CONSPICUOUS CONSUMPTION

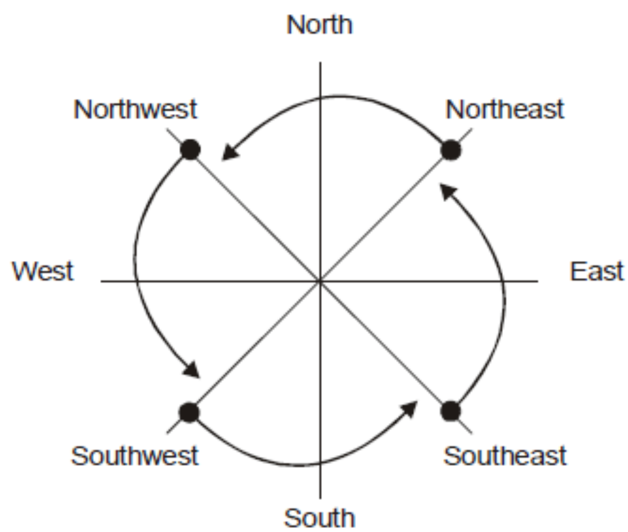
TASK **2**
ENERGY PERFORMANCE
DOCUMENTATION

WINDOW–TO–WALL RATIO

Calculate the window-to-wall ratio for each elevation and the entire building. The window-to-wall ratio of a building is the percentage of its facade taken up by light-transmitting glazing surfaces, including windows and translucent surfaces such as glass bricks. It does not include glass surfaces used ornamentally or as opaque cladding, which do not provide transparency to the interior. Only facade surfaces are counted in the ratio, and not roof surfaces.

Here is the procedure for classifying facades that do not face a cardinal direction. In general, any orientation within 45^{o} of true north, east, south, or west should be assigned to that orientation. If the orientation is exactly at 45^{o} of a cardinal orientation, use the diagram at right to classify the direction of the façade. For example, an east-facing surface cannot face exactly northeast, but it can face exactly southeast. If the surface were facing exactly northeast, it would be considered north-facing.

As the window-to-wall calculation is a ratio, you may enter area in square feet or meters.



North

Step 1: Total area of light transmitting glazing surfaces on north facade: **23,500 SF**

Step 2: Total area of north façade: **77,300 SF**

Window-to-wall ratio of north façade = number from step 1 / number from step 2 = **30.4%**

East

Step 1: Total area of light transmitting glazing surfaces on east facade: **21,480 SF**

Step 2: Total area of east façade: **62,251 SF**

Window-to-wall ratio of east façade = number from step 1 / number from step 2 = **34.5%**

South

Step 1: Total area of light transmitting glazing surfaces on south facade: **26,392 SF**

Step 2: Total area of south façade: **74,300 SF**

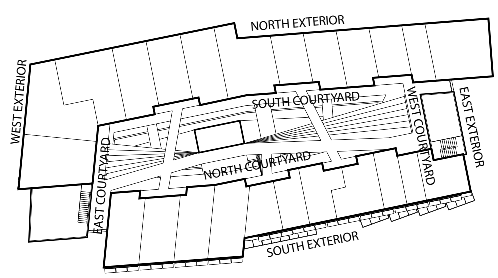
Window-to-wall ratio of south façade = number from step 1 / number from step 2 = **35.5%**

West

Step 1: Total area of light transmitting glazing surfaces on west facade: **23,310 SF**

Step 2: Total area of west façade: **54,670 SF**

Window-to-wall ratio of west façade = number from step 1 / number from step 2 = **42.6%**



SAMPLE FLOOR PLAN DIAGRAM

Total Building Windowa toa Wall Ratio

Step 1: Façade area$_{total}$ = step one$_{north}$ + step one$_{east}$ + step one$_{south}$ + step one$_{west}$ = **94,682 SF**

Step 2: Light transmitting glazing$_{total}$ = step two$_{north}$ + step two$_{east}$ + step two$_{south}$ + step two$_{west}$ = **268,521 SF**

Total window-to-wall ratio = number from step 1 / number from step 2 = **35.3%**

WINDOW–TO–WALL RATIO

			GLAZING AREA	FAÇADE AREA	WINDOW-TO-WALL RATIO
NELSON RISING ROAD (SOUTH BUILDING)	NORTH	COURTYARD	3200	17675	0.18
		EXTERIOR	6000	20775	0.29
		SUBTOTAL	9200	38450	0.24
	SOUTH	COURTYARD	3500	17380	0.20
		EXTERIOR	9072	19020	0.48
		SUBTOTAL	12572	36400	0.35
	EAST	COURTYARD	2000	4650	0.43
		EXTERIOR	4000	8801	0.45
		SUBTOTAL	6000	13451	0.45
	WEST	COURTYARD	2250	6270	0.36
		EXTERIOR	3600	5300	0.68
		SUBTOTAL	5850	11570	0.51
		TOTAL	33622	99871	0.34

			GLAZING AREA	FAÇADE AREA	WINDOW-TO-WALL RATIO
6TH STREET (WEST BUILDING)	NORTH	COURTYARD	2250	2350	0.96
		EXTERIOR	2500	8000	0.31
		SUBTOTAL	4750	10350	0.46
	SOUTH	COURTYARD	300	1200	0.25
		EXTERIOR	4200	10200	0.41
		SUBTOTAL	4500	11400	0.39
	EAST	COURTYARD	4530	16200	0.28
		EXTERIOR	5500	21000	0.26
		SUBTOTAL	10030	37200	0.27
	WEST	COURTYARD	3000	10500	0.29
		EXTERIOR	9000	20000	0.45
		SUBTOTAL	12000	30500	0.39
		TOTAL	31280	89450	0.35

			GLAZING AREA	FAÇADE AREA	WINDOW-TO-WALL RATIO
MISSION BAY BLVD. SOUTH (NORTH BUILDING)	NORTH	COURTYARD	2870	15000	0.19
		EXTERIOR	6680	13500	0.49
		SUBTOTAL	9550	28500	0.34
	SOUTH	COURTYARD	2320	11000	0.21
		EXTERIOR	7000	15500	0.45
		SUBTOTAL	9320	26500	0.35
	EAST	COURTYARD	2300	5500	0.42
		EXTERIOR	3150	6100	0.52
		SUBTOTAL	5450	11600	0.47
	WEST	COURTYARD	1780	4200	0.42
		EXTERIOR	3680	8400	0.44
		SUBTOTAL	5460	12600	0.43
		TOTAL	29780	79200	0.38

WINDOW OPENING AND WINDOW SHADING

In the space below, describe the design approach at window openings to regulating incoming light and heat from the sun. Briefly describe the type of window and glass used on the east, south, west and north elevations and the performance numbers targeted for U-factor, solar heat gain coefficient (SHGC) and visible transittance.

In all three buildings of the Mission Bay development, the façade regulates light and heat in the living spaces to provide thermal comfort to occupants and promote low energy use for heating and cooling. A clear, double glazed window was selected for use on all sides of the buildings. This provides for an optimal indoor experience for occupants, allowing for unobstructed views. The clearness of the glazing unit also provides an energy benefit. It allows for solar energy to enter the residential units during winter days. This passive heating strategy is elemental in creating a low energy use building, which provides the groundwork for achieving the zero net energy goal.

Exterior window shading is incorporated onto the south facades to block the intense summer sun. This strategy allows for the building to employ passive cooling with operable windows, thereby using very little energy to provide thermal comfort to occupants. Horizontal shading at each floor level blocks the summer sun while still allowing the winter sun to pass through the facade. The vertical shades are operable by building occupants, who can apply a greater level of solar shading to suit the time of year and their individual comfort levels.

Type of window and glass: Viracon 1" IGU with Optiwhite for all facades.

U-Factor: 0.38 (Winter)

SHGC: 0.82

VLT: 83%

East facing
U-factor: 0.38 (Winter); SHGC: 0.82; Visible Transmittance: 83%

South facing
U-factor: 0.38 (Winter); SHGC: 0.82; Visible Transmittance: 83%

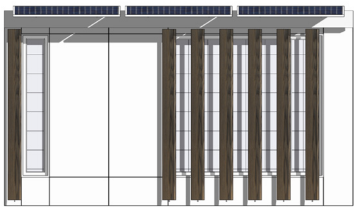
West facing
U-factor: 0.38 (Winter); SHGC: 0.82; Visible Transmittance: 83%

North facing
U-factor: 0.38 (Winter); SHGC: 0.82; Visible Transmittance: 83%

WINDOW OPENING AND WINDOW SHADING

South Elevation Shade Study

DECEMBER 21



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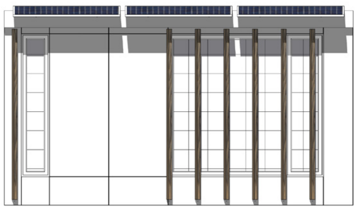

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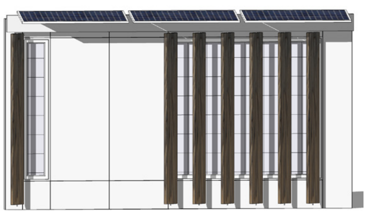

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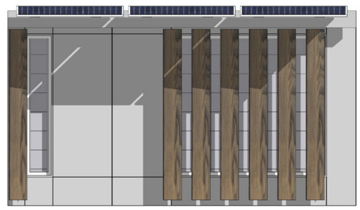
MARCH 21 / SEPT 21



