NOBLE ST ADU PASSIVE DESIGN/BUILD PROJECT BOOST REPORT

July 14, 2023

prepared by Emu Passive

for Best Techs Contracting

BTC002

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SUMMARY

The results from the energy modeling of the Noble St ADU project show that the current design has potential to significantly reduce the need for heating and cooling compared to minimum compliance with the Building Energy Code, and it is likely to meet the target PHI efficiency goals.

Considering the combination of project design, site and climate conditions, and performance indicators including among others heating demand, cooling demand, PHI's Hygiene and Comfort criteria, the most promising scenarios resulting from this analysis are highlighted in Table 16.

Table 13c																		
VARIATION OVER BASELINE SITE ENERGY HEATING + COOLING			Building Air Tightness [B]															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
			Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3			
			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kWh/y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	0.0%	-2.9%	-6.8%	-9.7%	-2.9%	-5.8%	-8.7%	-12.6%	-2.9%	-5.8%	-9.7%	-13.6%	-2.9%	-5.8%	-9.7%	-12.6%
			1030	1000	960	930	1000	970	940	900	1000	970	930	890	1000	970	930	900
	1.1	PH R-values 'low'	-26.2%	-29.1%	-33.0%	-35.9%	-29.1%	-31.1%	-35.9%	-38.8%	-30.1%	-33.0%	-35.9%	-39.8%	-29.1%	-32.0%	-35.9%	-38.8%
			760	730	690	660	730	710	660	630	720	690	660	620	730	700	660	630
	1.2	PH R-values 'medium'	-35.0%	-38.8%	-41.7%	-45.6%	-37.9%	-40.8%	-44.7%	-47.6%	-38.8%	-41.7%	-45.6%	-48.5%	-37.9%	-40.8%	-44.7%	-47.6%
			670	630	600	560	640	610	570	540	630	600	560	530	640	610	570	540
	1.3	PH R-values 'high'	-38.8%	-42.7%	-45.6%	-49.5%	-41.7%	-44.7%	-48.5%	-51.5%	-41.7%	-45.6%	-48.5%	-52.4%	-41.7%	-44.7%	-47.6%	-51.5%
			630	590	560	520	600	570	530	500	600	560	530	490	600	570	540	500
			Assumed seasonal coefficients of performance of generator				Heating	3.0		[-]								
							Cooling	3.2		[-]								

Table 16 (repeated): Decision Matrix for the Noble St ADU project, highlighting the scenarios that produce the greater impact in building energy efficiency.

For the description of the scenarios, refer to Table 05.

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THE PASSIVE HOUSE SCIENCE

Overview Video About Passive House

For an overview video about the value of Passive House past energy efficiency, watch the 'Passive Pitch'.

Passive House - Reference

The international Passive House Institute (PHI) is widely recognized for leading the way worldwide in the scientific research around extremely energy efficient, healthy, and comfortable buildings. Its standards are based on a high quality thermal envelope for the building envelope, allowing for a reduction of heating/ cooling in the range of 75-95% compared to conventional buildings.

Images 01,a, 01b, 01c: PHI certification plaques for the Passive House building standard (left), and for the Low Energy Building (right).

In this report, the results from the building energy modeling were benchmarked against the Passive House building standard, as well as against the the PHI Low Energy Building standard as established by PHI. The process carried out with the review identifies impactful changes to the project design at an early stage - changes that will significantly improve comfort level and overall performance at a minimum cost.

	Passive House building standard	**Low Energy Building standard**	**EnerPHit Standard**
Applicable to Project Type	New Construction and Building Retrofits	New Construction	Building Retrofits
Heating Demand	≤ 4.75 kBTU/ft2y	≤ 9.5 kBTU/ft2y	by climate
Cooling Demand	≤ 4.75 kBTU/ft2y + dehumidification (by climate)	≤ 9.5 kBTU/ft2y + dehumidification (by climate)	by climate
Primary Energy Demand (Source Energy)	by PH efficiency class	by PH efficiency class	by climate/project
Air Tightness	≤ 0.6 ACH50	≤ 1.0 ACH50	≤ 1.0 ACH50
PHI's Hygiene Criterion (absence of mold/ condensation)	Required	Required	Required
PHI's Comfort Criterion (absence of radiant asymmentry)	Required	Required	Required

Table 01: Key certification requirements for the PHI Passive House building standard, and for the PHI Low Energy Building standard (other requirements and/or alternatives apply).

The low energy demand can be easily offset via renewable energy sources, making the Passive House standards a streamlined pathway to Net Zero.

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Energy Modeling

The whole building energy modeling of the Noble St ADU project was executed with the Passive House Planning Package (PHPP v9). PHPP is specifically designed for high performance buildings, making it considerably more accurate than other modeling softwares (e.g. HERS Rating softwares, or Manual J)

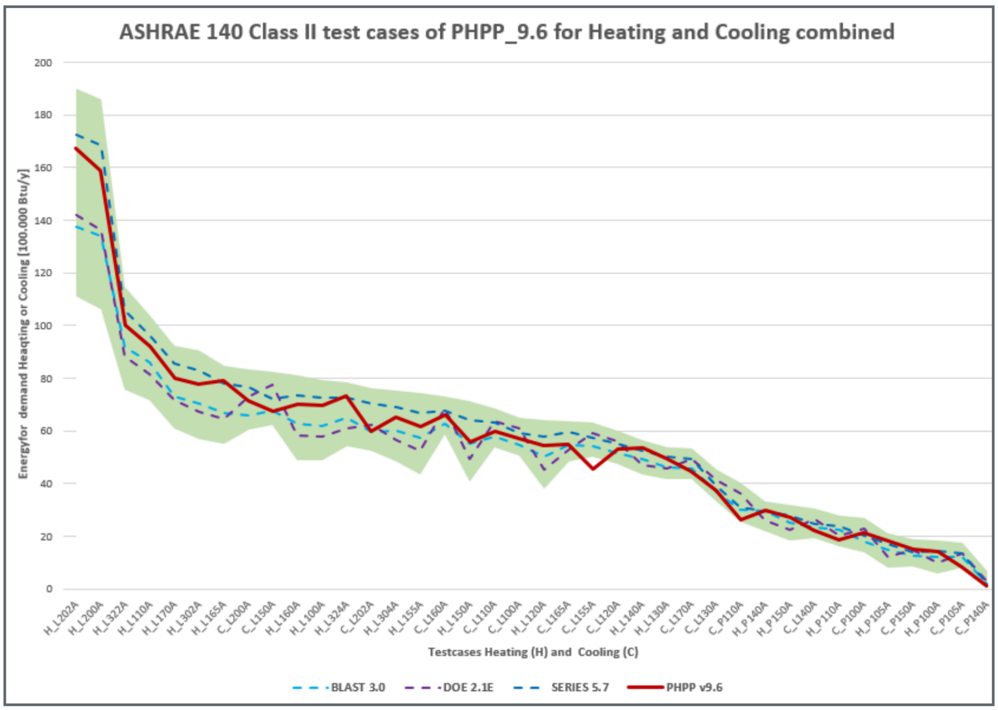

Image 02: Results of PHPP version 9.6 compared to the reference tools and confidence range in green, arranged according to magnitude of the results.

PHPP is validated according to ISO 13790 and ASHRAE Standard 140. Further information on PHPP ASHRAE Standard 140 can be found here.

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Building Quality Other Than Energy

The value provided by the Passive House (PH) approach expands beyond energy savings for heating and cooling. The following paragraphs provide a breakdown of additional benefits provided by implementing Passive House in the design and construction stages.

Durability and Air Tightness

Durability is one of the main goals of PH and it is achieved through robust building airtightness. Air can carry a significant amount of moisture into the building assemblies, leading to permanent moisture-driven damages.
The airtight layer of the assembly greatly reduces the amount of air exfiltrating through the building which prevents potential moisture-driven damages, as shown below.

Image 03 - Wood rot in a roof caused by air exfiltrating from the inside of the building to the outside. The moisture carried by the air caused permanent damage to the roof structure.

Absence of Mold/Condensation - PHI's Hygiene Criterion

The purpose of the Passive House Institute's (PHI) comfort criterion is to avoid mold and condensation on the internal surfaces of the building. This is achieved by the design of the construction assembly as well as by selecting climate-suitable building components that provide enough 'thermal protection' (via the temperature factor, fRsi value).

At this stage of the project, this translates to making climate-specific recommendations about product selection to prevent the issue.

Image 04a, 04b - Left: mold growing on the interior surfaces of walls and ceiling as consequence of a poorly planned building retrofit where the owners sealed up the building (by replacing the old windows) without providing a proper way to manage moisture. Note that mold can grow even if there is no condensation at all on the interior surfaces. Right: condensation forming on the inside of a window frame, due to the fact that the window is too 'thermally weak' for the local climate.

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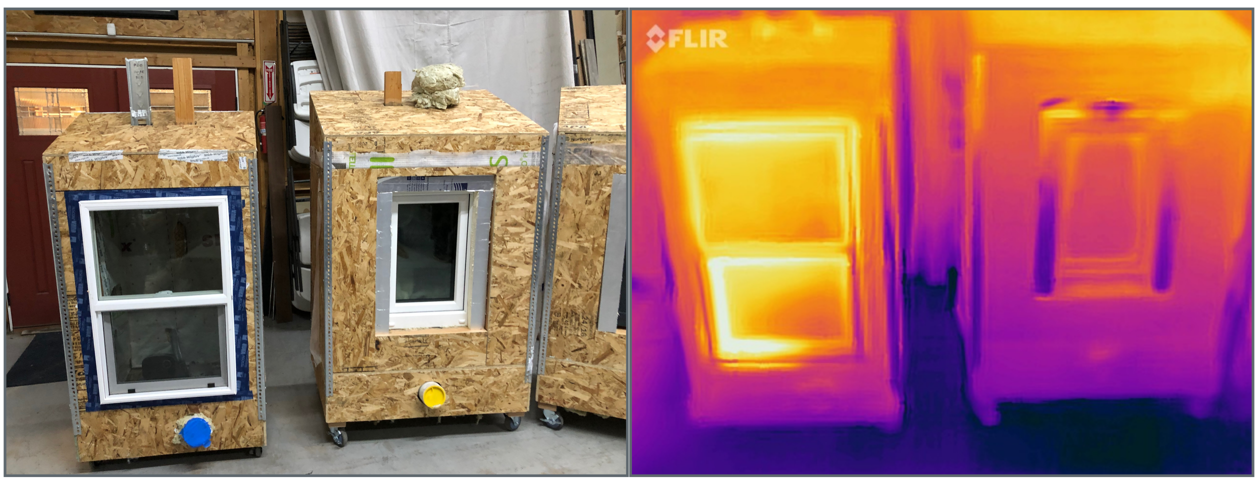
Thermal Comfort - PHI's Comfort Criterion

In order to guarantee high thermal comfort, all components of the building thermal envelope need to maintain an interior surface temperature 'close enough' to the operative room temperature. This parameter is addressed by making sure that the heat losses of windows, doors, and other transparent components are 'low enough' (by climate) to ensure a 'high enough' temperature on their interior surface. The maximum allowable temperature difference between the room average and the coldest surface is 7.6˚F, which is calculated by means of the installed thermal transmittance (U-value) of all transparent components. The proof of concept is illustrated in images 05a and 05b below.

For project certification, PHI requires the Comfort Criterion to be met by 100% of transparent components of the thermal envelope (with few exceptions.)



Images 05a, 05b - Left: a photo from Emu's Passive Pod Workshop, where a training Pod built according to the Passive standard (right hand side of the photo) is compared to a Pod built according to the 2018 Building Energy Code (left hand side in the photo). Right: infra-red image of the two Pods. The yellow/orange color shows areas with higher temperatures, corresponding to higher heat losses. The Red/purple areas correspond to areas of lower heat losses. In the Pod on the left (built according to the current Energy Code), the heat losses through the window are so high it literally glows. It is easy to understand that because of the high heat losses, the temperature on the inside of a non-Passive window are very low, leading to thermal discomfort.

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Indoor Air Quality

The combination of an airtight building envelope, and a continuous supply of filtered fresh air via a ventilation system, enables Passive House buildings to control the quality of air much better than in conventional buildings. This results in superior indoor air quality (IAQ).

Continuous ventilation via a fresh air ventilation system supplies building occupants with clean air, removes indoor pollutants, and filters out exterior pollutants.

