structural panels, Zip system R-sheathing from Huber, which includes polyiso rigid foam. Concerns about the actual availability of wood fiberboard insulation at the time of decision making mid-2024 led the team to consider the Zip-R product. The added benefits of an all-in-one insulation, sheathing, and air barrier product at a lower price point that could still meet energy usage goals made the final decision.

Cavity Insulation

The project team researched Ecotouch Pink for their Batt Insulation, which has better net emissions than the industry average, potentially saving around 2,000 kg CO₂e compared with the BEAM average. The company states that “Eco Touch is designed with the environment in mind with PureFiber® Technology, which contains more than 99% natural ingredients, and includes a minimum of 58% total recycled content—the highest certified recycled content available in the fiberglass industry. EcoTouch Insulation is GREENGUARD Children & Schools certified and is verified to be formaldehyde-free.”³ The team decided on Comfortbatt from Rockwool (which is GREENGUARD certified) due to various reasons, including availability

³ Owens Corning. “R-21 EcoTouch PINK FIBERGLAS Insulation with PureFiber Technology.” Accessed September 14, 2023. <https://insulation.owenscorning.com/professionals/insulation-products/products/r-21-fiberglass-insulation/>.

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO ₂ e)
FIBERGLASS BATT INSULATION						
	Fiberglass batt / CertainTeed / Sustainable Insulation / R 3.6/inch	29,751.0	ft ²	100%	☐	8,694
	Fiberglass batt / R 3.6/inch [BEAM Avg]	29,751.0	ft ²	100%	☐	6,209
	Fiberglass batt / Knauf / EcoBatt / R 3.6/inch	29,751.0	ft ²	100%	☐	5,642
	Fiberglass batt / Owens Corning / EcoTouch Pink batt and roll / R 3.6/inch	29,751.0	ft ²	100%	☒	4,291

Cladding

The project team looked at a combination of fiber cement lap siding and thin brick veneer for the cladding. Fiber cement products capture CO₂ from the environment over their operational lifetime. Hardie Plank, a siding product under consideration, reabsorbs an amount of CO₂ equivalent to over 27% of its cradle-to-gate carbon emissions⁴. The table to follow from the BEAM estimator shows a comparison between the embodied carbon of different fiber cement siding series.

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO ₂ e)	EMISSIONS (kg CO ₂ e)
FIBER CEMENT SIDING							
	Fiber Cement siding / Cembrit / Solid & Express / 8 mm (5/16")	19,040.6	ft ²	64%	☐	42,866	44,836
	Fiber Cement siding / Cembrit / Patina / 8 mm (5/16")	19,040.6	ft ²	64%	☒	17,818	19,788

Thin brick was explored as an option instead of standard full brick, which reduces the carbon footprint, since full brick is over three times the net emissions on average [BEAM]. The Westbricks Thin product is under consideration as it contains a high-performance pozzolan made from 100% recycled post-consumer glass.

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO ₂ e)
EXTERIOR WALL CLADDING						
COMMON BRICK						
	Brick, Clay / Interstate / Avg Face Brick / 3-5/8" x 2-3/4" x 7-5/8" (92 x 70 x 194 mm) incl. 3/8" mortar	7,140.2	ft ²	24%	☐	31,504
	Brick, Clay, Generic Modular / 3-5/8" x 2-3/4" x 7-5/8" incl. 3/8" mortar / Brick Industry Association / [Industry Avg US-Canada]	7,140.2	ft ²	24%	☐	31,342
	Brick, Cement / MidWest / Architectural Face Brick / 3-5/8" x 2-3/4" x 7-5/8" (92 x 70 x 194 mm) incl. 3/8" mortar	7,140.2	ft ²	24%	☐	24,015
	Brick, Calcium Silicate / Arriscraft / Contemporary Brick / 3-1/8" x 3-1/2" x any length, incl. mortar and ties	7,140.2	ft ²	24%	☐	19,993
NATURAL STONE MASONRY						
	Brick, Stone / Arriscraft / Natural Limestone Masonry / Weighted average product profile	3,570.1	ft ²	12%	☒	15,744
THIN FACE BRICK						
	Brick, Clay / Interstate / Avg Thin Face Brick / 3-9/16" x 5/8" x 11-5/8" (90 x 16 mm x 295) incl. 3/8" mortar	7,140.2	ft ²	24%	☒	9,135

The estimates from BEAM above show that using thin brick can easily reduce carbon emissions by two-thirds when compared to a traditional full depth brick.

⁴ "Sustainability Report." James Hardie, 2023.

Interior Walls

Cavity Insulation

The project team researched Thermafiber SAFB [sound attenuation fire blankets] Mineral Wool Insulation in the interior walls where a sound and/or fire rating is required. This product uses a minimum of 70% recycled content, as verified by ICC-ES Evaluation Report VAR-1025⁵. The team decided on Safe'N'Sound from Rockwool [which is GREENGUARD certified].

Drywall

For the drywall on the project, some manufacturers offer lower carbon alternatives than average that could be priced out. Since drywall would be used in many areas throughout the project, the savings could be significant. The BEAM estimator lists several options seen in the table to follow. It is interesting that a small change in a product series can have a much larger impact on the net emissions. The team is still analyzing what drywall product to select.

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO ₂ e)
CEILING FINISHES						
DRYWALL – 1/2"						
	Drywall 1/2" / Pabco / QuietRock / QuietRock 1/2"	46,036.0	ft ²	100%	☐	20,763
	Drywall 1/2" [BEAM Avg US & CA]	46,036.0	ft ²	100%	☒	10,416
	Drywall 1/2" / CertainTeed / M2Tech moisture resistant / 1/2" (12.7 mm)	46,036.0	ft ²	100%	☐	8,011
	Drywall 1/2" / CertainTeed / Easi-Lite / 1/2" (12.7 mm)	46,036.0	ft ²	100%	☐	6,537
	Drywall 1/2" / CertainTeed / AirRenew / 1/2" (12.7 mm)	46,036.0	ft ²	100%	☐	6,353

Floors

Floor Finish

The floor finish has a significant impact on the carbon emissions of the project. A standard LVT can use around 2.5 kg CO₂e/sf, which can add up to around 70,000 kg CO₂e at this scale, assuming it is used as the primary flooring in every unit. An alternative material like liquid-applied linoleum or laminated bamboo could reduce this down below 10,000 kg CO₂e, or even into the negatives with carbon storage.