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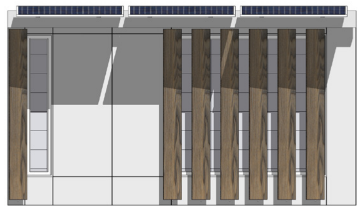

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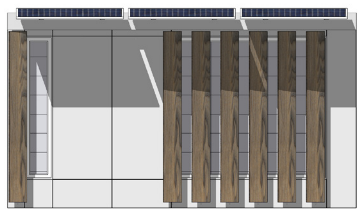

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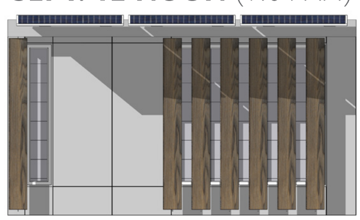

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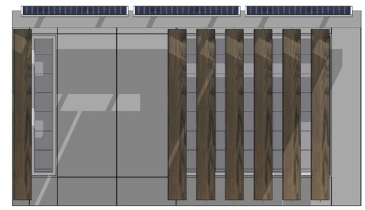
SEPT: 2 PM (3:04 PM)

MARCH: 4 PM (4:19 PM)
SEPT: 4 PM (4:04 PM)

JUNE 21



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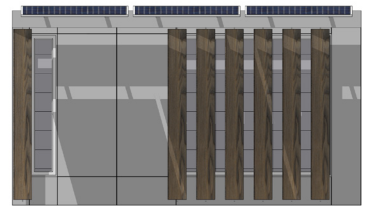

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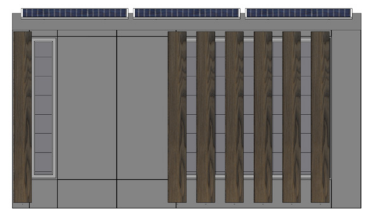

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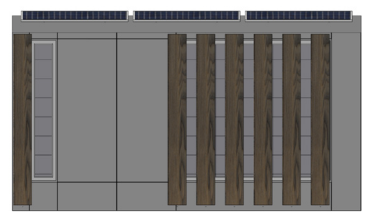

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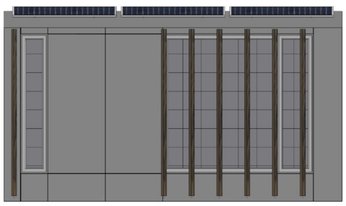
Times indicated are solar time; clock time shown in parentheses.

WINDOW OPENING AND WINDOW SHADING

West Elevation Shade Study

DECEMBER 21



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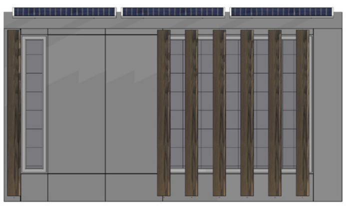

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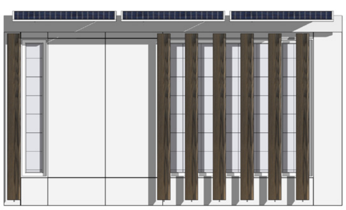

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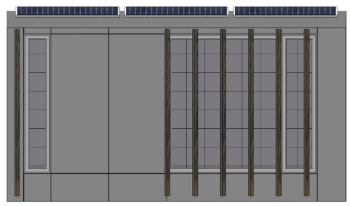
MARCH 21 / SEPT 21



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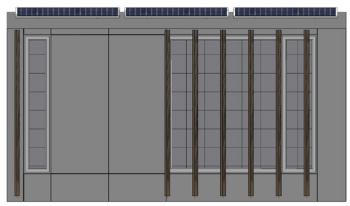

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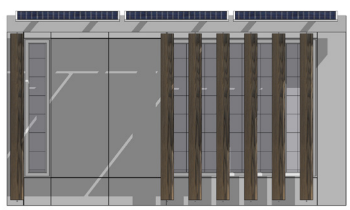

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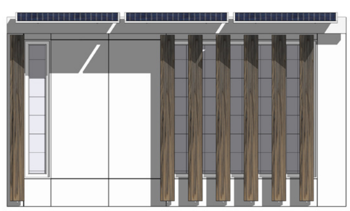

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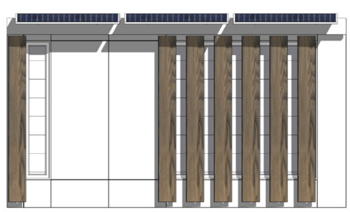

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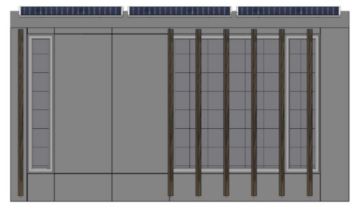
SEPT: 4 PM (4:04 PM)

JUNE 21



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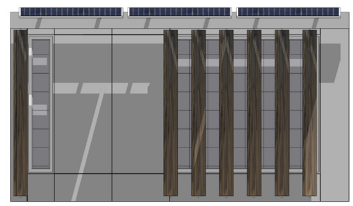

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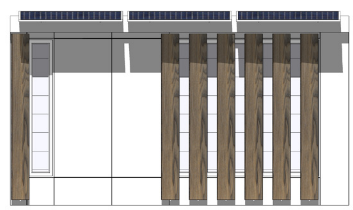

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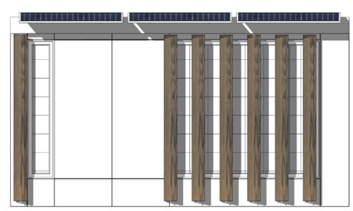

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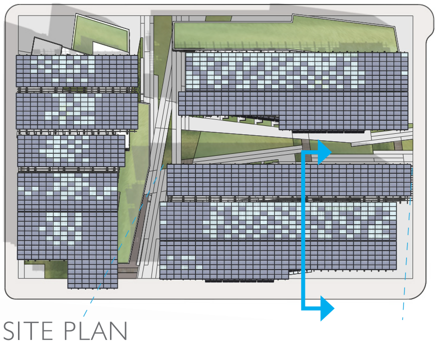
Times indicated are solar time; clock time shown in parentheses.

BUILDING ENCLOSURE DETAILS

For one of the proposed buildings, include a section diagram through an exterior wall of a residential unit that shows the point of connection between the roof and a vertical wall, a typical window head and sill, and the condition at a typical floor level. This section should demonstrate the design strategies and details used to reduce thermal bridging and air leakage and to control bulk water flow. Include a scale on the diagram.

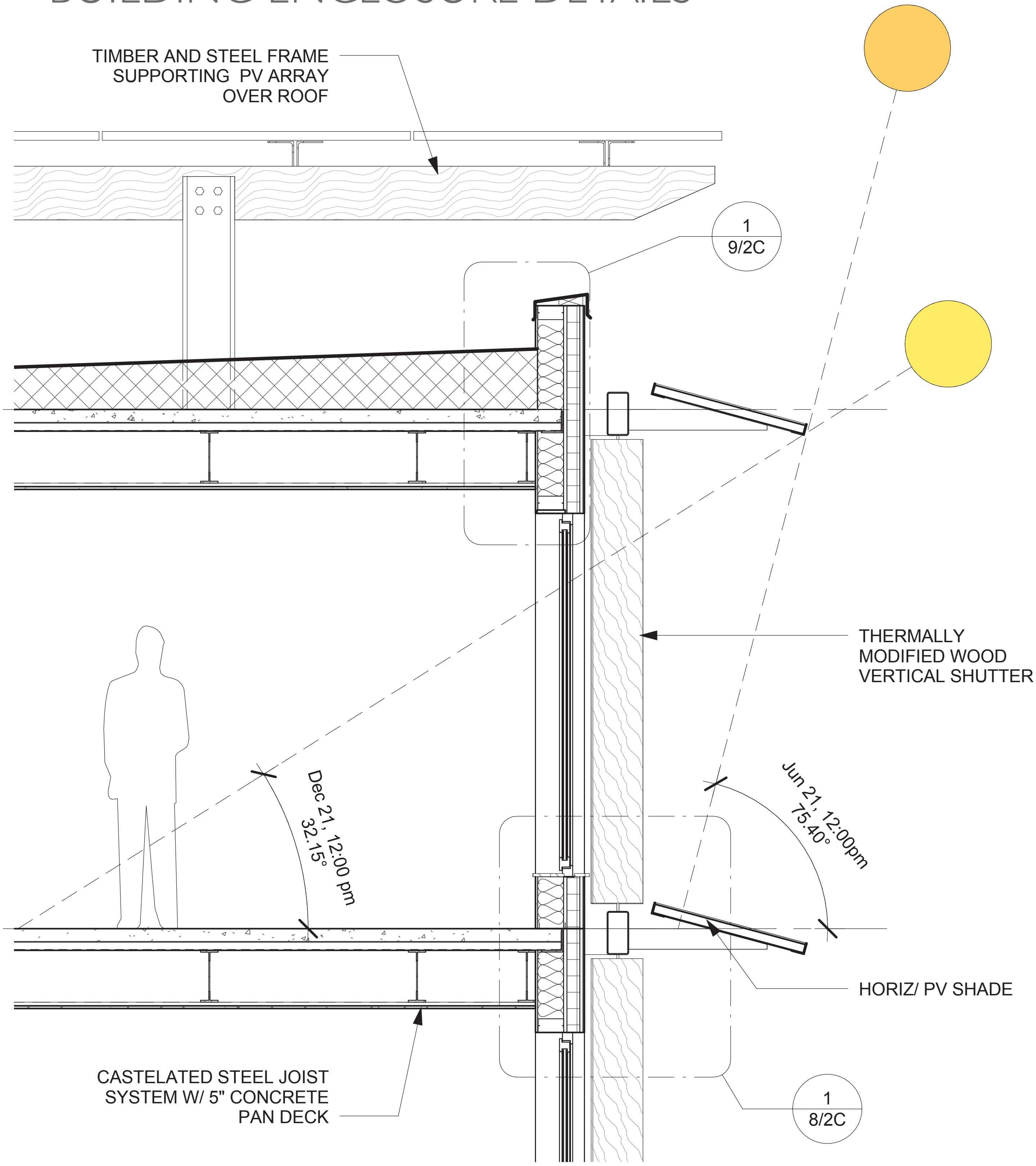
Provide a brief description of the insulation R-values used in the walls and roof. Include a description of other strategies used to reduce heat loss and air leakage. On the section diagram, note which building is being shown.