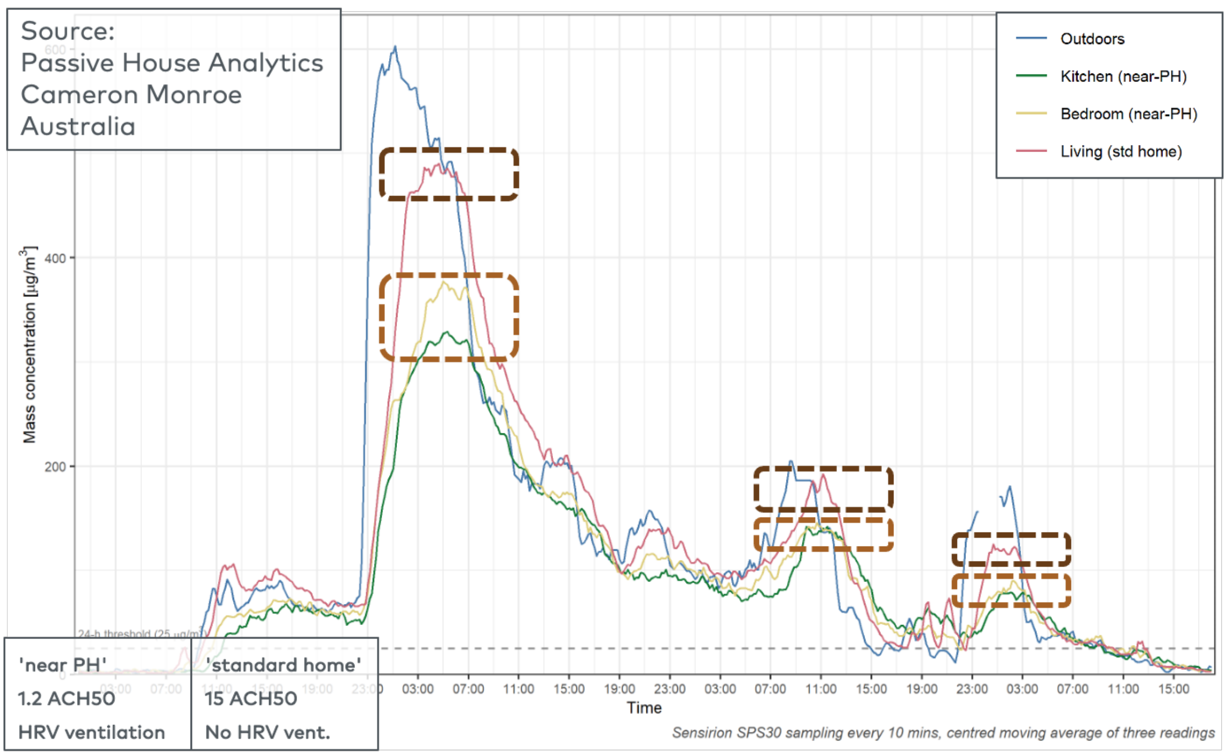

Image 06 - IAQ monitoring in Melbourne, Australia, comparing a conventional building (red line) with a building retrofitted with the Passive House method ('near PH', green and yellow lines). At the time of the monitoring, the outside air was polluted with wildfire smoke (resulting in high PM2.5 concentrations). The monitoring consistently showed that the combination of building air tightness, and continuous fresh air ventilation via an HRV system (more on this later) reduced the exposure of building occupants to pollution.

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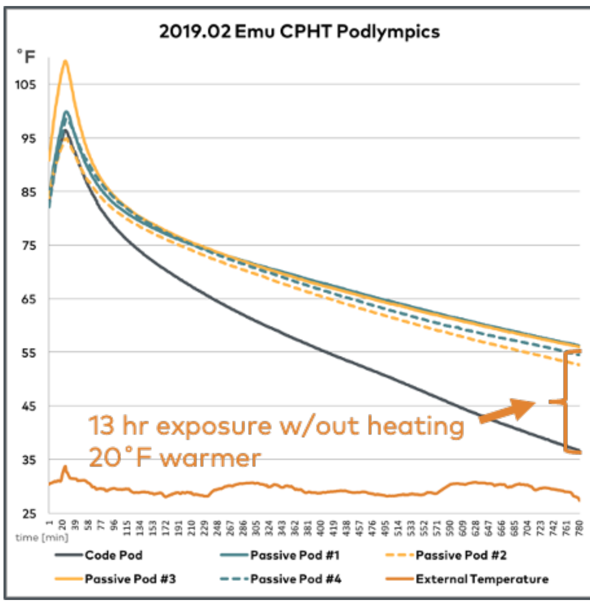
Thermal Resiliency - 'What happens if the power goes out'

Investing in a higher quality thermal envelope (i.e. higher R-values, better air tightness, quality windows/doors etc.) results in buildings having a higher thermal time constant. This means that interior of PH buildings can stay at a consistent temperature for long periods of time despite the exterior conditions. This thermal resiliency is substantially higher than conventional construction (e.g. buildings built to Code-minimum standards).

Thermally resilient buildings remain livable for longer periods of time, even if the power is out and the mechanical systems are not operating. The proof of concept is illustrated in images 07a and 07b below.



Images 07a, 07b: Resiliency test executed at the end of Emu's <u>Passive Pod Workshop</u>. The training Pods are heated up with the same amount of energy (250W for about 30 minutes). The heating is then turned off, and the Pods are left outside overnight (photo on right). The temperatures inside the Pods are recorded over night. The results from the February 2019 workshop are shown in the graph above (left). After 13 hours of exposure without heating, the four Passive Pods remained about 20°F warmer than the 'Code Pod' built in compliance with the 2018 Energy Code (IECC).

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PROJECT BOOST

Project Description

Project Name:	Noble St ADU
Project Type:	New Construction
City:	Orange, CA

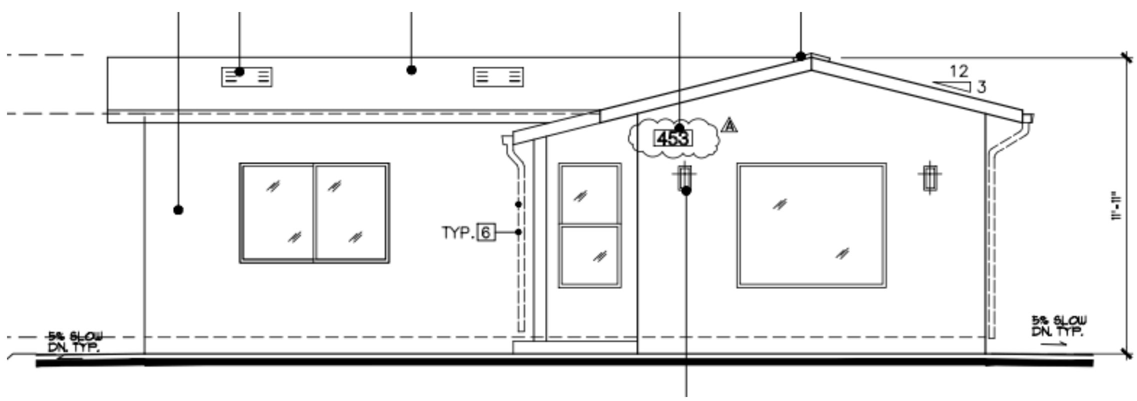

Image 08: Building elevation of the Noble St ADU project.

Location, Climate, And Modeling Conditions

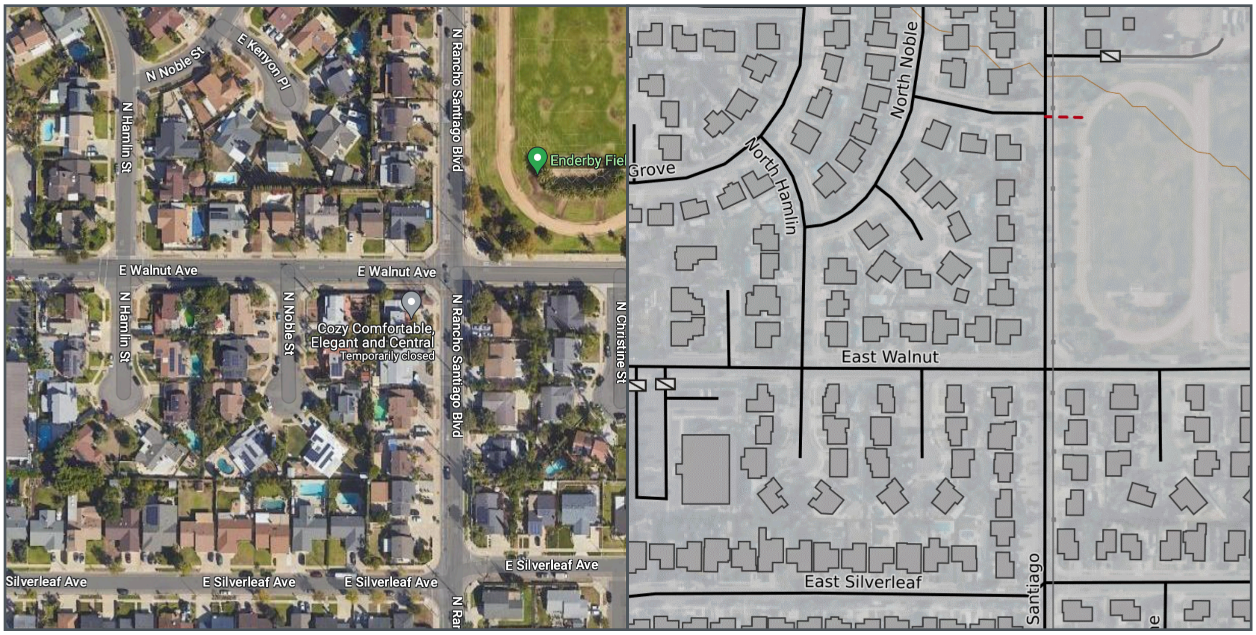

Image 09a, 09b: Satellite (left) and terrain topography (right).

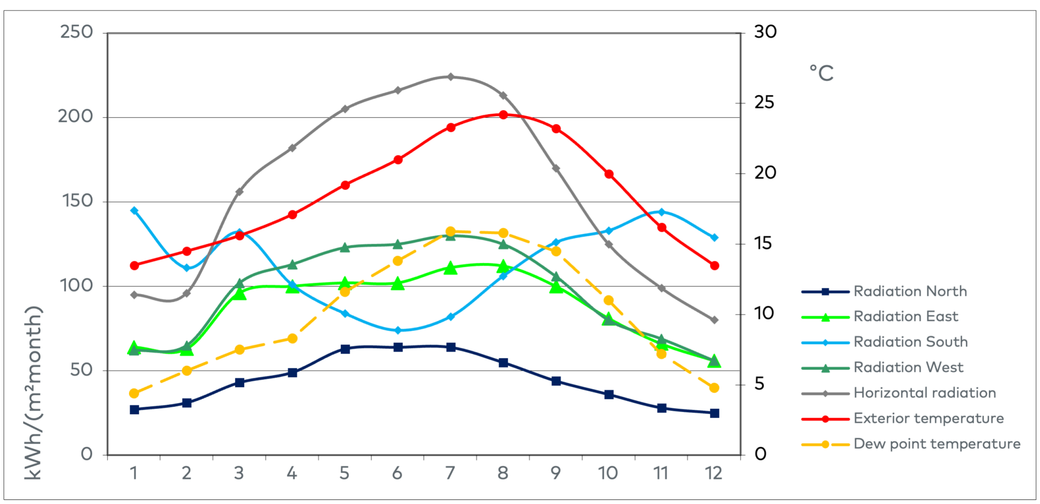

Image 10: Key parameters describing the climate of Orange, CA. For greater accuracy, the climate data set is adjusted to the elevation of the actual project site.

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Table 02				
SITE LOCATION AND CLIMATE				
Latitude	33.80		°	
Longitude	-117.80		°	
Site Elevation	95	m	312	ft
ASHRAE Climate Zone	3B	Warm, Dry		
PHI Climate Zone (site-specific)	Warm			
Site-Specific Reference Climate	Warm			
Exterior Temperature for PHI Hygiene Criterion	13.5	°C	56.3	°F
Exterior Temperature for PHI Comfort Criterion (1)	3.8	°C	38.8	°F
(1)	Average temperature of the 12 coldest consecutive hours of the year for the Project site location.			

Table 02: Summary of key parameters describing the climate of Orange, CA, and design conditions used in the PHPP building energy model.