⁵ "Thermafiber SAFB Mineral Wool Insulation." Owens Corning, April 2023.

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO ₂ e)	EMISSIONS (kg CO ₂ e)	STORAGE (kg CO ₂ e)
FLOORING								
LAMINATE FLOORING								
	Laminate flooring / Novalis / LVT	27,621.6	ft ²	80%	☒	69,542	69,542	0
RUBBER FLOORING								
	Rubber flooring / Resilient Floor Covering Institute / Includes tiles and rolls / 2mm [Industry Avg US & CA]	27,621.6	ft ²	80%	☐	40,032	40,032	0
	Rubber flooring / ECOsurfaces / 6mm	27,621.6	ft ²	80%	☐	15,140	15,140	0
HARDWOOD FLOORING								
	Hardwood flooring / CRAFT Artisan Wood Floors / Engineered / 5/8", SFI Certified	27,621.6	ft ²	80%	☐	39,518	39,518	0
	Hardwood flooring / mafi / Natural Hardwood Planks / 3/4", 3 ply laminated solid, oil pre-finished	27,621.6	ft ²	80%	☐	35,889	35,889	0
	Hardwood flooring / Action Floor Systems / 3/4" / FSC certified	27,621.6	ft ²	80%	☐	30,280	30,280	0
CERAMIC TILE FLOORING								
	Ceramic tile / Crossville / Porcelain / Standard grade	4,833.8	ft ²	14%	☒	10,733	10,733	0
	Ceramic tile / StonePeak / Porcelain / Porcelain, standard grade	4,833.8	ft ²	14%	☐	7,284	7,284	0
	Ceramic tile / porcelain, pressed, mosaic and quarry / TCNA [Industry Avg US & CA]	4,833.8	ft ²	14%	☐	5,901	5,901	0
CARPET								
	Carpet / EC3 database / 150 sample conservative average [US & CA]	27,621.6	ft ²	80%	☐	44,651	44,651	0
	Carpet / EC3 database / 150 sample average [US & CA]	27,621.6	ft ²	80%	☐	34,130	34,130	0
	Carpet / Interface / CQUEST BioX / 1.5 mm Modular tile carpet	27,621.6	ft ²	80%	☐	583	11,737	11,155
VINYL FLOORING								
	Vinyl flooring / Altro / Altro Lavencia Click /	27,621.6	ft ²	80%	☐	36,439	36,439	0
	Vinyl flooring / Altro / Altro Lavencia Plus /	27,621.6	ft ²	80%	☐	24,635	24,635	0
	Vinyl flooring / Gerflor / Creation 70 CLIC /	27,621.6	ft ²	80%	☐	16,013	16,013	0
	Vinyl flooring / Resilient Floor Covering Institute [Industry Avg US & CA]	27,621.6	ft ²	80%	☐	12,728	12,728	0
EARTHEN FLOORS								
	Adobe block floor / Avg of site made and factory made (Cyprus) / 4" (100 mm)	27,621.6	ft ²	80%	☐	2,558	2,558	0
	Earthen Floor / Cast-in-place / Clay, sand, and straw / 4" (100 mm) [US]	27,621.6	ft ²	80%	☐	1,694	8,853	7,160
CORK FLOORING								
	Cork flooring / Amorim / Revestimentos S.A. / Cork floating floor planks	27,621.6	ft ²	80%	☐	11,839	23,968	12,128
	Cork flooring / European Resilient Flooring Manufacturers' Institute [Industry Avg EU]	27,621.6	ft ²	80%	☐	-6,123	1,982	8,104
BAMBOO FLOORING								
	Laminated Bamboo flooring / MOSO / Bamboo Elite, Purebamboo / 15mm (9/16")	27,621.6	ft ²	80%	☐	-18,400	22,310	40,709
	Hard Bamboo flooring / MOSO / Bamboo Elite, Purebamboo / 13mm (1/2"), High Density	27,621.6	ft ²	80%	☐	-24,482	29,111	53,593
STONE PLASTIC COMPOSITE FLOORING								
	Polyester-limestone composite tile / Armstrong / BioBased Tile (BBT™) / 2.0 mm	27,621.6	ft ²	80%	☐	11,676	11,676	0
LINOLEUM FLOORING – LIQUID APPLIED								
	Liquid linoleum flooring / Duracryl Corques / Liquid Lino / 2.0 mm liquid applied	27,621.6	ft ²	80%	☐	4,843	10,213	5,370
LINOLEUM FLOORING – 2.5 MM SHEET								
	Linoleum flooring / Armstrong / Sheet style / 2.5 mm sheet style linoleum	27,621.6	ft ²	80%	☐	4,107	11,137	7,030
	Linoleum flooring / Forbo / Marmoleum / 2.5 mm sheet style linoleum	27,621.6	ft ²	80%	☐	4,011	10,317	6,306
	Linoleum flooring / 2.5 mm [BEAM Avg]	27,621.6	ft ²	80%	☐	2,725	9,408	6,683
	Linoleum flooring / Forbo / Marmoleum Striato / 2.5 mm sheet style linoleum	27,621.6	ft ²	80%	☐	58	6,771	6,713
LINOLEUM FLOORING – 4.0 MM SHEET								
	Linoleum flooring / Gerflor / DLW Linoleum / 4.0 mm sheet style linoleum	27,621.6	ft ²	80%	☐	-584	7,485	8,069

LVT flooring will likely be used in the units. Although the embodied carbon would be increased, LVT flooring can reduce maintenance needs due to tenant turnover in apartment style buildings like this. It's recommended that teams consider long term maintenance and replacement when making decisions as embodied carbon is only one factor.