SOUTH BUILDING SECTION

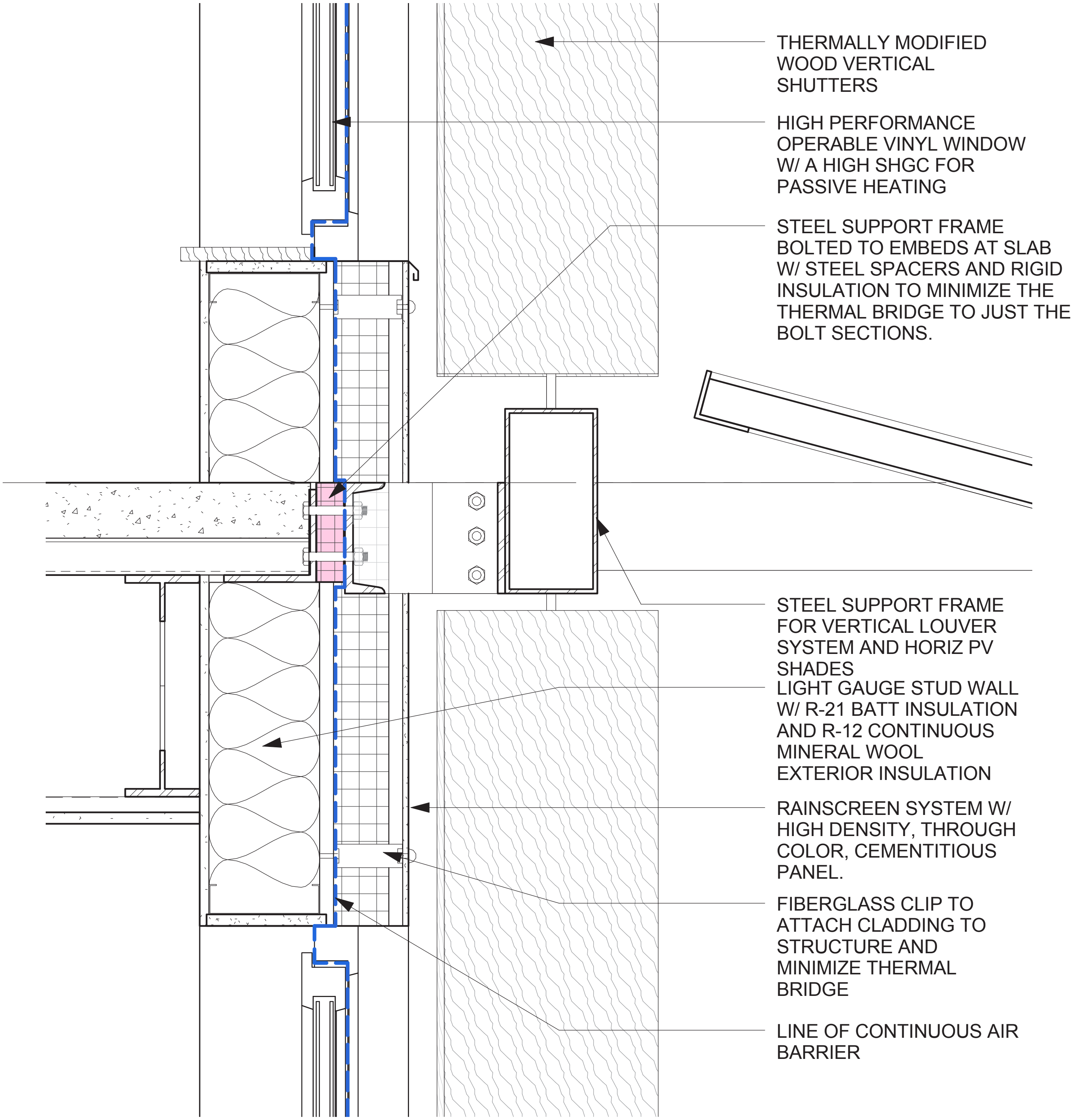


SITE PLAN

BUILDING ENCLOSURE DETAILS

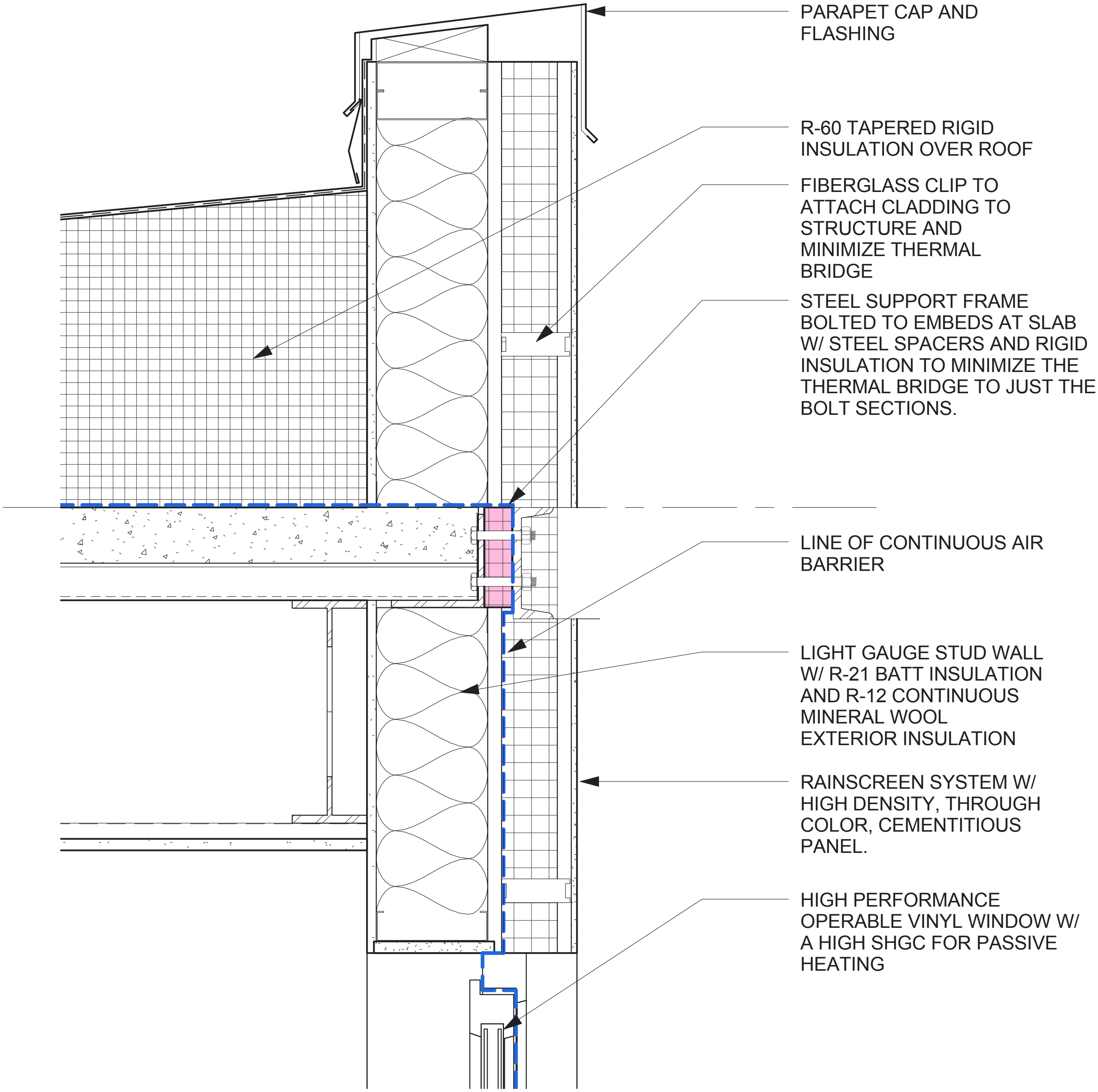


1 WALL SECTION - SOUTH BUILDING
3/8" = 1'-0"



1 FLOOR TO WALL DETAIL
1 1/2" = 1'-0"

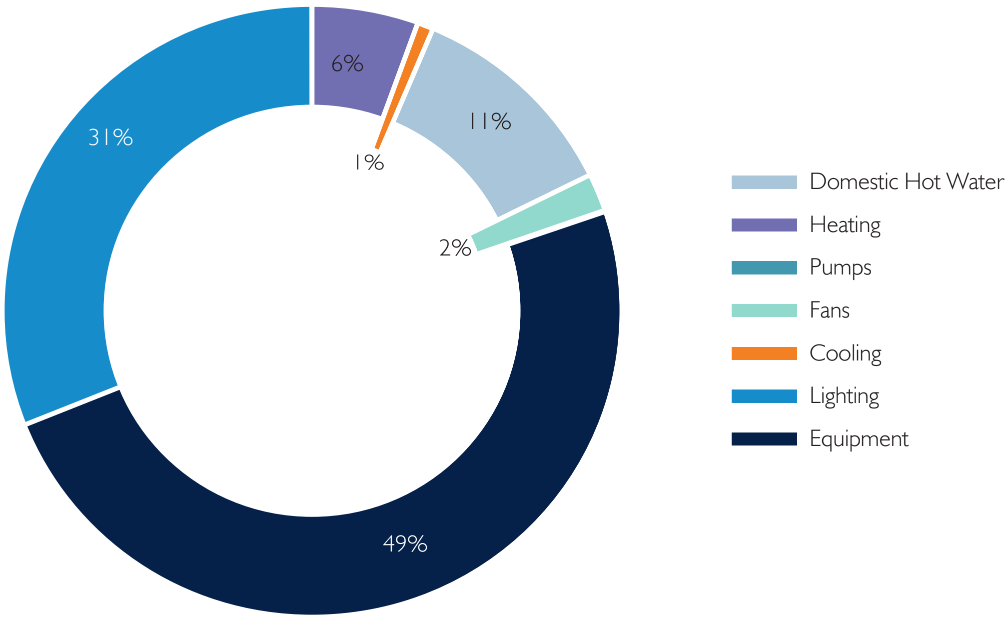
BUILDING ENCLOSURE DETAILS

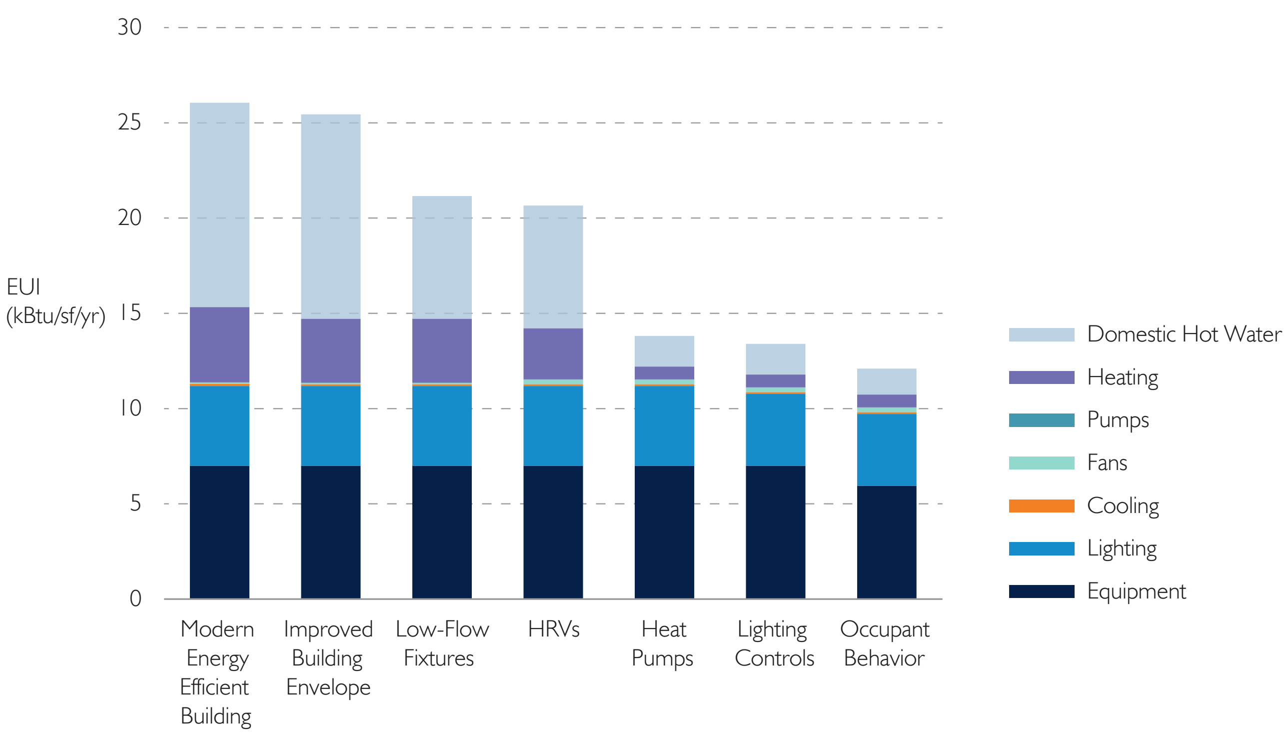


1 ROOF TO WALL DETAIL
1 1/2" = 1'-0"

END USE BREAKDOWN

As part of the Task 2 Energy Performance Documentation submittal, for each proposed building, provide annual energy use broken down by major end uses such as HVAC, lighting, domestic hot water, appliances, and miscellaneous electric loads. Please include the table below to summarize your calculations. Describe any measures taken to controls systems such as lighting and plug loads.





2D

END USE BREAKDOWN

Modeling Assumptions:

PLUG LOADS

The Energy Star website (http://www.energystar.gov/productfinder/product) provides a guide to the annual energy consumption of appliances based on a typical usage profile. It was assumed for the purposes of this project that these figures were accurate. The following appliances were included in the plug loads calculation:

Appliance	Number	Average Annual Energy (all Energy Star products) [kWh]
refrigerator	1 per unit	596.0
dishwasher	1 per unit	267.9
television	1 per unit	89.6
set-top box	1 per unit	68.3
computer	1 per unit	306.0

Energy Star does not certify residential cooking equipment, so an alternative approach was taken to calculated the energy associated with cooking using the following websites: consumerenergycenter.org | energyusecalculator.com

Appliance	Number	Average power draw over 1 hour of use [kW]
Electric convection oven	1 per unit	596.0
Electric induction range	1 per unit	267.9
Microwave oven	1 per unit	87.6

LIGHTING POWER

A lighting power density of 0.4W/sf was used in the energy model, which matches the prescriptive requirement of California Title 24.

FAN POWER

The fan energy used in the residential units was calculated assuming a specific fan power of 0.48W/cfm. This figure was developed by taking a representative heat recovery ventilator (HRV) at the expected average volume flow rate.
http://zehnderamerica.com/wp-content/uploads/2014/11/CA160-2015.03.25.pdf

HEATING AND COOLING ENERGY

An IES-VE model of the proposed design was simulated over the year in order to develop accurate heating and cooling profiles.