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Site Layout

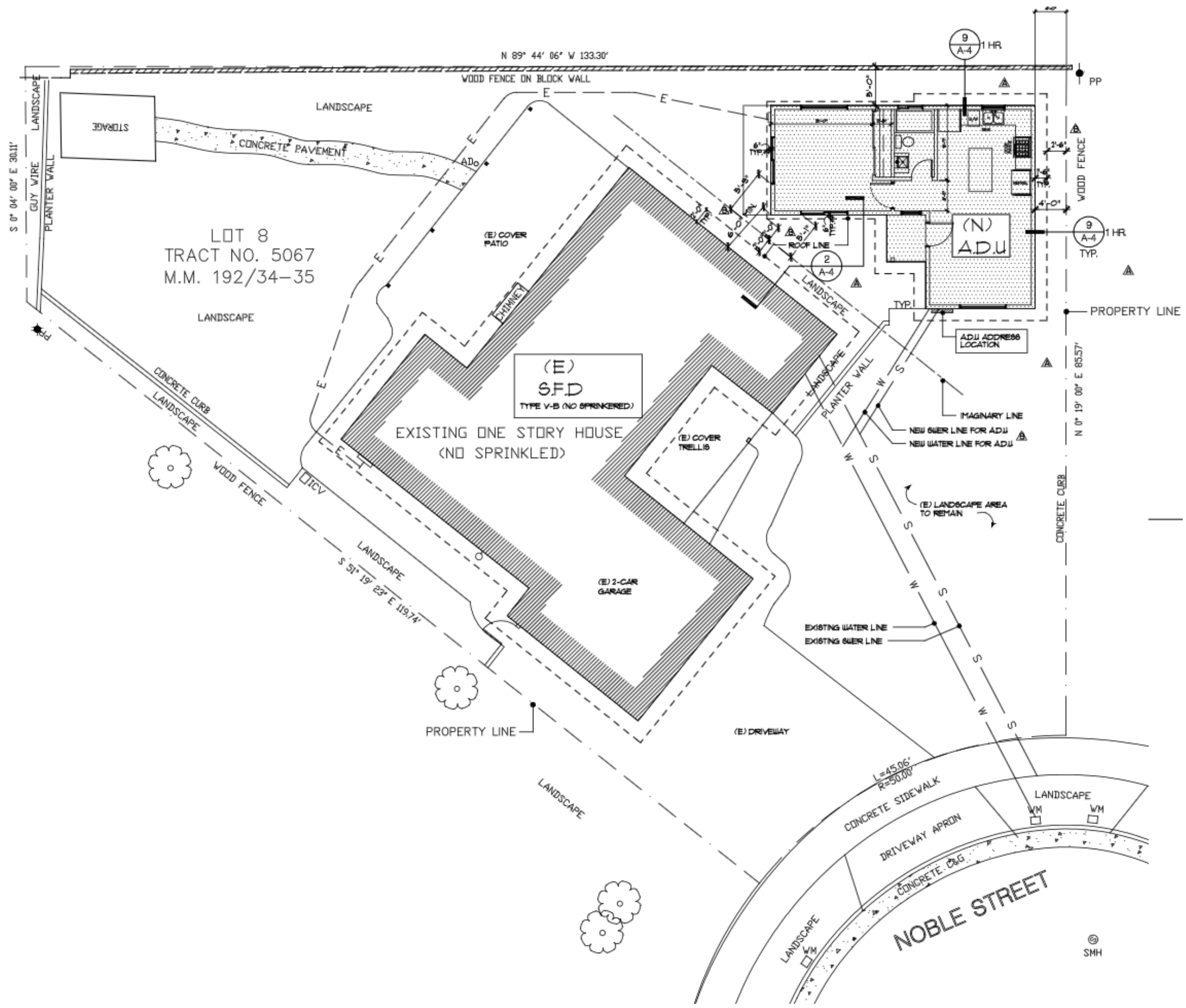


Image 11: Site plan of the Noble St ADU project, used to model the terrain and surrounding shading objects.

Architectural Design

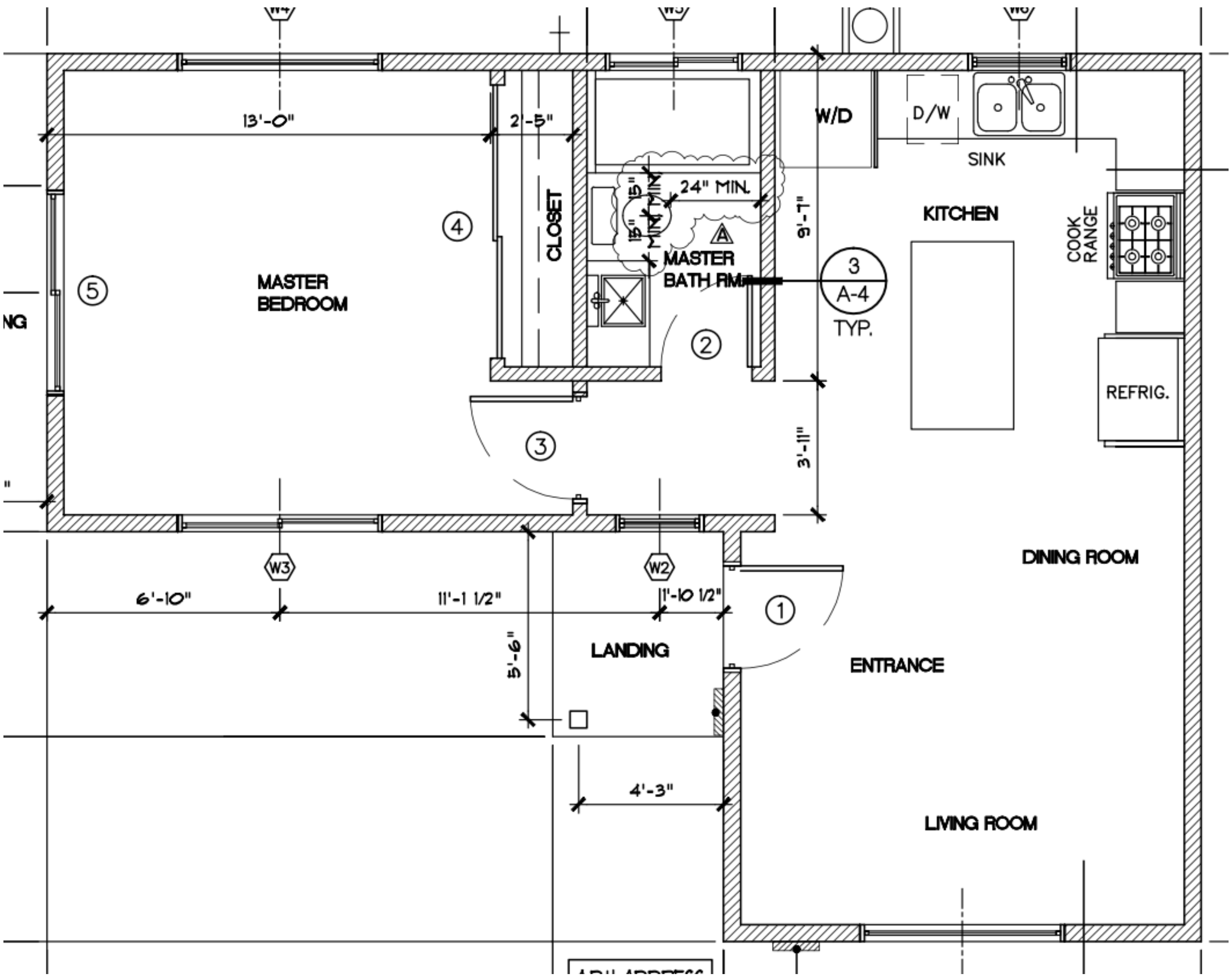


Image 12: Floor plan of the main level of the Noble St ADU project.

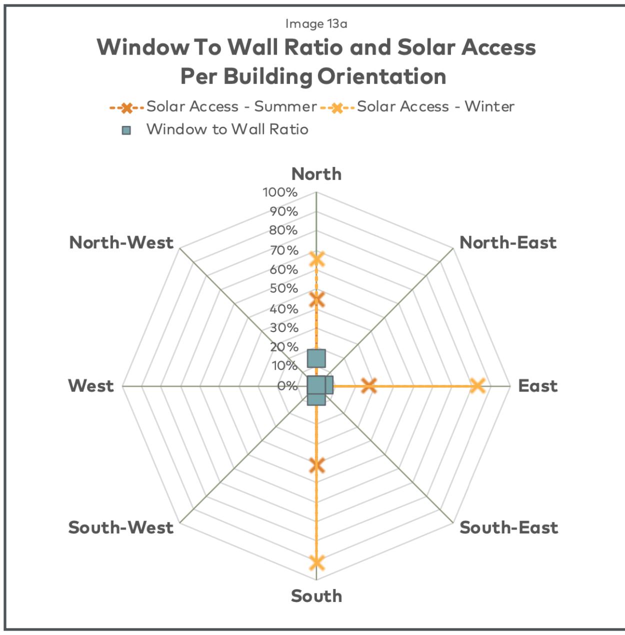
This Preliminary Review allows the project team to identify strengths and weaknesses in the project program and preliminary architectural design, in the context of the energy efficiency goals and the conditions of the local climate.

Good architectural design is critical to achieve the Passive House energy standard in a cost-effective manner.

The glazed components selected for the Noble St ADU project are important for a variety of reasons: aesthetics, views, project budget, energy performance, and Passive House Hygiene and Comfort Criteria.

Table 03a			
WINDOW/DOOR UNITS			
Description			**Comments**
Number of windows/door units (incl. skylights etc.)	2.8	/100 ft2 TFA	
Average unit size	9.8	ft2	

Table 03: Review of window/door unit breakdown for the Noble St ADU project.



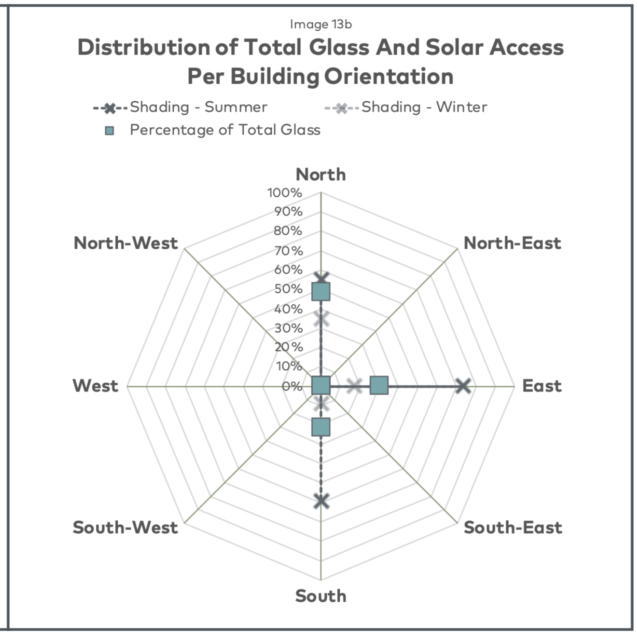


Image 13a and 13b: Window to wall ratio (left), and Distribution of gross glazed areas by orientation of envelope components to external ambient (i.e. not to ground) for the Project Baseline of the Noble St ADU project. In the graph, the labeling of the orientation refers to the broad direction (e.g. 'West', or 'South').

BUILDING MODELING

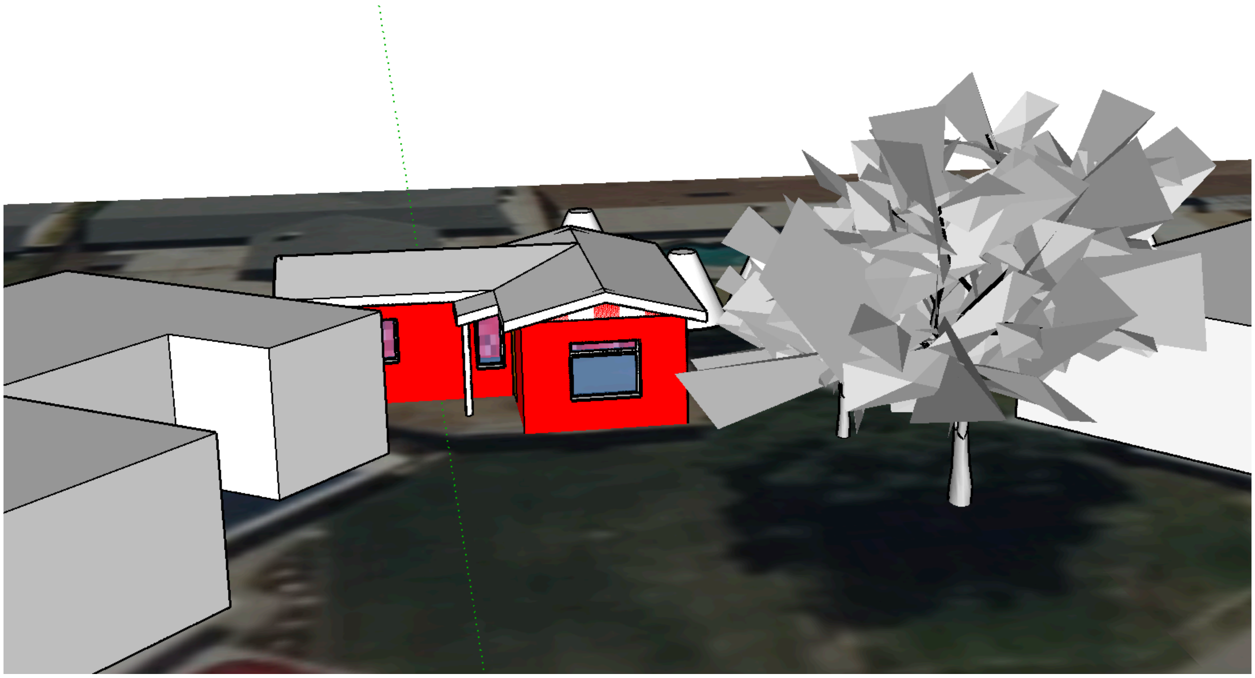


Image 14: The Noble St ADU project as modeled in DesignPH, before exporting the data to PHPP for further modeling.

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Pencil Rule

The pencil rule exercise identifies the recommended boundary of the building thermal envelope. The energy model developed for this report was based on the boundary identified through this exercise. To review the boundary at all project floors and building sections, please refer to Appendix A.