Floor Underlayment

The project team analyzed three options for floor underlayment:

- 1" Gyp-Crete over 3/8" sound mat and 3/4" Advantech subfloor sheathing



- Gyp-Crete Installation, <https://maxxon.com/>

- Homasote 440 Soundbarrier over 3/4" Advantech subfloor sheathing



- Homasote 440 Soundbarrier, <https://www.homasote.com/products/440-soundbarrier/>

- Exacor underlayment over 3/4" Advantech subfloor sheathing.



- Exacor Underlayment, <https://www.huberwood.com/uploads/documents/technical/EX-Sales-Sheets-Underlayment-REV-7-25-22.pdf>

Homasote was found to be the most cost-effective option, followed by Exacor and the traditional gypcrete. Exacor is a newer product and does not yet have embodied carbon information, but the manufacturers are working on obtaining an LCA/EPD.

Non-energy Co-Benefits Research

The following represents the project research conducted with resources from the Early Stage Design Support program regarding non-energy co-benefits to occupants including health, safety, productivity, and comfort. This includes identifying the feasibility of additional co-benefits for residents such as enhanced filtration and those that may be an inherent side effect of Passive House Design such as enhanced acoustical performance. Material database resources such as the International Living Futures Institute Declare labels are being reviewed to avoid the use of harmful LBC Red List items, high VOC materials, and other unsafe materials.

General

Analysts predict that healthier buildings will be a primary consideration when selecting an apartment rental⁶, especially as the COVID-19 pandemic endures. One of the most compelling aspects of the Passive House approach in a multifamily building is health resilience. The air-tight envelope coupled with continuous filtered ventilation, controlled humidity, and low-VOC materials provides superior air quality and reduces virus transmission. Select common areas will incorporate high-speed fiber optic internet sufficient for remote work activities like videoconferencing. Common areas will incorporate antimicrobial LED lighting from Troy-based company, Vyv [formerly Vital Vio]; unlike ultraviolet [UV] light, Vyv's light technology does not damage human or animal tissue and has been shown to inactivate and kill viruses. The project location affords copious additional health benefits such as immediate access to fitness and recreation areas, hiking/biking infrastructure, and locally sourced foodstuffs.

Methodology

To assess the non-energy benefits for specific products, the project team reviewed each product's specifications to determine whether it met third party standards for health and wellness. Acceptable third-party standards were based on the Indoor airPlus Construction Specifications [V1, Rev. 04],⁷ which was developed by the U.S. Environmental Protection Agency [EPA] to recognize new homes equipped with a comprehensive set of indoor air quality [IAQ] features.

Several products were UL GREENGUARD certified, which tests for low chemical emissions to demonstrate compliance with standards and commitment to healthier indoor environments. Other products did not have certification but communicated a commitment to healthier products through chemical-specific declarations such as "formaldehyde-free." These products are less reliable in terms of indoor air quality than a fully certified product, since they may not be addressing all high VOC materials, but the findings were included for reference. The team also reviewed the safety data sheets for several products, which helped to bring an understanding of any harmful chemicals associated with them that were declared by the manufacturer. While databases such as Declare and the HPD

⁶ Cole, Regina. "These Are The Multifamily Trends Experts Are Predicting For 2022." Forbes. Accessed September 21, 2023. <https://www.forbes.com/sites/reginacole/2021/11/08/multifamily-trends-in-2022/>.

⁷ "Indoor airPLUS Construction Specifications Version 1 [Rev. 04]." EPA. February 2018. https://www.epa.gov/sites/default/files/2018-03/documents/indoor_airplus_construction_specifications.pdf.

Public Repository are helpful to connect the team with alternate products, many of the products already under consideration for other reasons were not listed, so the project team looked to other methods to assess toxicity. The project team will continue to investigate products for health and safety throughout the project and prioritize products that meet third party standards.

Indoor Air Quality, Occupant Comfort, Emission Reduction by Material

Footings & Slabs

The team considered insulating under the concrete slab using Glavel. According to the Glavel website, they were one of the first in the industry to use formaldehyde-free veil in the manufacturing of foam glass gravel as a base below the pre-fired recycled glass powder mixture⁸. Formaldehyde is a red-list material often used as a binding agent in the construction industry. Instead the team is using rigid insulation under slab.

Structural Elements

Through the Early Stage Design support, the team investigated the use of an engineered bamboo-wood hybrid structural panel called BamCore, fabricated of responsibly sourced timber bamboo as well as mass timber. Bamcore has the advantage of showing substantial savings in greenhouse gas (GHG) emissions associated with the energy used for heating and cooling when compared to a SIPS or traditional home⁹. However, the team chose not to use BamCore, as the company had not proven financially stable at the time of decision-making. More information on this is included in the Embodied Carbon Research section of this report.

Exterior Walls

Sheathing

The project team researched and intends to use Huber Engineered Woods Zip System Sheathing for use on exterior walls. The Zip System sheathing in 7/16" was evaluated and found to meet the Indoor Air Quality (IAQ) emission requirements of CA Section 01350, and, therefore, is considered by LEED to be a low-emitting material¹⁰.

⁸ Dworshak, Tor. "Formaldehyde Veil Announcement - Glavel," April 22, 2022. <https://www.glavel.com/veil-announcement/>, <https://www.glavel.com/veil-announcement/>.

⁹ Thorbecke, Mariko, and Jon Dettling. "Evaluation of the Environmental Benefits of the BamCore Prime Wall System." Quantis, April 2019. https://www.bamcore.com/_files/ugd/77318d_eb887995481345dfad7436d121a92c40.pdf?index=true.

¹⁰ Potter, Bob. "Indoor Air Quality Evaluation ZIP System® Sheathing." Huber Engineered Woods LLC, 2018.

Cavity Insulation

The project team researched Ecotouch Pink for their Batt Insulation. EcoTouch Insulation is GREENGUARD Children & Schools certified and is verified to be formaldehyde-free¹¹. The team ultimately decided to use Comfortbatt from Rockwool [which is GREENGUARD certified] for various reasons, including availability.

Party Walls

The project team researched Thermafiber SAFB [sound attenuation fire blankets] Mineral Wool Insulation in the interior walls where a sound and/or fire rating is required. The product is formaldehyde-free and GREENGUARD-certified [UL2818] for low chemical emissions¹².