PUMPING

A specific pump power of 19W/gpm was assumed on all hot water, both domestic and heating.

For measures taken to control systems, refer to a detailed explanation of active systems in Section 2E and residential unit systems in Section 2F.

PROJECT NARRATIVE

As part of the Task 2 Energy Performance Documentation submittal, for each proposed building, include a high-level whole building diagram depicting the major components of the HVAC system or systems serving the ground floor commercial space, the residential units, and common space (any space in the residential facility that serves a function in support of the residential part of the building that is not part of a dwelling unit, such as corridors, community rooms, mechanical rooms, and staff offices). All the spaces are heated, but only the ground floor is cooled. The HVAC system may include traditional mechanical systems, emerging technologies, passive systems, or a hybrid of passive and active systems.

Overview

The project goal of achieving zero net energy (ZNE) requires the project to offset 100% of the energy consumed over the course of the year by generating renewable energy on-site.

We believe that the right solution for this project and this site is to integrate photovoltaic (PV) panels into the architecture. This approach maximizes annual electricity generation, while providing shading that is an important part of the passive design strategy.

One challenge of using PV to generate a quantity of energy equivalent to the building's annual energy use is the generation potential of the PV is limited by the available roof area. A consequence of this dependence on available roof area is the majority of ZNE buildings that use PV to offset their annual energy use have less than four floors. In order to accommodate the required program on the site, our design has eight floors. This presents a significant challenge to achieve a very low building energy use in order to meet the target of zero net energy.

Our design provides enough area of PV to generate 1,527,918 kWh annually, which means the target Energy Use Intensity (EUI) of the project (before credit is taken for renewable energy generation) is 12.4 kBtu/sf/year. Predicted energy use as shown in section 2D will be 12.1 kBtu/sf/year.