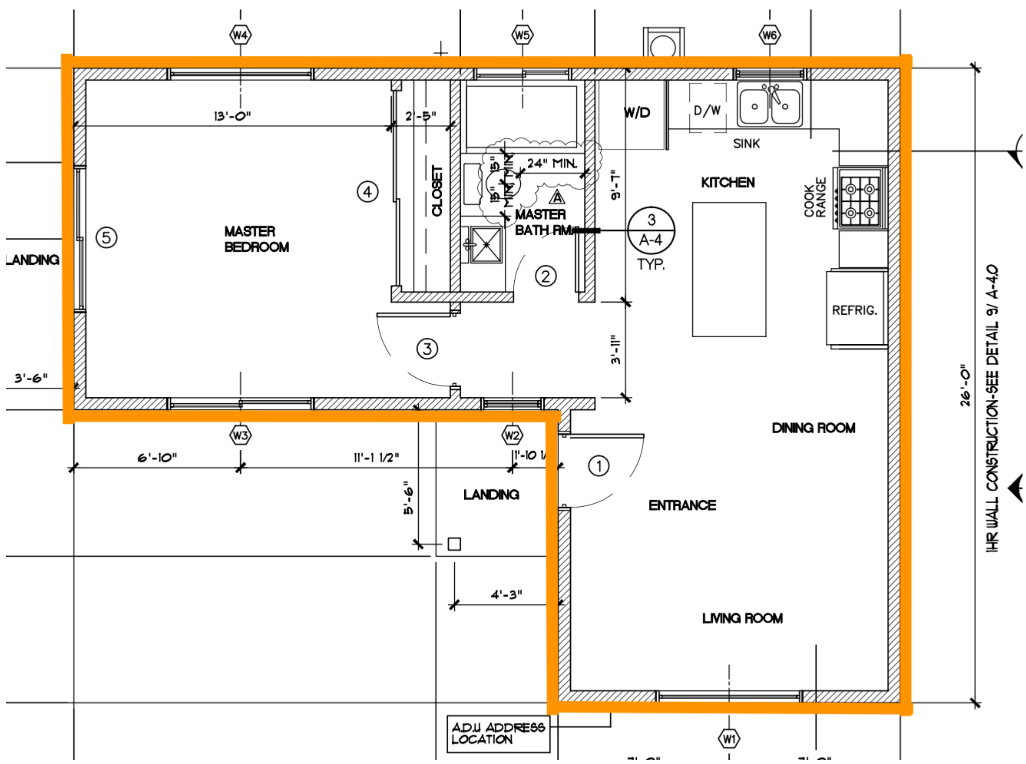

Image 15 - Boundary of the thermal envelope on the main floor of the Noble St ADU project.

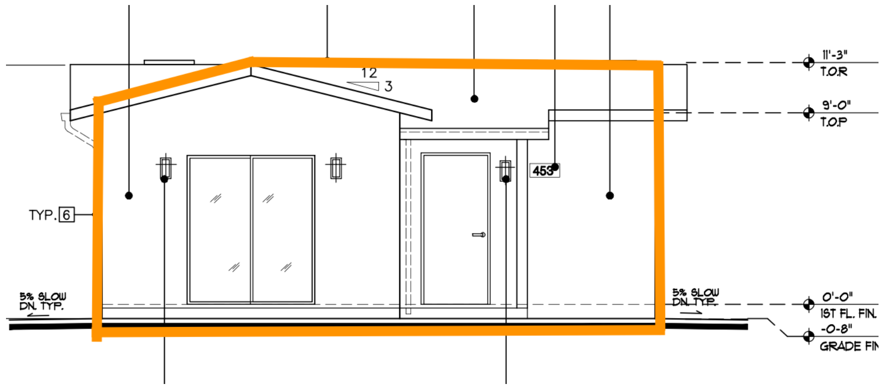

Image 16 - Boundary of the thermal envelope in building for the West Elevation

Building Thermal Envelope

Table 04				
BUILDING ENVELOPE				
Number of Units	1			
Occupancy	2			
Treated Floor Area	53.14	m2	572	ft2
Gross Envelope Area	246.91	m2	2657	ft2
Form Factor	4.6	ft2/ft2		
Building Net Volume (for BDT)	146	m3	5148	ft3
Ground Coupling Factor	0.26			

Table 04: Summary of key parameters of the energy model of the Noble St ADU project.

Form Factor

The form factor of a building envelope describes the compactness of its thermal envelope. It is calculated by dividing the 'skin' of the building (i.e. the gross surface area of the building envelope) by the treated floor area (TFA). The form factor It is a non-mandatory guideline for optimizing the architectural design towards Passive House goals.

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The smaller the form factor, i.e. the fewer square feet of building envelope per the building's TFA, the greater the energy efficiency.

For single family home buildings, it is ideal for the form factor to fall in the 2.5 to 3.5 range.

Thermal Mass

In general, the impact of thermal mass in the energy performance of residential buildings is often overrated (i.e. compared to non-residential projects). This has been covered in research projects carried out by PHI (see 'Passive House In South West Europe').

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Modeling Variables

#	Variable	Baseline	Variation #1	Variation #2	Variation #3
#1	**R-values Targeting**	R-values By Code minimum	PH R-values 'low'	PH R-values 'medium'	PH R-values 'high'
#2	**Thermal Quality Of Windows/Doors - Climate Zone 1-3**	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
#3	**Building Air Tightness [B]**	Code minimum, ACH50 = 3.0	ACH50 = 2.0	ACH50 = 1.0	ACH50 = 0.6
Code	latest energy code (e.g. 2021 IECC), for the local climate				
PH	PH: Passive House standard, for the local climate				
EnerPHit	Energy standard developed by the international Passive House Institute for retrofits, including step-by-step remodels				
ACH50	air changes per hour at 50Pa, i.e. anticipated level of air tightness of the building				
SHGC	solar heat gains coefficient, i.e. amount of solar gains allowed into the building by the glass dependin on its coating				
N, E, S, W	North, East, South, West (building elevations)				
phC, phB, phA	Passive House grading of thermal quality for the frames of windows and doors				
skinny' 3-pane	Triple pane glass unit for windows/doors having an overall thickness of about 1.0"				
beefy' 2-pane	Double pane glass unit for windows/doors having an overall thickness of about 0.9"				
beefy' 3-pane	Triple pane glass unit for windows/doors having an overall thickness of about 1.8"				
PH glass specs	Low-e coating, and pocket fill consitign of insulative gas (typically 90% Argon)				

Table 05: Variables considered in the energy modeling of this Preliminary Passive House Review.

The Variables considered for this Preliminary Passive House Review are listed in Table 05. These scenarios are compared with one another later in this report, and benchmarked with the target PHI energy goals identified for the project.

Project Baseline

Each Variable listed in Table 05 includes a baseline, numbered as '0' (zero). The Project Baseline is therefore the combination of the baseline scenario of each Variable (i.e. 1.0 + 2.0 + 3.0).

Envelope Assemblies And R-values

Table 06					
ASSEMBLIES AND REFERENCE R-VALUES					
Assembly		2021 IECC R-values	Passive House R-values 'low'	Passive House R-values 'medium'	Passive House R-values 'high'
01	Slab on Grade / Floor of Cond. Crawl Space	10	10	15	20
02	Wall to Exterior	20	25	30	35
03	Ceiling / Roof	43	45	60	65

Table 06: Incremental steps in assembly R-values considered in the modeling.

For the energy modeling of the Noble St ADU project, the baseline thermal performance of the building assemblies were agreed on by Best Techs Contracting and were chosen to reflect typical assemblies for the project's location. Table 06 summarizes the R-values of the main assemblies used in the energy model, and the incremental steps of insulation considered for each (if applicable).

Note that the R-values listed in Table 06 are calculated according to the conventional simplified method prescribed by Building Energy Code (IECC). In the PHPP energy model, the assemblies are actually modeled with a greater degree of accuracy, which is required for Passive House projects.

For examples of typical wall assemblies that meet the R-values illustrated in Table 06, please review Appendix B.

Windows, Doors, Skylights, and Other Glazed Components

At this preliminary stage, windows and transparent components are modeled by the performance grade of their frames. This allows the project team to consider a range of products that would yield similar results, and proceed with pricing before the energy model is finalized.

Frame Performance

Making the right decision in terms of performance of the frame of windows/ doors is just as important as the selecting double or triple pane glass for the project. Frame performance is rated by efficiency classes (phA, phB, phC, with A, B, and C being grades just like in school).

The performance grades for windows/door frames included in the modeling of the Noble St ADU project are listed in Table 07a. Appendix C provides a list of products available in the North American market, organized by the performance grade of the frames.

Note: throughout the Report, and in Appendix C, the grading of the frames refers to the operable window frame. It is assumed that fixed windows do perform better than, and doors perform not as well as, the operable window of the same product series.

Table 07a	
PERFORMANCE GRADES OF WINDOWS / DOORS	
Step	**Frame Grade**
.0	2021 IECC CZ 3-8 Windows/ Doors
.1	2021 IECC CZ 3-8 Windows/ Doors
.2	phC-Grade Windows/ Doors
.3	phC-Grade Windows/ Doors
Note	The performance grading of windows/doors refers to the thermal performance of the frames (i.e. frame width, frame U-value, glass edge thermal bridge, and air leakage). Frame grading listed refers to the operable windows. Fixed windows are assumed to perform better. Doors may be critical in that they may not perform as well

Table 07a: Frame grades modeled for the Noble St ADU project. Passive house frame grades refer to the PHI energy efficiency classes for transparent components.

Table 07c					
U-VALUES OF SOLID DOORS / HATCHES					
Door/ Access Hatch Type		2021 IECC R-values	Passive House R-values 'low'	Passive House R-values 'medium'	Passive House R-values 'high'
01	Exterior Door (solid)	0.40	0.29	0.20	0.17
02					

Table 07c: Thermal performance of the solid doors used for the energy model of the Noble St ADU project. The glazed doors follow the same requirements as the windows.

Table 07b

TYPES OF GLASS MODELED

#	Description	Heat Losses		Passive Solar Gains
		EN 673	NFRC	
		U-value (Ug) [BTU/ h*ft2*°F]	U-factor (Ucog) [BTU/ h*ft2*°F]	SHGC_c (g-value) [-]
.0	2021 IECC CZ 3-8 Glass, Low Gains	0.218	0.229	0.27
.1	Skinny' 3-pane Glass, PH specs (1.0" O/A, 2x low-e, gas fill), Low Gains	0.169	0.165	0.22
.2	Beefy' 2-pane Glass, PH specs (0.9" O/A, 1x low-e, gas fill), Low Gains	0.176	0.232	0.27
.3	Beefy' 3-pane Glass, PH specs (1.8" O/A, 2x low-e, gas fill), Low Gains	0.088	0.113	0.22
.4				
.5				
.6				
.7				
.8				
.9				
.10				
.11				
SHGC_c	Center of glass solar heat gains coefficient			
O/A	Overall thickness of the glass unit			

Table 07b: Specs of the different types of glass considered in the model.

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The combination of frame grade, type of glass units (IGUs), and installation details in the project assembly, determines the as-installed performance of the transparent components (windows, doors, skylights etc.). This performance is assessed via the installed Uw value (Uw_inst) of the transparent components.

The Uw_inst value and the local climate data are used to calculate the internal surface temperature of the transparent components. the internal surface temperature of transparent components corresponds to whether PHI's comfort criterion is met.

Table 08 shows the installed Uw values (Uw_inst) for the transparent components considered for the Noble St ADU project, and the resulting internal temperature in the climate of Orange, CA.

The same table shows the percentage of window/door units that meet the PHI Comfort Criterion under current design conditions, depending on the combination of frame grade and glass unit. Note that the low-e coatings used to adjust the passive solar gains of the glass units have an impact on the the thermal transmittance as well, as shown in Table 07b. For this reason, the selection of the glass solar control strategy has an impact on the Comfort Criterion too.

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Condensation Avoidance

As illustrated earlier in this Report, PHI's Hygiene Criterion has been developed with the primary purpose of preventing mold/condensation on the interior surfaces of building components.

For windows, doors, and other glazed components, this translates to achieving glass edge temperatures high enough to avoid condensation.

In practical terms, this means:

- require warm edge spacers (plastic, no metal) for all exterior windows, doors, skylights, and other glazed components
- operate the ERV/HRV continuously per the airflow rates specified in Appendix D attached to this Report.

With regards to divided lights (if applicable):

- in most climates actual divided lights cause a considerable thermal bridge, compromising the performance of windows/doors
- simulated divided lights (SDL) are cheaper and perform considerably better than actual divided lights.
- for SDLs, the muntin bars inserted inside the glass unit (i.e. the bars placed in between the glass panes) need to be plastic (i.e. not metal), in order to avoid thermal bridging.

Thermal Comfort

The perception of comfort is driven by even surface temperatures within a space: poorly performing windows and doors impact this negatively. Table 08 lists the windows/doors considered, and their impact on thermal comfort.

Further modeling is needed for the final verification of the Comfort Criterion. This needs to include the actual frame values of the products selected for the project, as well as how the frames are installed within the wall assembly.