The IBC 2015 specifies that walls, partitions, and floor/ceiling assemblies separating dwelling units or sleeping units from each other or from public or service areas shall have a sound transmission class of not less than 50 as the code minimum. Additionally, the ICC G2-2010 recommends a minimum STC of 55 for “acceptable” performance and STC 60 for “preferred” performance. By using products like Thermafiber SAFB in combination with double layers of Type ULX or ULIX at rated interior walls, the project team will achieve an STC of 50-58+ depending on assembly. The building envelope and compartmentalization air-sealing measures will lead to reduced noise from the exterior and adjacent units.

Cladding

The project team looked at a combination of fiber cement lap siding and thin brick veneer for the cladding. According to the safety data sheet for exterior fiber cement from James Hardie, fiber-cement boards in their intact state do not present a health hazard¹³. However, the dust generated from the boards by cutting, drilling, routing, sawing, crushing or otherwise abrading fiber cement, and when cleaning up, disposing of or moving the dust, can be harmful. Builders should follow the manufacturer’s recommendations to protect themselves during installation.

For the thin brick veneer, the project team investigated Westbricks thin brick products. Like fiber cement, most potential risks come from manufacturing and installation. According to the Westbricks safety data sheet, finished concrete masonry products are made with ingredients that are primarily nuisance dusts although some ingredients may contain crystalline silica. Some finished concrete masonry products may contain traces of residual materials from material enhancement additives such as plasticizers, accelerators, pigments or water repellants. The concentrations of trace materials are expected to be below reporting thresholds for the OSHA Hazard Communication Standard¹⁴.

¹² “Thermafiber® SAFB™ | Owens Corning Insulation | Owens Corning Insulation.” Accessed September 15, 2023. <https://www.owenscorning.com/en-us/insulation/products/thermafiber-safb-sound-attenuation-fire-blanket>.

¹³ “Safety Data Sheet for Exterior Fiber-Cement [Medium Density] HZ5 and HZ10 Products.” JamesHardie, April 11, 2022.

¹⁴ “Safety Data Sheet - Westbricks.” Westbrook Concrete Block, April 16, 2018. <https://westbricks.com/wp-content/uploads/2019/05/WCB-Westbricks-SDS.pdf>.

For the weather resistant barrier, the project team is currently considering GreenGuard Raindrop 3D Building Wrap. Despite the name GreenGuard, this product does not appear to be UL GREENGUARD certified. According to the safety data sheet, this building wrap appears relatively harmless with no hazardous ingredients by OSHA and WHMIS criteria¹⁵, but installers should still follow all manufacturer's guidelines.

Windows

The project team will be selecting Passive House certified windows and is currently considering using windows from Intus due to their performance and strong industry reputation. Passive House certified windows are thermally broken, airtight, and have low U-values, which help maintain better thermal and acoustic comfort inside the building. The final window selection will be determined based on the performance metric required in the WUFI energy model, availability, maintenance, reputation, and cost.

Floor Underlayment

Floor underlayments contribute significantly to acoustic separation between units, which is important for tenant comfort.

Roof

The project team researched Johns Manville JM Tapered Polyiso for insulation. According to the safe use instructions, this product is non-hazardous and chemically stable¹⁶.

¹⁵ "Woven Building Wrap - Safety Data Sheet." Greenguard. Accessed September 21, 2023.
<https://www.kingspan.com/content/dam/kingspan/kil/products/general---us-and-ca/kingspan-greenguard-woven-building-wrap-safety-data-sheet-en-us-ca.pdf>.

¹⁶ "Roofing Membranes, Cover Boards, Insulation, and Accessories." Johns Manville, August 1, 2022.
https://www.jm.com/content/dam/jm/global/en/MSDS/200000001890_US_EN.pdf.

Passive Survivability Research

Purpose

This section offers strategies to ensure and enhance passive survivability, such as how a building will maintain comfortable and safe thermal conditions and provide adequate, safe ventilation during an extended power outage or weather event. This section will highlight the importance of building resiliency, the Passive House strategy, and present associated case studies. Case study information and research summarized below was conducted by external parties and is included to provide relevant background and context.

Context

For many reasons, buildings are likely to become more vulnerable to extended power outages in the years and decades ahead. During a power cut in extreme heat or cold, everything hinges on a building's 'passive survivability': how long people can survive in it without power. Climate change is projected to cause a wide range of impacts, including more intense storms, sea level rise, drought, wildfire, and heat waves. Any of these disturbances can result in extended power outages. Other, non-climate-related disturbances, including earthquakes, tsunamis, and human actions, such as terrorism and cyber-terrorism, can also result in power outages and interruptions in heating fuel. For these reasons, there is growing interest in ensuring that our buildings will keep occupants safe and provide a reasonable level of functionality during extended power outages or loss of heating fuel. Utilizing Passive House design strategies for buildings can ensure that reasonably safe thermal conditions will be maintained passively in the event of lost power or heating fuel. Buildings can increase passive survivability by requiring features such as insulated windows, wall or roof insulation or built-in window shading to keep buildings cool.

Prioritizing the Thermal Enclosure

The most effective design strategy to address extreme temperature is a high-quality thermal enclosure. This means a combination of insulation, air sealing and appropriately sized windows to slow the flow of heat in or out of the building and maintain more stable indoor conditions. In colder climates, the value of a strongly insulated enclosure to maintain heat is already well recognized. Thick insulation and tight air sealing is the norm where very cold winters are common, and these more thermally resistive buildings are more resilient to extreme temperatures, both hot and cold.

Attention to the thermal enclosure is also critical in warmer and more temperate climates as less thermally resistant enclosures pose real risks during the uncertainty of the future climate. Energy code is considered from the perspective of conserving energy on average over a year. Today it makes more sense to consider the thermal qualities of our buildings from the perspective of resilience. A quality enclosure will always conserve more energy and provide greater comfort, but it also offers the ability to safely endure the coming heat domes and arctic blasts of the 21st century.