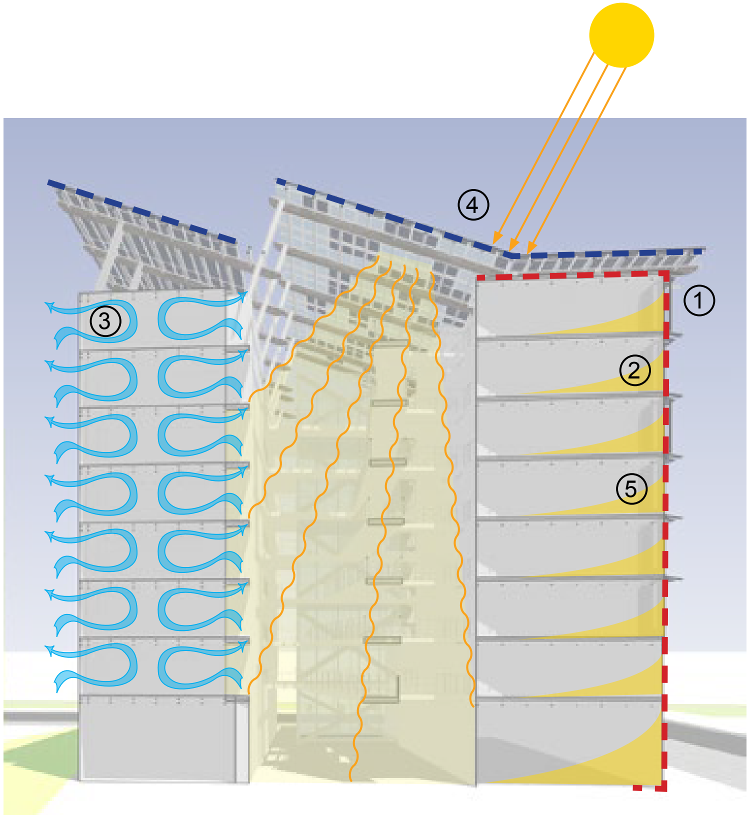
To put this target into the context of the program, based on the EUI figures for high-rise multifamily provided in Arup's study for California investor-owned utilities, the EUI of the building would be 19.6 kBtu/sf/year.

When designing to save energy it is of paramount importance to ensure users experience a high level of indoor environmental quality. It is necessary that users have ample ventilation, control over the brightness of the lighting and the temperature of their space. We have used a combination of passive and active building systems that will empower building users, giving them control over their environment, and providing them with the information they need to learn and adjust how they live to have the smallest environmental footprint possible.

PASSIVE DESIGN – OPTIMIZING THE BUILDING ENVELOPE

San Francisco's climate is relatively mild year-round, so through an appropriately designed building envelope, space heating demand can be kept very low. The first step in the process of designing an appropriate building envelope is to establish a window-to-wall ratio that balances access to natural light and minimizing heat loss. While developing this window-to-wall ratio it is important to consider the thermal properties of the glazed and opaque building elements.

High Level Whole Building Diagram – Passive Systems



COLD DAY:

1. Tight construction and good insulation minimize heat loss through the building envelope
2. Clear glass and open shutters maximize passive solar heat gain

WARM DAY:

3. Operable windows allow for cross ventilation and natural cooling
4. Solar Panel sprovide shading the roof, significantly reducing heat gain on upper floors

YEAR ROUND:

5. The window arrangement and glazing selection maximize natural light penetration into living spaces
6. Intermittent glass panels instead of PV allow natural light into the courtyards

PASSIVE DESIGN – OPERABLE WINDOWS

The residential units have no air-conditioning and rely on operable windows to provide passive cooling. The windows are placed strategically, and open at high and low levels to allow maximum air flow into the space. The open courtyard provides the opportunity for windows on both sides of the unit, allowing cross-ventilation.

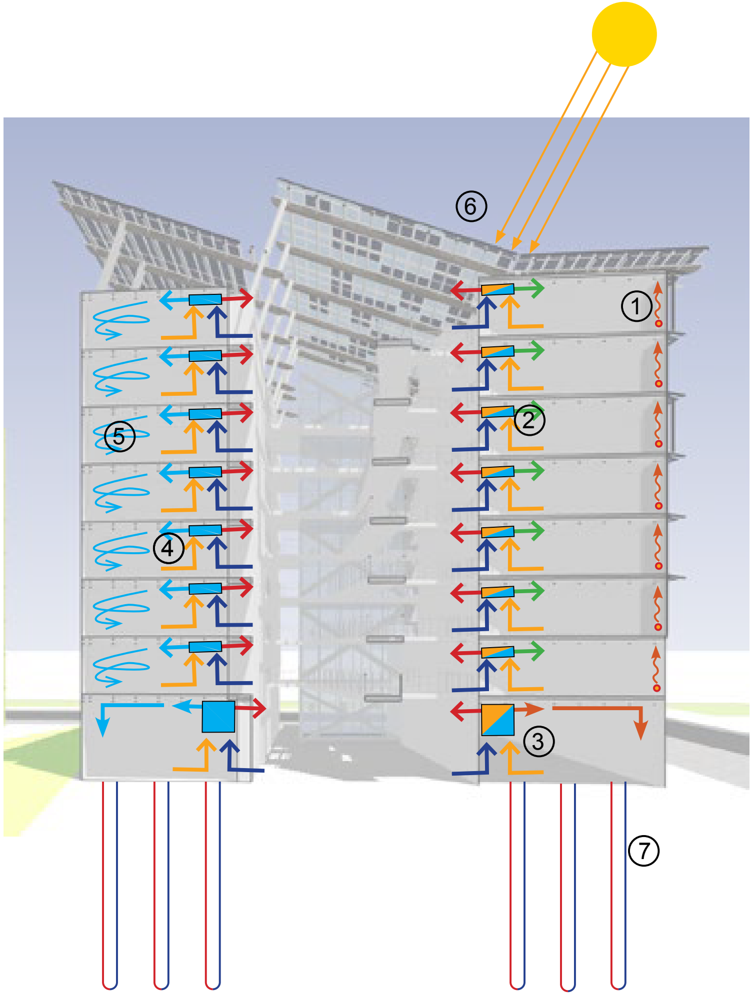
PASSIVE DESIGN – OPERABLE EXTERNAL SHUTTERS

To minimize the number of hours indoor air temperatures are too warm, when relying on passive cooling, it is necessary to manage peak solar gains. A common solution is to have a climate-responsive façade. This involves varying glazing area, using solar-selective glass, and providing different shading systems on each orientation.

Using solar-selective glass or fixed external shades is restrictive in that the more the system minimizes solar gain, no matter how carefully the shading is designed, it will have an adverse effect on passive solar heat gain, and is therefore likely to increase energy demand. Automated, operable shades or dynamic glass would allow the façade to adapt to the varying daily conditions, not just provide a one size fits all solution to each orientation, but such systems are costly, complex and can be challenging to maintain.

Our approach is different. Because the success of this project is dependent on the user being the most important part of the energy performance, we believe the user should control the facades adaptation to the external conditions. For that reason all elevations use the same clear glass to provide the best opportunity for daylight and maximize passive solar gains for the available glazing area. On cool, sunny days, the shades can be opened up to allow the sun to warm the unit, on cold windy days the shutters can be closed to minimize drafts, and on warm, sunny days the shutters can be angled to allow diffuse natural light in while blocking the direct sun.

High Level Whole Building Diagram – Active Systems



COLD DAY:

1. Perimeter heating maintains space temperature
2. HRV in residential units provides tempered ventilation air by recovering heat from exhaust air
3. Non-residential spaces conditioned with a VRF system and decoupled outdoor air.

WARM DAY:

4. HRV in residential units provides ventilation air, bypassing the heat recovery unit. This provides free cooling for the majority of the year in San Francisco
5. The use of HRV fans aid thermal comfort by providing air movement

YEAR ROUND:

6. Photovoltaic panels generate electricity
7. Vertical geoexchange wells integrated with structural ples provide high-efficiency heating and cooling

ACTIVE DESIGN – PERIMETER HEATING IN RESIDENTIAL UNITS

Space heating in the residential units has been completely separated from the ventilation system. The heat emitters are located where the heat loss exists: at the perimeter of the unit. This strategy yields the best performance from both a thermal comfort and an energy standpoint. The heat emitters rely on natural convection to deliver the heat to the space, and therefore require no fans. The hot water for heating is generated in the central plant using the most efficient hot water generating equipment available: ground-source heat pumps.

ACTIVE DESIGN – HEAT RECOVERY VENTILATORS IN RESIDENTIAL UNITS

While the tightly sealed, well-insulated building envelope minimizes the heating required due to conduction and infiltration, it is still necessary to heat the ventilation air supplied to the units. This is achieved by using in-unit heat recovery ventilators (HRVs) designed for use in Passive House buildings. These HRVs are capable of meeting all the exhaust and ventilation air requirements of the unit. They recover heat from the exhaust air, warming the supply air with 88% effectiveness. This means the HRV is capable of warming even freezing cold air to within a few degrees of room air temperature without expending any energy to heat it.

PROJECT NARRATIVE

If the operable windows are closed and heating is not desired, the heat recovery can be bypassed in order to take advantage of the free-cooling available for much of the year in San Francisco.

The outdoor air is passed through MERV 13 filters, thereby providing high quality ventilation air during times when the outdoor air quality is compromised. A high efficiency fan with an Electronically Commutated Motor (ECM) drives the airflow through the HRV. The HRVs are capable of modulating airflow in response to air quality by sensing the concentration of carbon dioxide (CO2) in the exhaust air. The main benefit of this capability is that it saves fan energy, but also has a small beneficial effect by further reducing heat demand. In San Francisco, the outdoor temperature is cooler than the indoor temperature for the vast majority of the year. If the occupant wants the windows closed, due to air quality or noise, but a cooling effect is required, the HRV airflow rate can be adjusted manually. This allows the occupant to bring in more, cool outdoor air and provide air movement within the unit, improving thermal comfort.

ACTIVE DESIGN – HEAT PUMPS

Integrated into the structural piles is a geo-exchange system that aims to provide all of the buildings' heating and cooling needs. Water runs through pipes surrounded in concrete and either pulls heat out of the ground (when the building is in heating mode) or rejects heat into the ground (when the building is in cooling mode).