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Table 08				
THERMAL COMFORT ANALYSIS				
Average Room Temperature	68.0			°F
Exterior Temperature for PHI Comfort Criterion (1)	38.8			°F
Max Temperature Difference To Avoind Discomfort	-7.6			°F
Noble St ADU Thermal Comfort Analysis				
	.0	**.1**	**.2**	**.3**
Frame Grade	2021 IECC CZ 3-8 Windows/ Doors	2021 IECC CZ 3-8 Windows/ Doors	phC-Grade Windows/ Doors	phC-Grade Windows/ Doors
Glass Unit	2021 IECC CZ 3-8 Glass	Skinny 3-pane Glass (1.0" OAT, 2x low-e, gas fill)	PH 2-pane Glass (0.9" OAT, 1x low-e, gas fill)	PH 3-pane Glass (1.8" OAT, 2x low-e, gas fill)
Performance As Installed (Uw_inst, project weighted average) [BTU/h*ft2*°F]	0.329	0.292	0.224	0.176
Resulting Average Temperature Over Interior Surface Of Windows/Doors	60.9	61.7	63.2	64.2
Window-Room Tempertature Difference	-7.1	-6.3	-4.8	-3.8
Number Of Window/Door Units Passing PHI's Comfort Criterion Requirements	100.0%	100.0%	100.0%	100.0%
(1)	Average temperature of the 12 coldest consecutive hours of the year for the Project site location.			

Table 08: Preliminary verification of the Comfort Criterion for the windows and transparent components of the Noble St ADU project. The percentage refers to the number of units (windows, doors, skylights, curtain wall units) that preliminarily meet the Comfort Criterion under current conditions.

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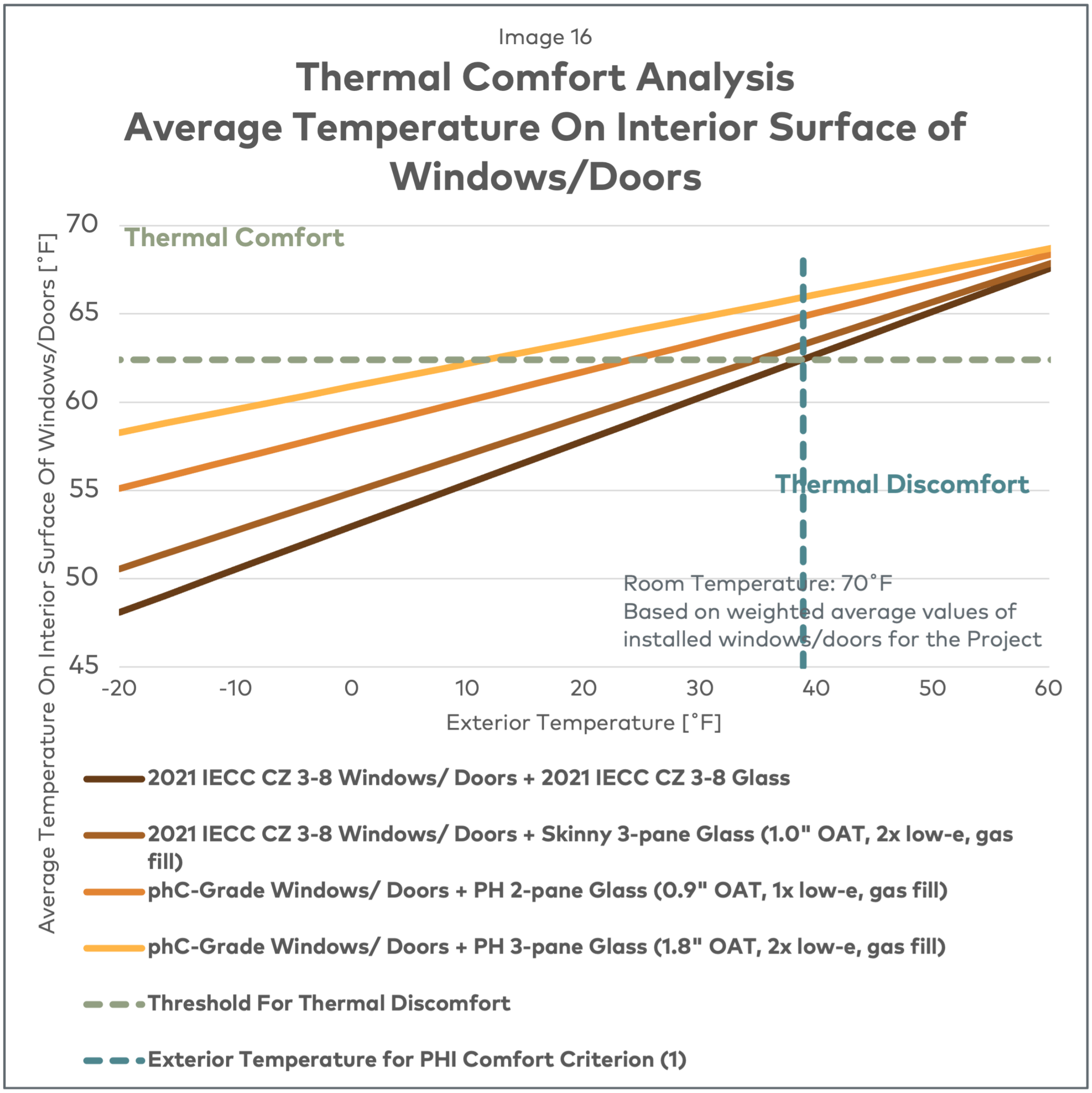

Image 16: Relationship between thermal quality of windows/doors for Noble St ADU, the climate of Orange, CA, and the perception of thermal comfort.

Passive Solar Gains vs Heat Losses

The physical properties of the insulated glass units (IGUs) included in the energy model of the Noble St ADU project are summarized in Table 07b. The resulting energy balance is shown in Image 17 comparing heat losses vs passive solar gains by building orientation.

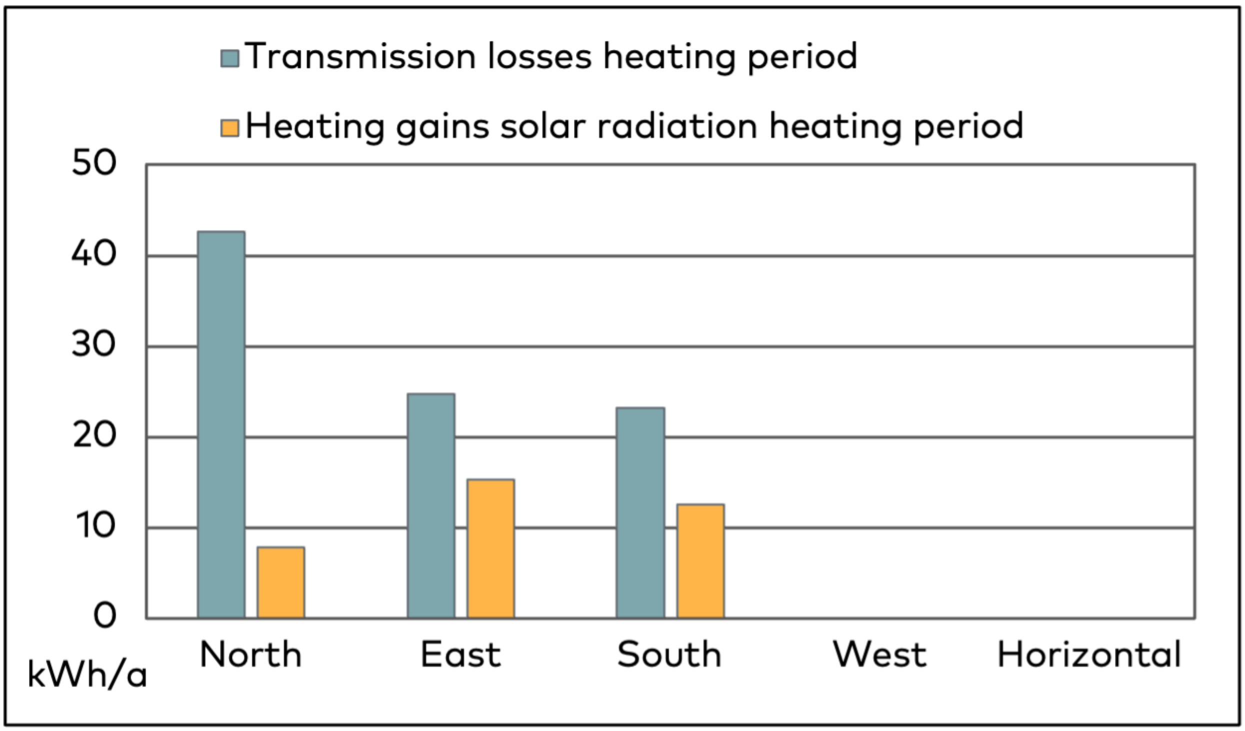

Image 17: Balance of heat losses and solar gains for the transparent components of the Noble St ADU by building orientation.

Shading

A proper shading strategy is key for the success of a project, both in terms of building energy performance as well as thermal comfort.

The first level of ‘shading’, is provided by the Solar Heat Gian Coefficient (SHGC) of the glass units considered. For the purposes of this review the SGHC of each glass unit are labeled as low medium and high and are listed in Table 07b. The selection of the level of solar gains provided by the glass units via their low-e coating constitutes a permanent (i.e. non-adjustable) type of shading that influences both the seasonal performance and the thermal comfort of the building.

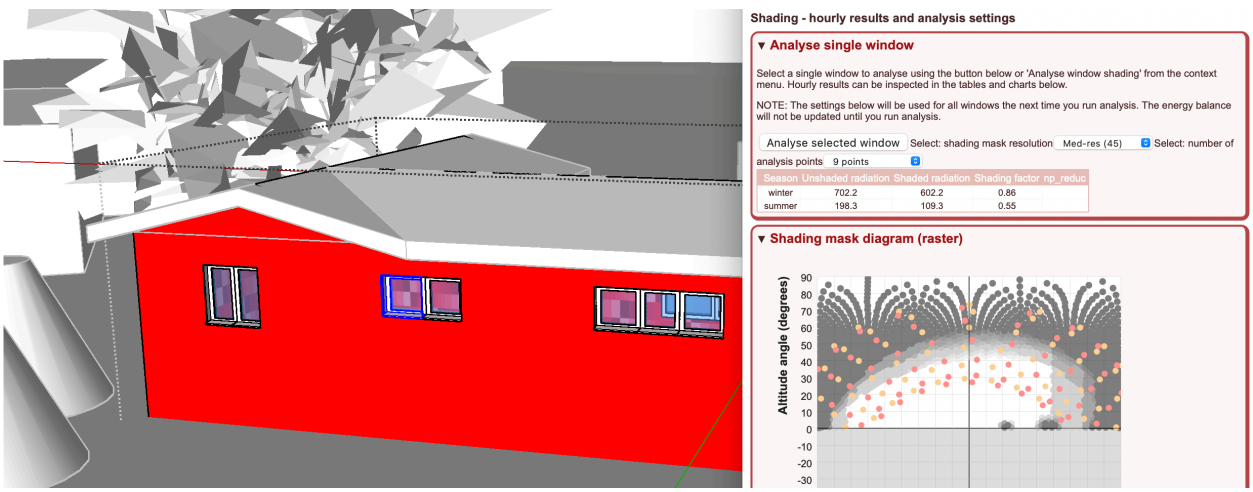

Image 18: Shading conditions modeled for the project. As an example, the grey mask on the left of the image represent the shading conditions specific to the window highlighted in blue.

Fresh Air Ventilation System (ERV/HRV)

The primary purpose of a fresh air ventilation system (ERV/HRV) is to deliver high indoor air quality (IAQ) to the building, by means of a continuous supply of filtered fresh air.

In prioritizing IAQ over other goals (e.g. heating/cooling, or odor control), an ERV/HRV fresh air system is fundamentally different from e.g. a regular forced air system, or conventional bathroom fans.

Table 10

FRESH AIR RATES PER OCCUPANT

	Type of ventilation	cfm/ person (1)	Air Filtration
Code-Minimum Ventilation	Conventional Bathroom fans	12	None
ERV/HRV Continous Ventilation	Continuous venting through HRV/ERV	20	Intake Air: F7 filter (MERV 13)
1)	24hr average over the entire building		

Table 10: Estimated supply of fresh air to the occupants of the Noble St ADU project.

For details and specs of the fresh air ventilation system (ERV/HRV) recommended for the Noble St ADU project, please refer to Appendix D.

Heating and Cooling Systems

The Passive House energy model (PHPP) was used to determine the whole building heating/cooling loads. PHPP is validated according to ASHRAE Standard 140, and it is a suitable (and more detailed) alternative to conventional Manual J calculations.

Table 11 summarizes the design conditions used in determining the loads for the building. Tables 12a and 12b summarize the heating/cooling loads for the scenarios considered in this report.

Table 11				
DESIGN CONDITIONS FOR HEATING / COOLING				
Design Temperature for Heating	20.0	°C	68.0	°F
Design Temperature for Cooling	25.0	°C	77.0	°F
Exterior Temperature for Peak Heating Load	8.8	°C	47.8	°F
Exterior Temperature for Peak Cooling Load	29.8	°C	85.6	°F
Active Cooling Included?			Yes	
Additional Standalone Dehumidification Recommended?			No	

Table 11: Design conditions considered in determining the loads for the building.