In addition to a strong thermal enclosure, orientation and shading are also effective design strategies for mitigating extreme temperature events, especially extreme heat. Solar heat gain will significantly

contribute to a building's indoor temperature and cooling load. If temperatures are above "normal" and the mechanical systems are unable to keep up, the addition of solar heat gain can push the indoor environment into unsafe conditions. Western exposure is often the culprit and designs that limit glazing on the western side of the building will remain cooler and reduce A/C loads compared to buildings with significant western-facing glass. The ability to shield windows with shades, curtains, or shutters is also an effective strategy to keep heat out of a building whenever it's warm, but especially during extreme heat events. Sol Apartments has fairly constrained site location and orientation; however selection of windows and shading considered the impact of solar orientation for resilience.

The Power of Passive Systems

These strategies – a quality enclosure, effective glazing area, operable windows, building orientation, and shading – are all traditional passive design strategies that have been used for thousands of years to keep buildings comfortable. More recently, they have been used to effectively conserve energy usage for both heating and cooling purposes. It's not surprising that the same collection of strategies can be depended on to keep occupants safe from extreme temperatures, and this remains the case whether or not the power goes out. Power outages pose an additional challenge during extreme weather events, and the building's design team needs to consider and design for the possibility that a power outage will be coupled with extreme temperatures. Snow and ice storms have been known to bring down power lines, and during the summer, extreme heat can lead to brown outs if everyone is running their A/C on high and the utility is unable to provide adequate electrical capacity. Backup power is a useful solution in these situations, but it should not be relied on alone. Generators or batteries are most effective when coupled with appreciated passive design strategies.

During the Texas ice storm of 2021, the temperature inside many homes quickly dropped below freezing when the power went out, resulting in frozen pipes and deaths from exposure. During the 2021 Portland heat wave, indoor temperatures spiked into the 100s in apartments that didn't have cooling systems or effective operable windows, also resulting in deaths. In both cases [reviewed in detail in the pages to follow], buildings with a quality thermal enclosure would have maintained indoor temperature at safe levels for longer periods of time. In the case of extreme heat, shades to block the daytime sun and windows that open to provide night cooling are simple and essential design strategies that can keep people safe. Specific case studies are included in the pages to follow to elaborate on these scenarios, projects are not affiliated with SCI and are examples of Passive House impact on project resiliency generally.

While the challenges of climate change are new, the most effective strategies have been around for as long as buildings have. To mitigate the risks of extreme temperatures when designing a building today, focus on passive systems. Choose a higher insulation value and more thermally resistant glazing than the code minimum recommends and pay extra attention to air sealing to keep infiltration to an absolute minimum. Additionally, avoid unnecessary western glazing, provide effective shades, and ensure that windows can open enough to effectively cool and ventilate passively. Cooling systems are necessary in most locations that have not required cooling in the past, and backup power for life safety systems continues to be necessary, but it's important not to mistake active systems for an architectural design solution. The buildings of the future that effectively protect the health, safety, and welfare of the public depend on the thoughtful application of age-old passive design strategies.

Case Study 1-The Farmers House, Austin, TX [2021 Texas Deep Freeze]

In February 2021, Texas experienced a 1-in-30-year cold weather event that resulted in sub-freezing temperatures well below average for over six days.¹⁷ Given the state's reliance on electric heating, the extreme cold weather drove winter electricity demand to unprecedented levels. The Farmer family had recently undertaken a Passive House retrofit of their home which allowed them to live comfortably during the Texas deep freeze. They turned their drafty Craftsman-style bungalow with no subfloor or insulation into something that would be more comfortable and sustainable.

The Farmer's incorporated the following Passive House standards:

- A 6,500 W solar panels on the roof's southern side
- Electric appliances
- Triple-pane windows
- R-30 [double the code] continuous insulation: the Farmers used Rockwool batts inside the house, and Zip System integrated sheathing [R-6] for the exterior.
- A heat pump water heater located in conditioned attic space
- An energy recovery ventilator [ERV]
- Improved air tightness. Because of Austin's climate zone, the codes for airtightness are low — five air changes per hour. "It's three changes in other parts of Texas and the rest of the country. In a Passive House, it's 0.6. Once you get down to 2 or 1, you get pretty big energy savings because you're not leaking air that's been heated or cooled."

How did the Farmer's Passive House compare to traditional homes during the 2021 Texas Winter Storm? Anecdotally, a Reddit thread compared three Austin homes, each of which lost power for more than 50 hours:¹⁸

- House 1: 800 SF, built in 1919 with single-pane windows, balloon framed, no insulation in the walls [owner had installed R-80 in the attic and R-20 in the floor]. It dropped below 40F in a matter of five hours after losing power and would hover around 31F.
- House 2: 2,300 SF, 2009 code-built house, standard spray foam insulation, no attic, sealed crawl space. It dropped below 40F in 48 hours. "They could float in the 50's with their gas burners at full blast".
- House 3 [Farmer's House]: 2,100 SF, built on Passive House 2018 pilot standard. It never dropped below 49F. The Farmers' monitor their home using AirThings, which keeps track of temperature; humidity; indoor air quality, including carbon dioxide levels, radon, VOCs, and particulate matter.

¹⁷ Freed, Stacey. "How A Texas Passive House Survived the 2021 Deep Freeze." Rise. July 1, 2021. <https://www.buildwithrise.com/stories/texas-passive-house-weathered-the-2021-storm>

¹⁸ Tsondu_Nordsin. "This is an excellent paper if you've not yet read it." Comment on Reddit post *A Framework for Considering Resilience in Envelope Design and Construction – RMI Modeling paper [8 Anecdotal Confirmation from Austin's Storms Last Week in Comments]*. 2021. <https://www.reddit.com/r/buildingscience/comments/lqmg5d/comment/goh5wv8/>.

Case Study 2- The Oaks Senior Living, Portland, OR [2021 Oregon Heat Wave]

In June 2021, Oregon experienced a record-breaking heat wave. The heat wave, known as a “heat dome”, trapped hot air over the region, causing several high temperature records to be shattered across the state.¹⁹ Portland saw a record high temperature of 116 degrees, breaking its own record for three days in a row. “The Oaks” zero-energy homes built to Passive House standards are part of the senior living community of Rose Villa in Portland. The Oaks maintained indoor temperatures below 80 °F throughout the heatwave, and were the only buildings on the Rose Villa campus that did not require supplemental cooling though some of the equipment used in the buildings was pushed to its limits. The ductless heat pump equipment satisfying the typically low cooling loads was only rated to 115°F. As a result, the capacity of the equipment was significantly reduced during these high temperatures.