Our design uses this system to meet all of the heating and cooling demands for the building. Depending on the ground conditions, it is sometimes necessary to balance heating and cooling loads that depend on a geo-exchange loop. If there is not a great deal of ground water movement, and there is significantly more heating over a year than cooling, the ground temperature can be lowered over time.

If it was found that ground conditions require a more balanced heating and cooling annual profile, then the domestic hot water (which constitutes approximately ¾ of the total annual heating demand) could be met using CO2 heat pumps. These machines use carbon dioxide as a refrigerant and can heat cold water to high temperatures at a very high efficiency (comparable to ground source heat pumps, but producing hotter water). They would extract heat out of the air rather than the geo-exhange system therefore allowing the project to balance heating and cooling loads in the ground.

ACTIVE DESIGN – AIR-CONDITIONED SPACE

Some program elements accommodated on the ground floor require air-conditioning. The area of program required is too small to lend itself to a centralized chilled water system, but it is desirable to link these spaces to the central plant. One reason to do this is to give the opportunity to recover heat from a cooling dominated space and transfer that heat to the hot water system. Another reason to do this is to allow the heat to be used to recharge the geo-exchange loop.

The most appropriate system to accomplish this is to provide each air-conditioned spaces with a water-cooled Variable Refrigerant Flow (VRF) system. This system works similarly to a water-source heat pump system. A condenser water line is run from the central plant to the air conditioned space, and the VRF system either pulls heat out of or rejects heat into the condenser water depending on whether cooling or heating is required. The geo-exchange loop maintains a relatively neutral water temperature, making the VRF operate very efficiently in both heating and cooling.

In addition to providing mechanical cooling, the spaces are provided with outdoor air that is oversized to allow free cooling for the vast majority of the year. This system is independent of the VRF system. During cold or hot weather, the volume of outdoor air can be turned down to save heating or cooling energy while still providing the required ventilation rate.

ACTIVE DESIGN – LIGHTING

The proposed lighting system makes use of dimmable LEDs that will not only respond to the levels of natural light in the space, but also provide sufficient illumination so the users do not feel the need to supplement lighting with additional lamps. Task lighting will be provided where appropriate to allow the user to reduce the general illumination levels.

ACTIVE DESIGN – PLUG LOADS

All electrical equipment in the units will be Energy Star rated, and separate circuits will be provided for equipment that does not need to remain on when the unit is unoccupied. The users will be provided with the means to easily shut-off power as they leave, or by remotely shutting off the power using their smart phones.

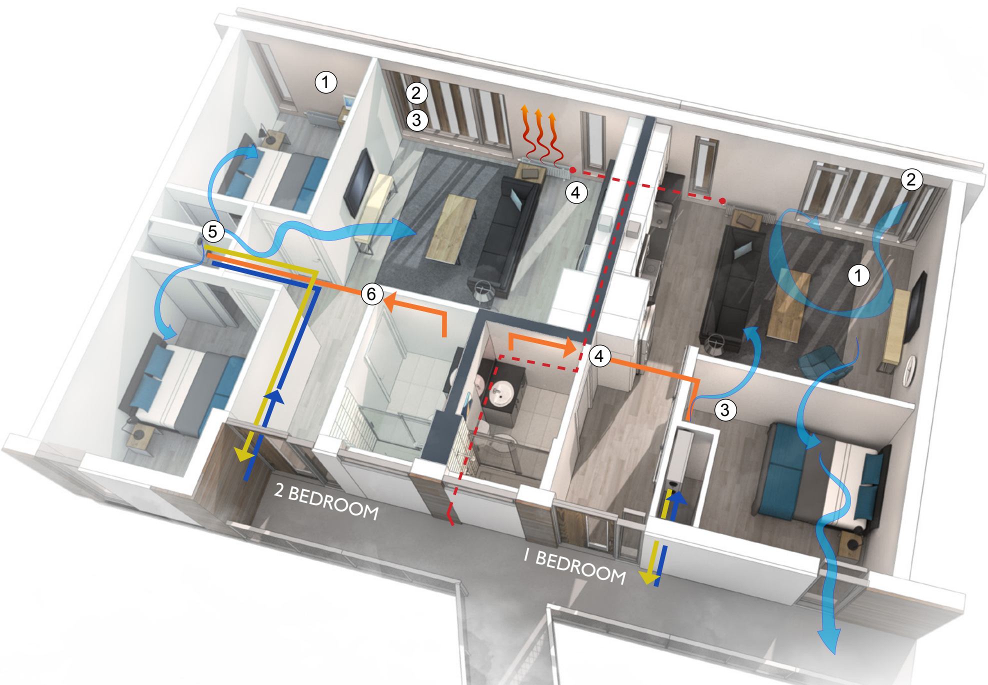
RESIDENTIAL UNIT SYSTEMS

1) how the space is heated, ventilated, and cooled (without AC);
2) how water is heated and delivered to the unit; and
3) the design of the electric lighting in the unit (not provided later by the tenants)

The sketch should show the location of equipment and how hot air and water will be distributed.

WARM DAY

1. Operable windows for passive cooling.
2. External shutters provide users control over solar heat gain and glare.
3. HRV provides ventilation when necessary (CO2 control) - no heat recovery
4. HRV provides bathroom exhaust when required.



- Exhaust air
- Exhaust air - heat recovered
- Outdoor air
- Tempered fresh air
- Hot water piping

COLD DAY

1. Tightly sealed, well-insulated envelope minimizes heat loss.
2. External shutters are open to allow passive solar heat gain.
3. Clear glass maximizes opportunity to receive passive solar heat.
4. Hydronic radiator provides heating at perimeter supplied by a high efficiency central plant.
5. HRV provides ventilation - with heat recovery.
6. HRV provides bathroom exhaust when required.

Simple diagrammatic sketch of a typical 1 bedroom residential unit

RESIDENTIAL UNIT SYSTEMS

Provide a brief (1 page or less) written description of the approach to space heating, ventilation, and water heating of the residential units. Describe your approach to cooling the residential units and common spaces without AC. Describe the types of systems used (such as a gas-fired boiler that heats water and distributes it to radiators in residential units) and any energy efficient strategies or equipment metrics. Note any major differences in the approach between the buildings.

Description of Residential Unit Systems

The buildings are designed to use very little energy to deliver thermal comfort and fresh air to occupants. As such, the HVAC systems work in concert with the operable façade in each residential unit to provide climate-responsive heating and cooling enabled by building occupants.

On a cold day, the well-insulated envelope minimizes heat loss. At approximately 35% window-to-wall ratio with double glazed windows, the envelope has been optimized for a passive heating strategy. In the winter, the external operable shutters will be opened to allow passive solar heat gain, providing a significant portion of the heating required. Clear glazing with a high solar heat gain coefficient (SHGC) maximizes the opportunity for the room to receive the solar gain. If additional heating is required for the coldest days, hydronic radiators will provide heating at the perimeter using hot water generated from ground source heat pumps. A low-energy-use heat recovery ventilator (HRV) in each unit provides tempered outdoor air for ventilation and bathroom exhaust when required. The demand-control ventilation system monitors CO2 concentration in the units, ensuring that enough fresh air is being provided to occupants even when the windows are closed.

On a hot day, extensive user-enabled shading prevents the solar heat gain from entering the unit, thereby reducing cooling loads without using energy. Operable windows enable passive cooling by flushing the room with outside air. These points of operability allow the occupants full control over their indoor environment, providing for daylight and cooling conditions unique to each unit. In passive cooling mode, fresh air is delivered to the units through the heat recovery ventilator when airflow through the windows is not sufficient. In summer mode, no heat is recovered from the room because no additional heat is required.

The electric lighting is designed to be low-energy-use and dimmable, to give occupants full control over their indoor environment. Coupled with external operable shades, occupants will be able to choose their light level and the appropriate mix of natural and electric light to suit the needs of their activities. Each unit also has a master switch that allows residents to completely shut off their lighting upon exiting, enabling them to save energy while they are gone. When they return and occupy the unit again, the lighting resumes at their preferred setting.

RENEWABLE ENERGY

1. For each building, list all solar electric and solar thermal system types included, assumptions about performance metrics, and the square footage for each in a summary table. Also include any other renewable systems (such as building integrated wind).

2. For each building, calculate the total annual energy production of each renewable energy system included in your design and shown on the annotated site plan. List the energy production of each and the total energy production at the building site in the summary table. Include the calculations in part of the Task 2 Energy Performance Documentation submittal. If the renewable systems are shaded at different times of day or year, this will affect total energy production and should be incorporated into the calculations.

3. Does your design reach ZNE performance? Provide a brief (2 pages) description of how close the project site gets to ZNE and any major reasons why it does or does not. You may include the results of whole building energy models – be sure to include a description of the software used and any major assumptions, as well as which building is modeled.