The conditions listed in Table 10 for exterior temperatures may be less extreme than other reference design temperatures for the same location (e.g. ASHRAE 99% or ASHRAE 99.6%). This is based on the fact that a building implementing Passive House design strategies is considerably more resilient than conventional buildings. As a consequence, the building is considerably less exposed to sudden changes in the exterior weather compared co Code-minimum built buildings. Images 07a and 07b above demonstrate the greater thermal resilience of buildings implementing Passive House strategies for their thermal envelope.

The energy model of the Noble St ADU project was set up to include active cooling.

Modern Passive House ventilation units (ERV/HRV) come with an automatic setting for 'summer bypass', that allows the incoming fresh air to bypass the heat exchanger providing free cooling to the building at night, as long as the external conditions are favorable. This was also considered in the modeling of the Noble St ADU Residence project.

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Table 13a

VARIATION OVER BASELINE HEATING DEMAND			Building Air Tightness [B]															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
			Thermal Quality Of Windows/Doors - Climate Zone 1-3				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**			
8.26			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kBTU/ft2y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	0.0%	1.0%	-2.7%	-4.2%	-6.8%	-5.9%	-9.6%	-11.2%	-13.6%	-12.7%	-16.5%	-18.1%	-16.3%	-15.4%	-19.2%	-20.8%
			8.26	8.35	8.04	7.91	7.70	7.78	7.47	7.34	7.14	7.21	6.90	6.77	6.92	6.99	6.68	6.54
	1.1	PH R-values 'low'	-38.5%	-37.9%	-41.6%	-43.3%	-44.9%	-44.4%	-48.0%	-49.8%	-51.1%	-50.7%	-54.3%	-56.1%	-53.5%	-53.2%	-56.8%	-58.6%
			5.08	5.13	4.83	4.69	4.55	4.60	4.29	4.15	4.04	4.08	3.77	3.63	3.84	3.87	3.57	3.42
	1.2	PH R-values 'medium'	-50.4%	-49.9%	-53.5%	-55.2%	-56.5%	-56.1%	-59.7%	-61.4%	-62.5%	-62.2%	-65.7%	-67.5%	-64.8%	-64.6%	-68.1%	-69.8%
			4.10	4.14	3.84	3.70	3.59	3.62	3.33	3.19	3.10	3.12	2.83	2.69	2.91	2.93	2.64	2.49
	1.3	PH R-values 'high'	-56.1%	-55.7%	-59.2%	-60.9%	-62.1%	-61.8%	-65.3%	-67.0%	-67.9%	-67.7%	-71.1%	-72.9%	-70.1%	-69.9%	-73.4%	-75.1%
			3.63	3.66	3.37	3.23	3.13	3.16	2.87	2.73	2.66	2.67	2.39	2.24	2.47	2.48	2.20	2.06

Table 12a: Whole building heating load for the scenarios considered.

Table 13b

VARIATION OVER BASELINE COOLING DEMAND			Building Air Tightness [B]															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
			Thermal Quality Of Windows/Doors - Climate Zone 1-3				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**			
5.47			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kBTU/ft2y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	0.0%	-9.2%	-12.7%	-18.9%	4.9%	-4.4%	-7.9%	-14.1%	14.2%	4.8%	1.3%	-5.0%	20.3%	10.8%	7.3%	1.0%
			5.47	4.96	4.77	4.44	5.73	5.23	5.03	4.69	6.24	5.73	5.54	5.19	6.57	6.06	5.87	5.52
	1.1	PH R-values 'low'	-6.0%	-15.2%	-18.6%	-24.7%	-2.3%	-10.3%	-15.0%	-19.8%	5.2%	-3.0%	-7.0%	-12.6%	10.6%	2.6%	-1.4%	-7.1%
			5.14	4.63	4.45	4.12	5.34	4.91	4.65	4.39	5.75	5.30	5.09	4.78	6.05	5.61	5.39	5.08
	1.2	PH R-values 'medium'	-10.2%	-19.5%	-22.7%	-28.7%	-6.9%	-16.3%	-19.5%	-25.6%	0.9%	-8.6%	-11.7%	-17.9%	6.4%	-3.2%	-6.3%	-12.5%
			4.91	4.40	4.23	3.90	5.09	4.57	4.40	4.07	5.51	4.99	4.82	4.49	5.81	5.29	5.12	4.78
	1.3	PH R-values 'high'	-11.1%	-20.4%	-23.5%	-29.6%	-7.7%	-17.1%	-20.2%	-26.3%	0.3%	-9.3%	-12.2%	-18.4%	4.3%	-3.8%	-6.9%	-13.1%
			4.86	4.35	4.18	3.85	5.05	4.53	4.36	4.03	5.48	4.96	4.80	4.46	5.70	5.26	5.09	4.75

Table 12b: Whole building cooling load for the scenarios considered.

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ENERGY PERFORMANCE

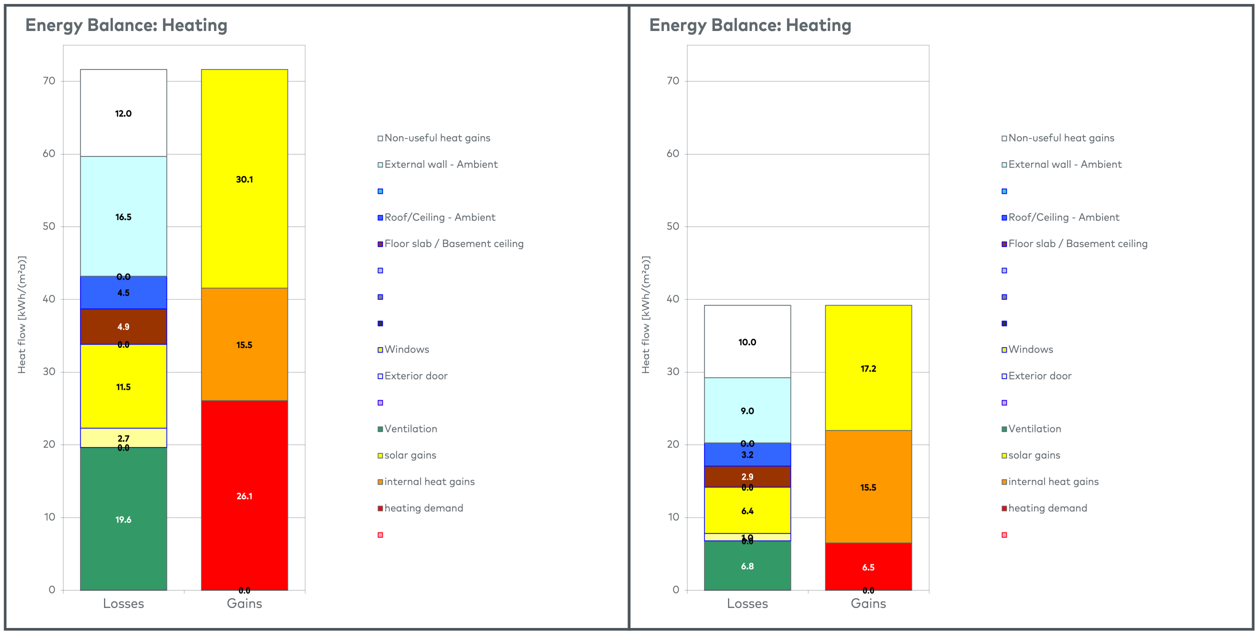

Image 19a, 19b: For the heating balance of Noble St ADU two scenarios were considered: Project Baseline (left), and the scenario with PH High R-values, phC grade windows and 0.6 ACH (right). The left column shows the heat losses, while the right one shows the gains. In each graph, please note the two yellow boxes, representing the solar gains received by the building through the transparent components (column on right), vs the heat losses through the same transparent components (column on left). In each graph, the active heating needed by the building is shown by the red box. To compare heating and cooling combined for all scenarios modeled, please refer to Table 13c.

Building energy performance was evaluated via the energy balance between losses and gains. The results for the heating balance for the project baseline and one of the more promising scenarios modeled are shown in images 19a and 19b, whereas the balances for cooling are shown in images 19c and 19d. These results are considered preliminary, because the values for thermal bridges were not included in the Energy model at this early phase.

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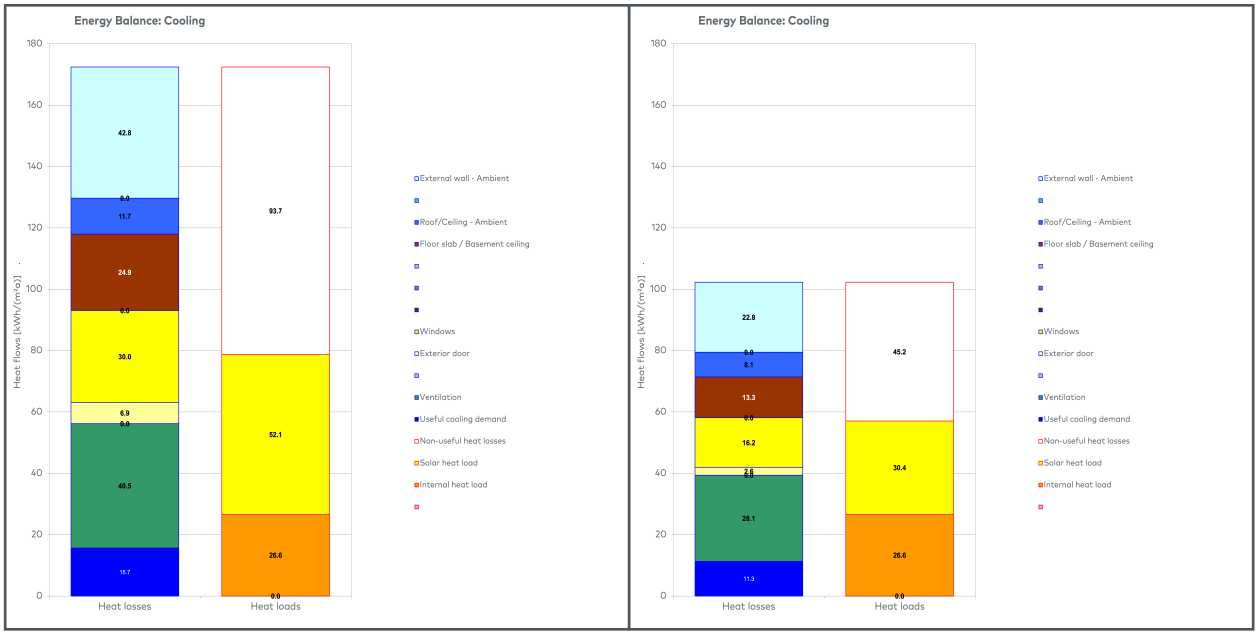

Image 19c, 19d: For the Cooling balance of Noble St ADU two scenarios were considered: Project Baseline (left), and the scenario with PH High R-values, phC grade windows and 0.6 ACH (right). The active cooling needed by the building is shown by the blue box at the bottom of the column. To compare heating and cooling combined for all scenarios modeled, please refer to Table 13c.

Tables 13a and 13b show the heating and cooling demand for the individual scenarios considered, benchmarked against the Project Baseline. Values greater than zero listed in the table actually show higher energy demand (worse performance) compared to the Project Baseline.

With regards to the Noble St ADU project meeting the target PHI goals, tables 14a and 14b benchmark the results of the individual scenarios against the Passive House building standard (heating and cooling, respectively). Tables 15a and 15b benchmark the same results against the Low Energy Building standard.

Table 13a

VARIATION OVER BASELINE HEATING DEMAND			Building Air Tightness [B]															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
			Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3			
8.26			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kBTU/ft2y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	0.0%	1.0%	-2.7%	-4.2%	-6.8%	-5.9%	-9.6%	-11.2%	-13.6%	-12.7%	-16.5%	-18.1%	-16.3%	-15.4%	-19.2%	-20.8%
			8.26	8.35	8.04	7.91	7.70	7.78	7.47	7.34	7.14	7.21	6.90	6.77	6.92	6.99	6.68	6.54
	1.1	PH R-values 'low'	-38.5%	-37.9%	-41.6%	-43.3%	-44.9%	-44.4%	-48.0%	-49.8%	-51.1%	-50.7%	-54.3%	-56.1%	-53.5%	-53.2%	-56.8%	-58.6%
			5.08	5.13	4.83	4.69	4.55	4.60	4.29	4.15	4.04	4.08	3.77	3.63	3.84	3.87	3.57	3.42
	1.2	PH R-values 'medium'	-50.4%	-49.9%	-53.5%	-55.2%	-56.5%	-56.1%	-59.7%	-61.4%	-62.5%	-62.2%	-65.7%	-67.5%	-64.8%	-64.6%	-68.1%	-69.8%
			4.10	4.14	3.84	3.70	3.59	3.62	3.33	3.19	3.10	3.12	2.83	2.69	2.91	2.93	2.64	2.49
	1.3	PH R-values 'high'	-56.1%	-55.7%	-59.2%	-60.9%	-62.1%	-61.8%	-65.3%	-67.0%	-67.9%	-67.7%	-71.1%	-72.9%	-70.1%	-69.9%	-73.4%	-75.1%
			3.63	3.66	3.37	3.23	3.13	3.16	2.87	2.73	2.66	2.67	2.39	2.24	2.47	2.48	2.20	2.06

Table 13a: Variation over the Project Baseline for heating demand for the individual scenarios modeled.