The Oak’s incorporated the following Passive House standards:

- Tilt-turn triple pane windows and triple pane doors
- Heat recovery ventilation systems
- Mini-split heat pump
- Electric appliances
- Solar panel
- Super insulated airtight envelope

Climate Safe Housing – Strategy into Action

Most buildings are not designed to remain habitable during extended power outages. Heat loss through the building envelope determines how quickly interior temperatures will rise or fall. A high-performance envelope is especially valuable during a power outage because indoor temperatures change more slowly, increasing a building’s “passive survivability.”

Resilience Strategies:

The following is a list of strategies design and construction teams can implement to make homes more resilient. Integrating these features can create structures that are more comfortable during outages like the Farmer’s House and The Oaks.

- Reduce air leakage
 - Seal high leakage areas including elevator shafts, stairwells with permanently open louvers, dumbwaiters, window air conditioners, packaged terminal air conditioning units (PTACs), interior partitions, penetrations through the building envelope for pipes and conduits, band joists, cantilevered decks, doorways and windows. In rooftop elevator machine rooms, install an automatic louver that will stay open only when ventilation is needed.
 - Continuous membrane that prevents thermal bridges — spots on the facade where energy can leak through.

¹⁹ Samayoa, Monica. “Pacific Northwest heat wave was a freak, 10,000-year event, study finds.” OPB. September 28, 2022. <https://www.opb.org/article/2022/09/28/pacific-northwest-heat-wave-2021-oregon-summer-weather-heat-dome-climate-change/>.

- Thicker-than-normal insulation.
- Roof
 - Insulate the roof and ensure that all equipment located on the roof and attached to the building is properly anchored. To keep the roof cover intact during high winds, the flashing edge must be secured. Loose flashing will allow wind and rain to penetrate the roof cover, causing moisture damage and uplift pressure. A roof cover system can also peel away from the edge if the flashing fails. This is a common failure point which can cause partial or total failure of the system.
- Windows
 - Casement windows open on a hinge and provide a tight seal; double-hung windows open vertically and are usually less airtight.
 - Multiple layers of glass in sealed insulated glass units. Triple-glazed windows are preferable.
 - Low-emissivity coating. At minimum one low-e coating; two low-e coatings can boost performance further.
 - Low-conductivity gas fill. Argon is most common. Krypton is more expensive but performs better.
 - Durability. Look for AAMA Product Certification indicating that a window has passed tests for water, wind and air-tightness.
- Natural ventilation
 - Natural ventilation can greatly reduce the need for air conditioning. Ensure that windows in resident areas are operable. During a power outage when the HVAC system is out, a building can quickly overheat if its windows can't be used.
 - It often makes sense to close windows during the day, preventing warm outdoor air from entering the building. Windows or vents can be opened in the evening, after the sun has gone down and temperatures have dropped. This "night flushing" strategy costs much less than air conditioning.
 - Installing ceiling fans and providing residents with window fans can increase natural ventilation and cut energy use during warm months.
- Reduce "heat island" effect
 - Areas with more vegetation, bodies of water and lighter-colored surfaces are typically cooler.
 - Vegetation: Through a process called evapotranspiration, trees and other vegetation cool the ambient temperature by an average of 4 to 6 degrees F. Broadleaf trees provide shade in summer but allow sunlight through during winter.
 - Albedo refers to how light or dark a surface is. A light-colored surface will reflect heat; a dark surface will absorb it. Painting roofs white, installing light-colored facades and limiting blacktop surfaces will greatly reduce your building's heat absorption. Painting a rooftop white is a fast and highly cost-effective way to reduce energy use.
- Passive Cooling Systems
 - Shading, overhangs, cantilevers, low-lying operable windows that pull cool air into buildings, solar chimney that vents hot air out at the top.
 - Use of natural air flow, protecting glazing from direct solar gain and designing the enclosed space to allow for air movement.
 - Glazing ratio and solar orientation.

- Insulate pipes to prevent freezing
- Electric heat systems
- Backup power generator

Framework for Resilience in Building Envelope Design

The Rocky Mountain Institute developed a framework for considering resilience in building envelope design and construction. In simulating power outages during a cold snap [also relevant to heat waves], data was collected on how long a home can maintain thresholds of comfort and safety before reaching unsafe indoor air temperatures. House models analyzed were typical homes of the 1950's and 1980's, code compliant 2009 homes, net-zero energy ready and Passive House. The research highlights the opportunity to factor building envelope efficiency into resilience planning and home valuation.

Insights:

- Dangers of extreme cold stress on the human body can cause serious health conditions.

Cold Stress Scale

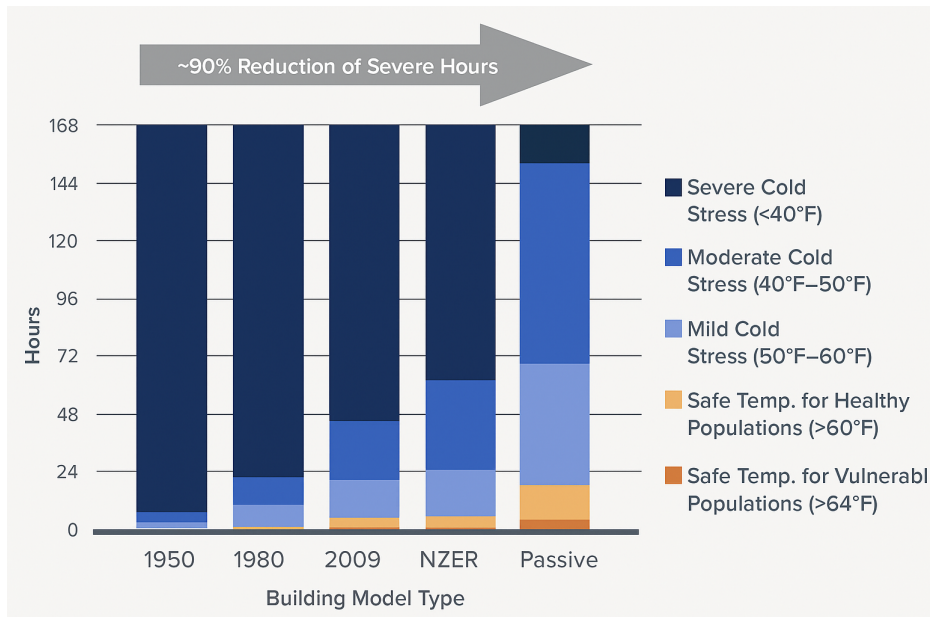
Minimum Safe Temperature for Vulnerable Populations	Minimum Safe Temperature for Healthy Populations	Mild Cold Stress for Healthy Populations	Moderate Cold Stress for Healthy Populations	Severe Cold Stress for Healthy Populations
>64	60	60–50	50–40	<40