Renewable Energy Summary Table

		Roof Area Utilized (SF)			Total Annual Production (kWh)		
Renewable System	**Efficiency**	South Bldg	West Bldg	North Bldg	South Bldg	West Bldg	North Bldg
Solar Photovoltaic	21%	21,586	17,071	13,072	569,425	621,521	336,973
TOTAL		**51,729**			**1,527,918**		

2G

RENEWABLE ENERGY

Renewable Energy Table

		BUILDING		
		6th Street (West Bldg)	Nelson Rising Road (South Bldg)	Mission Bay Blvd. S. (North Bldg)
PV System Parameters	PV Module Efficiency	21%	21%	21%
	Azimuth (°)	175	175	175
	System Energy Density (W/SF)	19	19	19
ARRAY 1	Tilt Angle (°)	0	0	0
	Total Array Area (SF)	6,230	8,830	7,910
	Percentage Area Utilization	100%	100%	100%
	Roof Area Utilized (SF)	6,230	8,830	7,910
	Array Size (kW)	118	168	150
	System Performance (kWh/kW)	1,361	1,361	1,361
	Total Annual Production (kWh)	161,102	228,335	204,545
ARRAY 2	Tilt Angle (°)	20	20	20
	Total Array Area (SF)	4,470	5,200	9,740
	Percentage Area Utilization	75%	53%	53%
	Roof Area Utilized (SF)	3,353	2,756	5,162
	Array Size (kW)	64	52	98
	System Performance (kWh/kW)	1,531	1,531	1,531
	Total Annual Production (kWh)	97,521	80,169	150,163
ARRAY 3	Tilt Angle (°)	20	20	
	Total Array Area (SF)	3,800	10,000	
	Percentage Area Utilization	100%	100%	
	Roof Area Utilized (SF)	3,800	10,000	
	Array Size (kW)	72	190	
	System Performance (kWh/kW)	1,531	1,531	
	Total Annual Production (kWh)	110,538	290,890	
ARRAY 4	Tilt Angle (°)	20		
	Total Array Area (SF)	4,900		
	Percentage Area Utilization	100%		
	Roof Area Utilized (SF)	4,900		
	Array Size (kW)	93		
	System Performance (kWh/kW)	1,531		
	Total Annual Production (kWh)	142,536		
ARRAY 5	Tilt Angle (°)	20		
	Total Array Area (SF)	4,900		
	Percentage Area Utilization	100%		
	Roof Area Utilized (SF)	4,900		
	Array Size (kW)	93		
	System Performance (kWh/kW)	1,531		
	Total Annual Production (kWh)	142,536		
Total Production				**1,608,335**
Annual Loss Due to Shading				**5%**
Total Production				**1,527,918**

RENEWABLE ENERGY

Renewable Energy Narrative

The project site achieves zero net energy, producing all of the energy used by the buildings on an annual basis, through the strategic combination of low energy building design and rooftop renewable energy systems.

Solar photovoltaics (PV) provide all of the energy required to meet the zero net energy goal. The PV system has been designed with 21% efficient SunPower PV panels, which is the most efficient PV technology commercially available. Employing a single renewable energy technology is the most aesthetically succinct solution, and also provides simplicity for construction, building operation and maintenance. PV can directly provide renewable electricity for all of the electrical building loads and, with the use of a heat pump, can provide efficient domestic hot water heating.

The rooftop photovoltaic arrays provide the optimal intersection of energy production, façade shading, and daylight availability. The southern-most portions of the rooftop solar arrays lie flat on the roof, generating a two foot overhang to shade the southern facades. This horizontal shading, repeated on each floor of the southern facade, is elemental in the passive cooling strategy through operable windows, promoting thermal comfort by blocking the intense summer sun before it enters the residential units through the windows. The horizontal PV at each floor line, in addition to providing overhead shading, generate power for the vertical shutters. For simplicity of construction and operation, the façade PV and operable shades are tied to the central building electrical systems. However, microinverters and submetering enable this localized energy production and end use to be metered and dynamically tracked at the apartment level, further informing and educating residents about daily and seasonal cycles of the net zero energy building.

The 20° pitch of the solar arrays is the design aspect of the roof mounted PV system that makes zero net energy possible. The sloped arrays provide the bulk of the PV system efficiency producing 12% more energy per square foot than the flat arrays.

Finally, the solar arrays on each building incorporate a distribution of clear glass panels to provide daylight access to the atrium spaces below. About 20% of the total solar array area is glass panel. This approach provides benefits to energy savings and occupant comfort, reducing the need for electric lighting in the central courts which creates the units' primary circulation. The PV arrays with distributed glazing were designed to reduce solar gain while maximizing PV energy output.

Due to the density of PV required to meet the zero net energy goal, some seasonal overshadowing will occur on the solar arrays. However, the annual energy production benefit gained by incorporating the affected PV is greater than the energy loss if these panels were not included. In order to minimize the production loss due to shading, microinverters will be employed throughout the rooftop PV arrays. The overall production loss due to overshadowing is estimated at 5% annually. The energy modeling undertaken to evaluate this design approach accounts for this loss and is consistent with the current NREL research on performance modeling with module-level distributed power electronics.

OCCUPANT BEHAVIOR

Provide a brief description of aspects of each building design, if any, that are intended to influence the behavior of residents to reduce energy demand.

UCSF Student Profiles

In order to better engage tenants for energy efficiency, and provide a more accurate model, it is useful to tailor the energy model to specific occupant profiles rather than default settings.

The design team researched the student demographics for the campus as a whole using university records. Interviews of students from UCSF and other schools were conducted, providing insight into occupancy and use patterns of on-campus residents. From that data, the future residents were divided into three profiles:

Profile 1 includes PHD, Masters, PharmD, and DDS students, who make up an estimated 50% of residents.

Profile 2 includes MD and Nursing students, and makes up an estimated 33% of residents.

Profile 3 includes faculty and families of all student and faculty types, and make up the remainder 17% of residents.

The three profiles were charted compared to the default multifamily residential settings in the energy model, and a weighted average (in the proportions outlined above) is indicated to refine the assumption of occupancy and lighting patterns in the residential units. We also know, from speaking with representatives of the UCSF Housing Services, that on campus housing is nearly 100% occupied year round.

Current UCSF Mission Bay housing data, provided by UCSF Housing Services staff:

> *"Our student tenants come from a variety of degree programs. Tenants are selected through a lottery process to live in campus housing. As of today we have 454 student tenants from the following programs:*
>
> *Graduate Division – 133*
> *School of Medicine – 53*
> *School of Nursing – 41*
> *Post-baccalaureatte – 12*
> *School of Dentistry – 84*
> *School of Pharmacy – 131"*

PROFILE 1 - PHD, MASTERS, PHARMD, DDS

This group of residents maintains a fairly regular 9:00am to 5:00pm schedule, either working in a research lab on campus or attending classes. They are likely to be home in the evenings and in and out on the weekends.

Neuroscience PhD student interview 8/30/15:

> *"I work in a research lab and maintain a M-F 9-5 schedule so I'm mostly home in the evenings and in and out on the weekends... Most people take short (~30 min) lunches and are in the lab aside from that. Even people who live on campus tend to pack a lunch."*

OCCUPANT BEHAVIOR

Pharmacy student interview 9/04/15:

> *"Okay, so during pharmacy school depending on what year I was, different "chunks" of the day were dedicated to school. We would have a set 3-4 hour period of classes, sometimes AM, sometimes mid morning-afternoon, sometimes late afternoon. We were predictably always done by 5pm at the absolute latest. We would have a lab once a week that would keep us an additional 3-4 hours (again, scheduled to be done by 5pm). Weekends were exclusively at home for me, unless a huge exam was coming up, then we would camp out at the school or library."*

PROFILE 2 - MD, NURSING

This group of residents has a less regular schedule than the residents of Profile 1. While these students may have classes during the 9:00am to 5:00pm time period, their clinical shifts, which are held at locations throughout the city, can be up to 12 hours long and may often begin in the early morning hours or end in the late evening. We have made the assumption that they are away from home for longer periods of time and are more likely to stay in on the evenings and weekends, primarily to sleep, rest, and study.

Medical student interview 9/03/15:

> *"Ideally, med students would have a galactic pod where the bed makes itself, a self-cleaning kitchen spits out 3 nutritional bars per day, and a handful of individual pods are oriented around a deluxe study/conference room with natural light and whiteboards galore. We really have no predictability in our schedule unfortunately, unless you map it on a calendar by days and proximity to exams. Some people live out of the library and never go home, whereas others (like me) stay at home and watch lectures on my computer and avoid the library like the plague. But everything after the end of second year is more predictable because we're on the wards. Then its more like M-F, 4am-6pm-ish, depending on the rotation. Usually they're all about 12hrs per day and M-F, but they vary in start time by specialty....and everyone rotates through different specialties in different orders...."*

Nursing student interview 9/03/15:

> *"Personally, my program was fairly 9-5 with some variation (for instance, one quarter I had clinical consistently on Saturday, and my final quarter was a complete hodgepodge because I was doing my senior practicum and following my preceptor's schedule). Clinicals tend to follow the hospital's schedule, starting early around 7am and ending at 3:30pm or 7:30pm (depending whether it's an 8- or 12-hour shift). Class days started in the morning between 7:30-9 and ended in the mid-afternoon/evening. Most of my at-home time and energy use was in the evenings after class or clinical, and I was home for most of the weekends as well. ....thoughts on housing needs are the importance of quiet study spaces (and well-insulated walls, for that matter), and opportunities for self-care (exercise room, gardens, space for socialization)."*