Table 13b

VARIATION OVER BASELINE COOLING DEMAND			Building Air Tightness [B]															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
			Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3			
5.47			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kBTU/ft2y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	0.0%	-9.2%	-12.7%	-18.9%	4.9%	-4.4%	-7.9%	-14.1%	14.2%	4.8%	1.3%	-5.0%	20.3%	10.8%	7.3%	1.0%
			5.47	4.96	4.77	4.44	5.73	5.23	5.03	4.69	6.24	5.73	5.54	5.19	6.57	6.06	5.87	5.52
	1.1	PH R-values 'low'	-6.0%	-15.2%	-18.6%	-24.7%	-2.3%	-10.3%	-15.0%	-19.8%	5.2%	-3.0%	-7.0%	-12.6%	10.6%	2.6%	-1.4%	-7.1%
			5.14	4.63	4.45	4.12	5.34	4.91	4.65	4.39	5.75	5.30	5.09	4.78	6.05	5.61	5.39	5.08
	1.2	PH R-values 'medium'	-10.2%	-19.5%	-22.7%	-28.7%	-6.9%	-16.3%	-19.5%	-25.6%	0.9%	-8.6%	-11.7%	-17.9%	6.4%	-3.2%	-6.3%	-12.5%
			4.91	4.40	4.23	3.90	5.09	4.57	4.40	4.07	5.51	4.99	4.82	4.49	5.81	5.29	5.12	4.78
	1.3	PH R-values 'high'	-11.1%	-20.4%	-23.5%	-29.6%	-7.7%	-17.1%	-20.2%	-26.3%	0.3%	-9.3%	-12.2%	-18.4%	4.3%	-3.8%	-6.9%	-13.1%
			4.86	4.35	4.18	3.85	5.05	4.53	4.36	4.03	5.48	4.96	4.80	4.46	5.70	5.26	5.09	4.75

Table 13b: Variation over the Project Baseline for cooling demand for the individual scenarios modeled.

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Table 13c																		
VARIATION OVER BASELINE **SITE ENERGY HEATING + COOLING**			**Building Air Tightness [B]**															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
			Thermal Quality Of Windows/Doors - Climate Zone 1-3				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**			
			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kWh/y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	0.0%	-2.9%	-6.8%	-9.7%	-2.9%	-5.8%	-8.7%	-12.6%	-2.9%	-5.8%	-9.7%	-13.6%	-2.9%	-5.8%	-9.7%	-12.6%
			1030	1000	960	930	1000	970	940	900	1000	970	930	890	1000	970	930	900
	1.1	PH R-values 'low'	-26.2%	-29.1%	-33.0%	-35.9%	-29.1%	-31.1%	-35.9%	-38.8%	-30.1%	-33.0%	-35.9%	-39.8%	-29.1%	-32.0%	-35.9%	-38.8%
			760	730	690	660	730	710	660	630	720	690	660	620	730	700	660	630
	1.2	PH R-values 'medium'	-35.0%	-38.8%	-41.7%	-45.6%	-37.9%	-40.8%	-44.7%	-47.6%	-38.8%	-41.7%	-45.6%	-48.5%	-37.9%	-40.8%	-44.7%	-47.6%
			670	630	600	560	640	610	570	540	630	600	560	530	640	610	570	540
	1.3	PH R-values 'high'	-38.8%	-42.7%	-45.6%	-49.5%	-41.7%	-44.7%	-48.5%	-51.5%	-41.7%	-45.6%	-48.5%	-52.4%	-41.7%	-44.7%	-47.6%	-51.5%
			630	590	560	520	600	570	530	500	600	560	530	490	600	570	540	500
			Assumed seasonal coefficients of performance of generator				Heating	3.0		[-]								
							Cooling	3.2		[-]								

Table 13c: Whole building site energy demand building heating and cooling combined.

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Table 14a

Benchmarking Agains Goal: PHI Passive House Standard			Building Air Tightness [B]															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
HEATING DEMAND			Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3			
4.75			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kBTU/ft2y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	74.0%	75.7%	69.3%	66.6%	62.1%	63.7%	57.3%	54.5%	50.3%	51.8%	45.3%	42.5%	45.7%	47.1%	40.6%	37.7%
	1.1	PH R-values 'low'	6.9%	8.0%	1.6%	-1.3%	-4.1%	-3.2%	-9.6%	-12.6%	-14.9%	-14.2%	-20.6%	-23.6%	-19.2%	-18.5%	-24.9%	-27.9%
	1.2	PH R-values 'medium'	-13.7%	-12.8%	-19.1%	-22.0%	-24.4%	-23.7%	-29.9%	-32.9%	-34.7%	-34.2%	-40.4%	-43.4%	-38.8%	-38.4%	-44.5%	-47.5%
	1.3	PH R-values 'high'	-23.7%	-22.9%	-29.1%	-32.0%	-34.1%	-33.5%	-39.6%	-42.6%	-44.1%	-43.7%	-49.8%	-52.8%	-48.0%	-47.7%	-53.7%	-56.7%

Table 14a: Benchmarking against the Passive House building standard (heating demand).

Table 14b

Benchmarking Agains Goal: PHI Passive House Standard			Building Air Tightness [B]															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
COOLING DEMAND			Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3			
5.38			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kBTU/ft2y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	1.5%	-7.8%	-11.4%	-17.6%	6.5%	-2.9%	-6.5%	-12.8%	16.0%	6.4%	2.8%	-3.5%	22.1%	12.5%	9.0%	2.6%
	1.1	PH R-values 'low'	-4.6%	-13.9%	-17.3%	-23.5%	-0.8%	-8.9%	-13.6%	-18.5%	6.9%	-1.5%	-5.5%	-11.3%	12.4%	4.2%	0.1%	-5.7%
	1.2	PH R-values 'medium'	-8.8%	-18.2%	-21.5%	-27.6%	-5.5%	-15.0%	-18.2%	-24.4%	2.4%	-7.2%	-10.4%	-16.6%	8.0%	-1.7%	-4.9%	-11.1%
	1.3	PH R-values 'high'	-9.8%	-19.2%	-22.4%	-28.5%	-6.3%	-15.8%	-18.9%	-25.1%	1.9%	-7.9%	-10.9%	-17.1%	5.9%	-2.3%	-5.4%	-11.8%

Table 14b: Benchmarking against the Passive House building standard (cooling demand).

Table 15a																		
Benchmarking Agains Goal: **PHI Low Energy Building Standard**			**Building Air Tightness [B]**															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
HEATING DEMAND			**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**			
9.50			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kBTU/ft2y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	-13.0%	-12.1%	-15.4%	-16.7%	-19.0%	-18.1%	-21.4%	-22.7%	-24.8%	-24.1%	-27.3%	-28.7%	-27.2%	-26.5%	-29.7%	-31.1%
	1.1	PH R-values 'low'	-46.5%	-46.0%	-49.2%	-50.6%	-52.1%	-51.6%	-54.8%	-56.3%	-57.5%	-57.1%	-60.3%	-61.8%	-59.6%	-59.3%	-62.4%	-64.0%
	1.2	PH R-values 'medium'	-56.9%	-56.4%	-59.5%	-61.0%	-62.2%	-61.8%	-65.0%	-66.5%	-67.4%	-67.1%	-70.2%	-71.7%	-69.4%	-69.2%	-72.2%	-73.8%
	1.3	PH R-values 'high'	-61.8%	-61.4%	-64.5%	-66.0%	-67.0%	-66.7%	-69.8%	-71.3%	-72.0%	-71.9%	-74.9%	-76.4%	-74.0%	-73.9%	-76.8%	-78.3%

Table 15a: Benchmarking against the Low Energy Building standard (heating demand).

Table 15b																		
Benchmarking Agains Goal: **PHI Low Energy Building Standard**			**Building Air Tightness [B]**															
			3.0				3.1				3.2				3.3			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0				ACH50 = 1.0				ACH50 = 0.6			
COOLING DEMAND			**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**				**Thermal Quality Of Windows/Doors - Climate Zone 1-3**			
10.13			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kBTU/ft2y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	-46.1%	-51.0%	-52.9%	-56.2%	-43.4%	-48.4%	-50.3%	-53.7%	-38.4%	-43.5%	-45.4%	-48.7%	-35.1%	-40.2%	-42.1%	-45.5%
	1.1	PH R-values 'low'	-49.3%	-54.3%	-56.1%	-59.4%	-47.3%	-51.6%	-54.1%	-56.7%	-43.2%	-47.6%	-49.8%	-52.9%	-40.3%	-44.7%	-46.8%	-49.9%
	1.2	PH R-values 'medium'	-51.6%	-56.6%	-58.3%	-61.6%	-49.8%	-54.9%	-56.6%	-59.9%	-45.6%	-50.7%	-52.4%	-55.7%	-42.6%	-47.8%	-49.5%	-52.8%
	1.3	PH R-values 'high'	-52.1%	-57.1%	-58.8%	-62.0%	-50.2%	-55.3%	-56.9%	-60.2%	-45.9%	-51.1%	-52.7%	-56.0%	-43.7%	-48.1%	-49.8%	-53.1%

Table 15b: Benchmarking against the Low Energy Building standard (cooling demand).

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CONCLUSIONS

The goal of the Preliminary Passive House Review was to identify strengths and weaknesses of the Noble St ADU project as related to the climate of Orange, CA, and to the target PHI energy standards.

The preliminary modeling results of the Noble St ADU show that the current design is able to meet the target PHI energy efficiency goals.

Considering the value metrics covered in the report, including among others thermal comfort, indoor air quality, as well as reduction of heating and cooling demand, the most promising scenarios resulting from this analysis are highlighted in Table 16.

Table 13c

VARIATION OVER BASELINE — SITE ENERGY HEATING + COOLING			Building Air Tightness [B]							
			3.0				3.1			
			Code minimum, ACH50 = 3.0				ACH50 = 2.0			
			Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3			
			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kWh/y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	0.0%	-2.9%	-6.8%	-9.7%	-2.9%	-5.8%	-8.7%	-12.6%
			1030	1000	960	930	1000	970	940	900
	1.1	PH R-values 'low'	-26.2%	-29.1%	-33.0%	-35.9%	-29.1%	-31.1%	-35.9%	-38.8%
			760	730	690	660	730	710	660	630
	1.2	PH R-values 'medium'	-35.0%	-38.8%	-41.7%	-45.6%	-37.9%	-40.8%	-44.7%	-47.6%
			670	630	600	560	640	610	570	540
	1.3	PH R-values 'high'	-38.8%	-42.7%	-45.6%	-49.5%	-41.7%	-44.7%	-48.5%	-51.5%
			630	590	560	520	600	570	530	500

VARIATION OVER BASELINE — SITE ENERGY HEATING + COOLING			Building Air Tightness [B]							
			3.2				3.3			
			ACH50 = 1.0				ACH50 = 0.6			
			Thermal Quality Of Windows/Doors - Climate Zone 1-3				Thermal Quality Of Windows/Doors - Climate Zone 1-3			
			2.0	2.1	2.2	2.3	2.0	2.1	2.2	2.3
[kWh/y]			Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)	Code-minimum Windows/ Doors	Code-minimum Windows/Doors, upgraded to 'skinny' 3-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 2-pane Glass (PH specs)	phC Windows/ Doors, 'beefy' 3-pane Glass (PH specs)
R-values Targeting	1.0	R-values By Code minimum	-2.9%	-5.8%	-9.7%	-13.6%	-2.9%	-5.8%	-9.7%	-12.6%
			1000	970	930	890	1000	970	930	900
	1.1	PH R-values 'low'	-30.1%	-33.0%	-35.9%	-39.8%	-29.1%	-32.0%	-35.9%	-38.8%
			720	690	660	620	730	700	660	630
	1.2	PH R-values 'medium'	-38.8%	-41.7%	-45.6%	-48.5%	-37.9%	-40.8%	-44.7%	-47.6%
			630	600	560	530	640	610	570	540
	1.3	PH R-values 'high'	-41.7%	-45.6%	-48.5%	-52.4%	-41.7%	-44.7%	-47.6%	-51.5%
			600	560	530	490	600	570	540	500

Assumed seasonal coefficients of performance of generator			
	Heating	3.0	[-]
	Cooling	3.2	[-]

Table 16: Decision Matrix for the Noble St ADU project, highlighting the scenarios that produce the greater impact in building energy efficiency.

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For the detailed description of the scenarios modeled, refer to Table 05.

Both the achievements of the Passive House and Low Energy building standard are likely to be met in the current design.