- Homes with poorly built walls systems present the most risk.

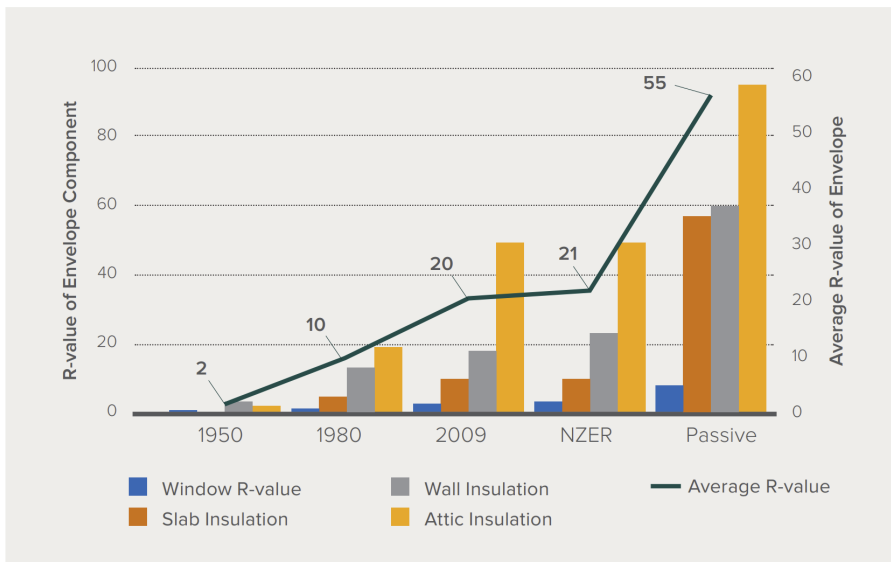
Time to Fall Below 40°F in a Power Outage

House model	Number of hours
Typical 1950s home	8
Typical 1980s home	23
Code-compliant 2009 home	45
Net-zero energy ready home	61
Passive House	152

- Passive House performance adds value. Homes with Passive House standard building envelopes and net-zero energy buildings maintained safe indoor temperatures for significantly longer than even code-compliant new buildings, lasting over six days before indoor air temperature dropped below 40 degrees.
- The Passive House building was able to buffer the cold temperatures for the longest period during an outage. There was a 90% reduction in severe cold stress hours between the 1950's model and the Passive House model. Passive House buildings performed over 7% better than the next most efficient building type, the net-zero ready building. The more we improve the insulation, thermal bridging, and air sealing of homes, the more hours of safety the home will provide, with dramatic differences from current code up to Passive House standards.



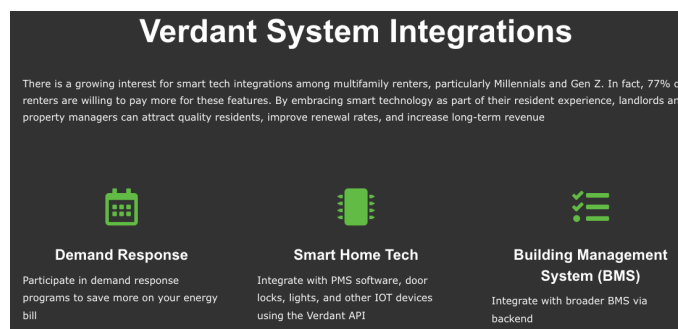
R-Values for the Various Envelope Components (left axis) and Average R-Value of the Envelope (right axis)



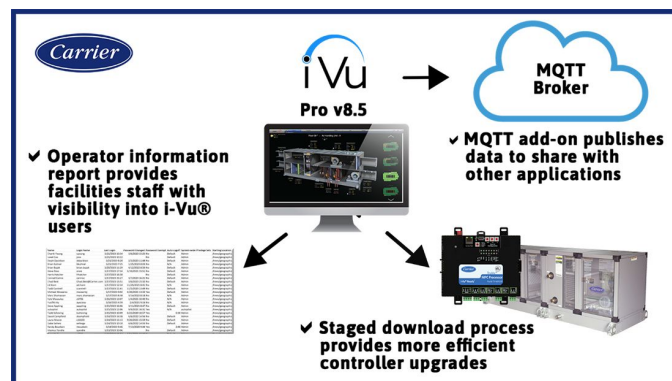
Building Controls

In-unit HVAC equipment will be controlled via Verdant VX4 smart thermostats. Verdant, originally developed for the hospitality industry as a means to control utility expenses, has continued to innovate on its products and broaden its horizons into multifamily with a focus on sustainability. Rosenblum has successfully deployed Verdant at all of its multifamily properties. Verdant allows building operators to incorporate an array of variable settings, including day/night adjustments and occupancy-based settings. VX4 thermostats integrate occupancy sensors and auxiliary bedroom sensors, which widen setpoints when residents are not in their apartment. The plan-view dashboard and real-time trend monitoring allow building engineers to assess all connected units quickly and intuitively, with color coding and highlighting units that are not performing within their defined parameters. This cloud-based software can be accessed remotely to allow for quick action 24/7.