As a result of this analysis, the next steps for the Noble St ADU project include:

1. define the project's energy performance goals
2. develop a construction set based on these goals. For examples of typical wall assemblies, please see Appendix B
3. price out a window and door package

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APPENDIX A - PENCIL RULE

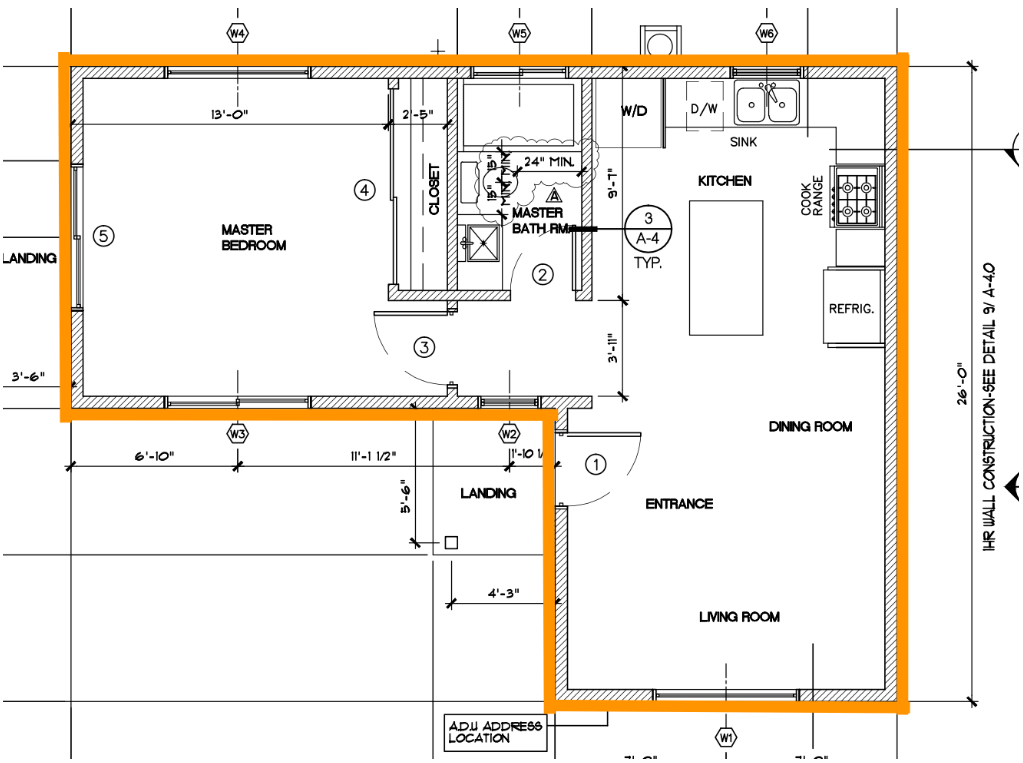

Image A.01 - Boundary of the building thermal envelope on floor 01.

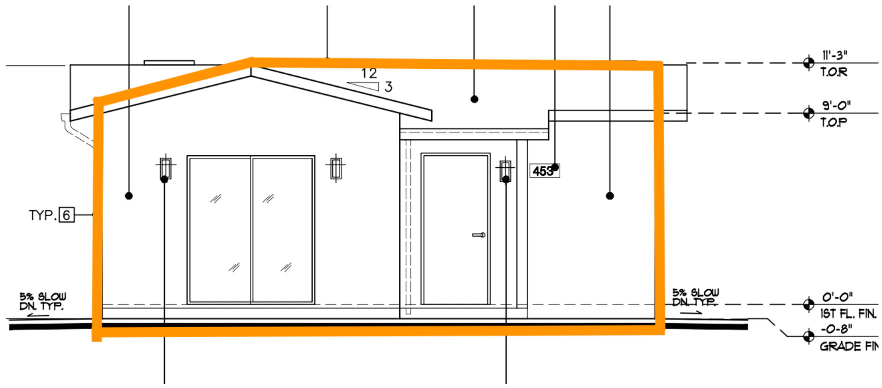

Image A.11 - Boundary of the building thermal envelope for the West building Elevation.

APPENDIX B - TYPICAL WALL ASSEMBLIES

The following pages summarize two examples of typical wall assemblies that would meet the R-value target requirements illustrated in Table 06.

The scope of this Report does not include the delivery of specific construction details past the examples illustrated below.

If you're interested in receiving Passive House-suitable construction details for your project, and possibly support during the next steps of design and construction, please review Emu's Pilot Program (fees apply).

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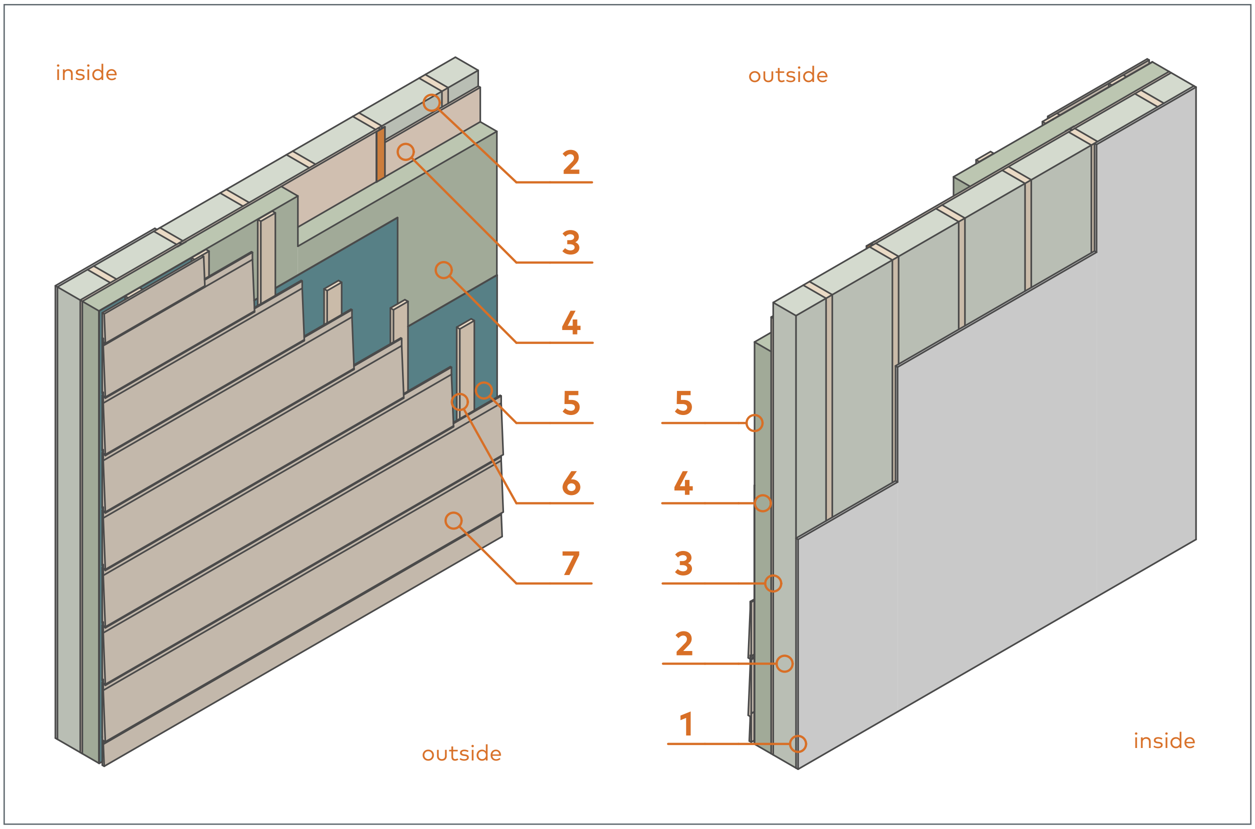
EMU REPORT



Images B.01a and B.01b: Typical wall assembly consisting of 2x6 framing and exterior insulation. View from the outside in (left), and from the inside out (right). For details about R-values and control layers, please refer to Table B.01

Table B.01					
A	**2x6 + Continuous Insulation**	**1**	**2**	**3**	
		PH R-values 'low'	PH R-values 'medium'	PH R-values 'high'	Notes
Target R-value		25.0	30.0	35.0	
	interior				
1	drywall w/ vapor-open paint	0.5"	0.5"	0.5"	
2	stud cavity filled with vapor-open insulation (cellulose fiber, dense-pack fiberglass, or mineral wool batts)	5.5"	5.5"	5.5"	
3	sheathing (OSB or plywood) sealed at all seams and penetrations as air barrier	0.5"	0.5"	0.5"	
4	continuous insulation (mineral wool, EPS, or wood fiber). Metal fasteners ø 3/16", spaced 16oc x 24oc	1.5" - 2.5"	3" - 4"	4" - 5"	
5	weather resistive barrier system, vapor open, as wind barrier				
6	vented cavity w/ pressure-treated furring strips	0.75"	0.75"	0.75"	
7	wall finish	per architectural	per architectural	per architectural	
	exterior				

Table B.01: Breakdown of a typical wall assembly consisting of 2x6 framing and exterior insulation. The three columns (1, 2, and 3) list the ranges insulation thicknesses required for the wall to meet target R-values listed in Table 06.

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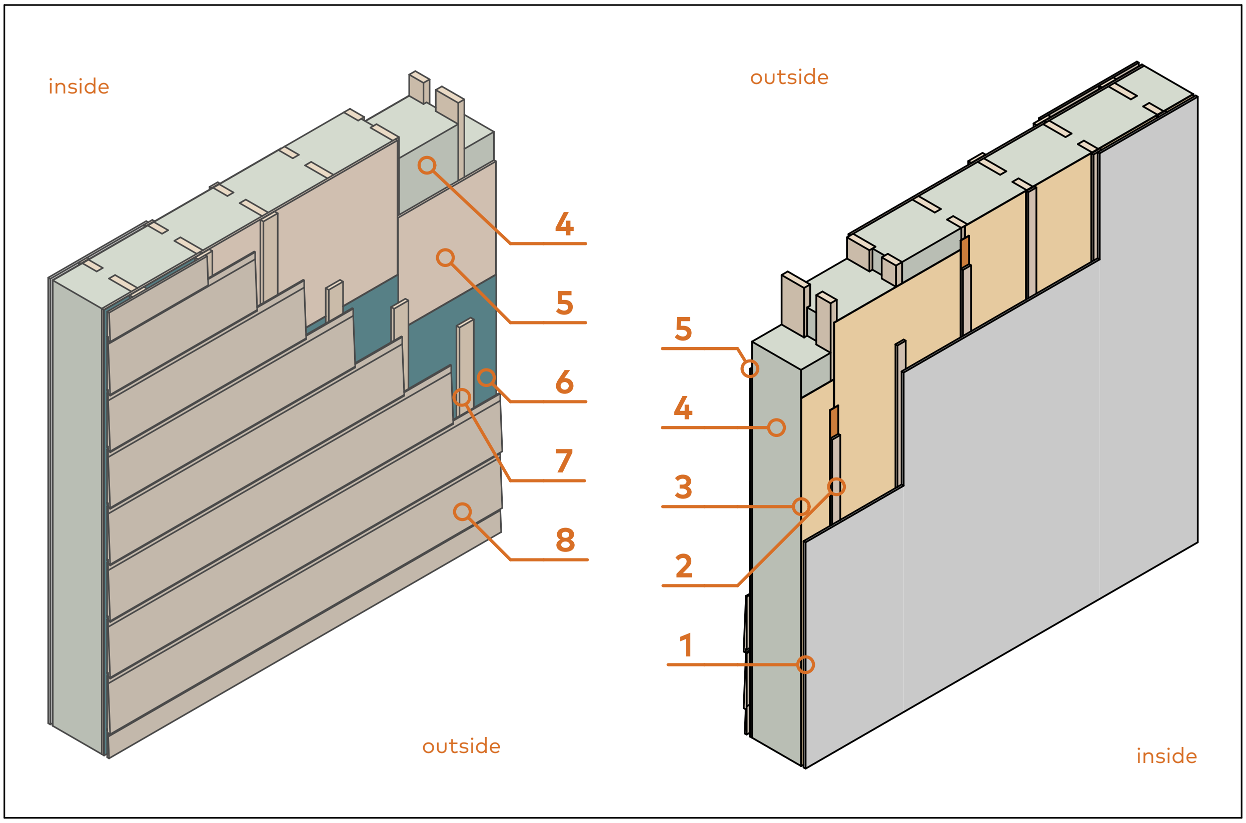

Images B.02a and B.02b: Typical wall assembly consisting of a double wall and dense-pack insulation. View from the outside in (left), and from the inside out (right). For details about R-values and control layers, please refer to Table B.02

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Table B.02					
B	**Double Stud Wall**	**1** PH R-values 'low'	**2** PH R-values 'medium'	**3** PH R-values 'high'	Notes
Target R-value		25.0	30.0	35.0	
	interior				
1	drywall w/ vapor-open paint	0.5"	0.5"	0.5"	
2	air gap w/ plywood furring strips to separate the drywall from the air barrier membrane	0.5"	0.5"	0.5"	
3	smart vapor retarder membrane sealed at all seams and penetrations as air barrier				
4	double stud cavity filled with vapor-open insulation (cellulose fiber, dense-pack fiberglass, or mineral wool batts)	N/A"	8" - 10"	10" - 12"	a)
5	sheathing (OSB or plywood)	0.5"	0.5"	0.5"	
6	weather resistive barrier system, vapor open, as wind barrier				
7	vented cavity w/ pressure-treated furring strips	0.75"	0.75"	0.75"	
8	wall finish	per architectural	per architectural	per architectural	
	exterior				
a)	The depth value is provided from outer face of exterior stud to inner face of interior stud. If the air gap between the two studs ends up being less than 1.5", stagger studs by ≥ 6".				

Table B.02: Breakdown of a typical double wall wall assembly. The three columns (1, 2, and 3) list the ranges insulation thicknesses required for the wall to meet target R-values listed in Table 06.