Additionally, the new VX4 model can receive signals from the local utility to accommodate demand response events. The project is participating in the Building to Grid demand response pilot to test peak reduction strategies.



All centralized equipment- ERVs, DHW, Geothermal, & common area equipment- will be managed through the Carrier iVu Pro system. Similar to Verdant, iVu allows the building engineers to remotely and in real time monitor the function of all centralized and common building equipment. iVu reports out on a multitude of data points across the building operations systems, and its BACnet communications protocol can be adapted to integrate with most devices and APIs for third-party software like demand response devices. Going one step beyond Verdant, iVu also has predefined alarm settings that immediately notify building engineers of equipment failures or performance issues.



Conclusion

NYSERDA's Early-Stage Design Support funding provided our team with the opportunity to thoughtfully investigate design strategies to achieve a high-performing, sustainable, and healthy building for the Sol Apartments multifamily project. The proposed building is projected to use less energy than base code with a reduced carbon footprint. Passive House strategies such as increased airtightness, reduction of thermal bridges, and system efficiency improvements contribute to its high performance. The team assessed various approaches for minimizing thermal bridges using THERM modeling and enhancing air sealing through architectural detailing. An investigation into domestic hot water delivery systems was conducted, alongside an exploration of the applicability of drain water heat recovery. Research on embodied carbon was carried out to evaluate the carbon implications of design choices. Additionally, the study examined the non-energy co-benefits and passive survivability associated with high-performance design. The study concluded with an analysis of potential building control systems. The early-stage design research and analysis performed by our team will move the project closer to achieving its goal of an all-electric building that reduces embodied carbon and provides comfortable, resilient, and more affordable housing for its residents.

This report has outlined key early-stage design investigations that support the project's goals for energy efficiency, resilience, and sustainability. Notable findings include that the selected geothermal-fed domestic hot water system is projected to achieve a COP of 3.6, offering significant energy savings over typical electric resistance or even air-source systems. Thermal bridge modeling efforts demonstrated that minor detail changes reduced heating demand by over 11,000 kBtu per year. Air sealing strategies informed by redlined details and a newly developed field guide are expected to improve airtightness and construction quality, with lessons that are already informing other projects. Energy modeling revealed that Passive House design features such as superior insulation, high-performance glazing, and heat recovery ventilation could reduce site energy use by up to 25,000 kWh/year compared to code baseline scenarios. Embodied carbon research identified material swaps, such as fly ash concrete mixes and mineral wool insulation, that can meaningfully reduce lifecycle carbon emissions with minimal cost impacts. These findings, among others, are presented in detail to support replicability for future projects.

Appendix A: Tear Sheet Case Study



Owner: The Rosenblum Companies | Location: Troy, NY
NYSERDA Buildings of Excellence Early-Design and Demonstration Awardee

Sol Apartments [Troy, NY] is a 55,000 sq ft, four-story, all-electric, zero-emission multifamily development by The Rosenblum Companies that transforms a blighted and underutilized downtown lot at 1818 Fifth Avenue into contextually appropriate, high-performance, pedestrian- and public transit-friendly housing. The roughly \$22M new construction urban infill project consists of 71 predominantly studio apartments and communal amenities such as resident coworking space, conditioned indoor bicycle storage and a pet spa. Sol was designed to achieve Phius CORE certification and utilizes Passive House strategies including geothermal heat pumps for space conditioning and hot water, continuous-insulation, airtight envelope with triple-pane windows, energy-recovery ventilation, and a rooftop PV array that dramatically cut operational energy and improve indoor comfort.

NYSERDA Support

Sol was awarded NYSERDA Buildings of Excellence Demonstration Award as well as the Early-Stage Design Program to allow the project to research cutting edge decarbonization techniques, including the innovative Passive House and geothermal design, and produce a full air sealing guide. NYSERDA awards include:

- Buildings of Excellence Demonstration: \$1,000,000
- Early Design Support: \$250,000
- NY-Sun: TBD [\$0.25/W]



The key finding of the NYSERDA Early Stage Design Report can be found here:

<https://www.nyserdera.ny.gov/All-Programs/Multifamily-Buildings-of-Excellence/Early-Design-Support-Program>

Integrated Design Process

NYSERDA's early-stage design support was critical in enabling an integrated design process that brought together the developer, design team, and contractors at the earliest phases. This collaboration allowed for iterative energy modeling to evaluate envelope assemblies, window-to-wall ratios, and mechanical system options against performance and cost targets. The modeling was completed by Sustainable Comfort Passive House Consulting Team using WUFI Passive software guided by the Passive House program. The modeling informed the selection of a geothermal system, seamlessly integrated into the project to provide efficient heating, cooling, and domestic hot water without the carbon intensity of fossil fuels. In addition to modeling, drawing details were reviewed for compliance with the co-requisite programs including Energy Star Multifamily New Construction, DOE Zero Energy Ready Home, and EPA Indoor AirPLUS.

Technical Details

Walls:	2" R-12 Polyiso over 2x6 wood studs with R-21 batts
Windows:	Intus Supera Casement U-0.175 Kawneer Storefront U-0.30
Roof:	Flat roof polyiso R-41 assembly accounting for fasteners
Slab:	R-5 XPS insulation below 4" slab
Heating & Cooling:	Whalen Vertical Stack Ground Source Heat Pump Annual 3.19 COP
Ventilation:	Swegon Gold Semi-Central ERV's 82% Energy Recovery
Hot Water:	Water Source Heat Pump Watts by Lync Aegis W 350 with 1000 gallon storage
Appliance:	All electric with condensing dryers
Lighting	All LED Efficient Lighting
Solar PV	60 kW Rooftop Solar Array

Air Sealing Guide

Sustainable Comfort was able to develop a full air sealing guide to ensure the ambitious airtightness goals of Passive House can be achieved. This customized air sealing guide includes detailed diagrams, sequencing, and photographs. This hands-on resource provides trades with clear expectations and visual examples, reducing errors in the field and ensuring that the design intent translated into measurable performance.



Download the full Air Sealing Guide here:

<https://greenrater.com/airsealingguide>