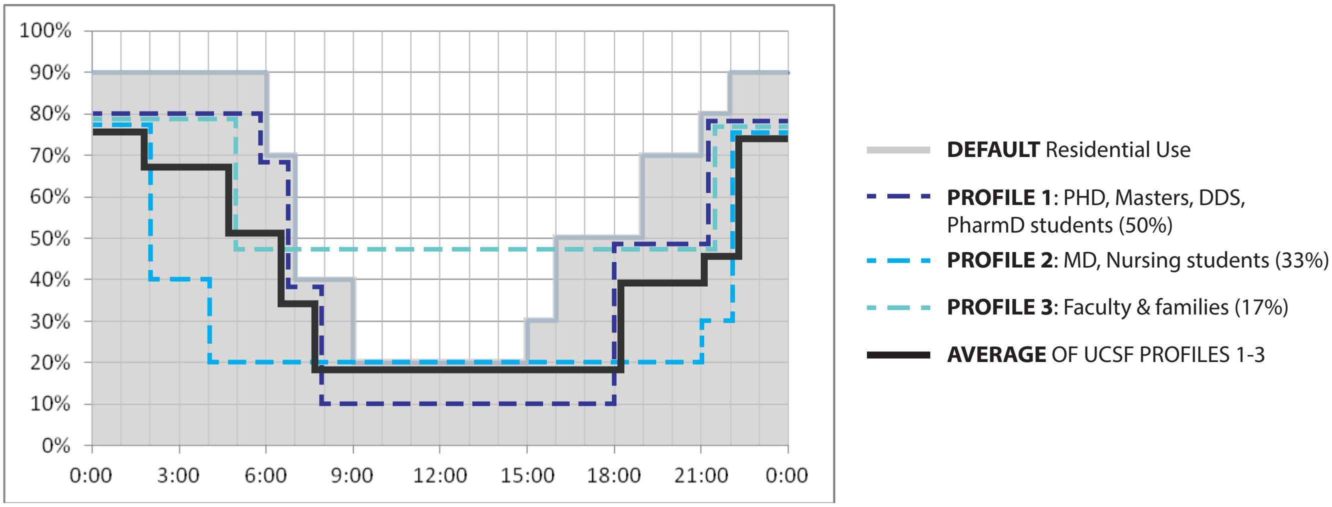
PROFILE 3 - FACULTY AND FAMILIES OF OTHER STUDENT TYPES

While some faculty may maintain on-campus 9:00am to 5:00pm positions, there are some that may not work on campus everyday and have some work they choose to do at home. We assume that the families living with the students or faculty do not maintain the '9 to 5' schedule, therefore the group of residents in Profile 3 are more likely to be home in the middle of the day than other residents. We assume they prepare more meals at home, and spend more active time with family in the home over the weekends.

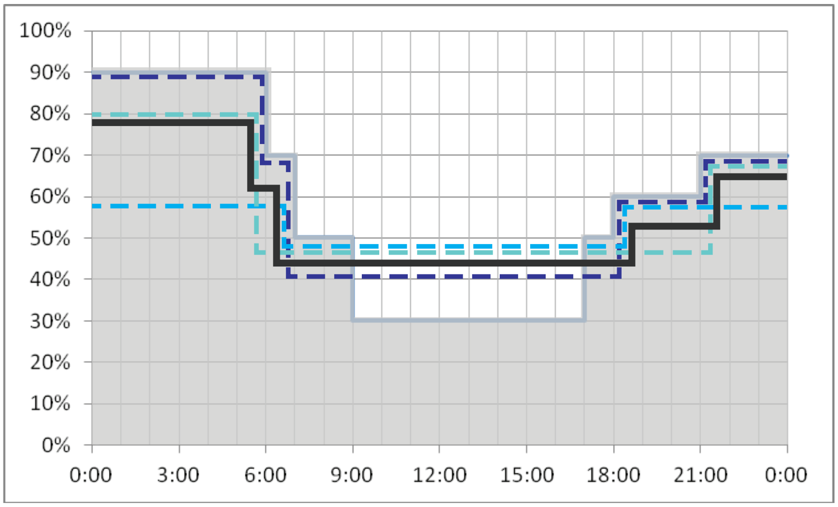
Faculty (former PhD student) interview 9/04/15:

> *"I teach 2-3 courses per semester, advise students, and work on research. Currently I usually try to set my schedule as two teaching days, and one advising / meeting day. The remaining two days I work on articles and research. My schedule is such that I can work from home or the office, it is not 9-5. Some days 6am to 10pm, some days 12pm to 4pm... As a PhD student at Davis I had classes most days of the week at first, but then the schedule slowed down so I would commute up there a few days per week by train."*

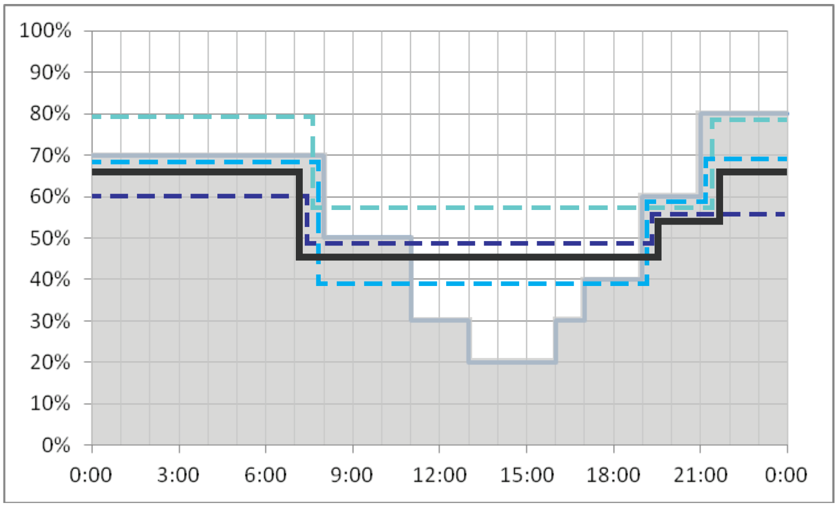
OCCUPANT BEHAVIOR



Occupancy – Weekday

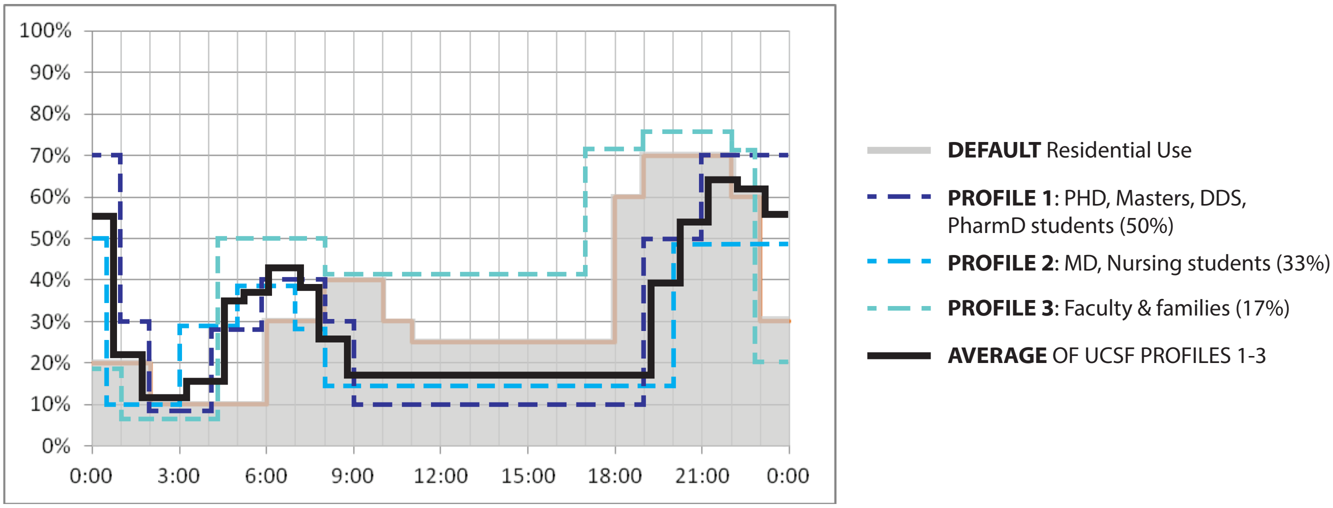


Occupancy – Saturday

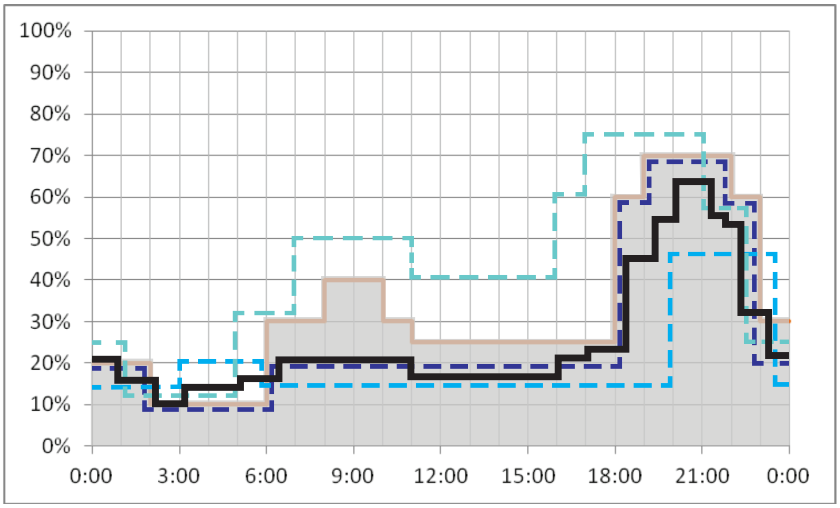


Occupancy – Sunday

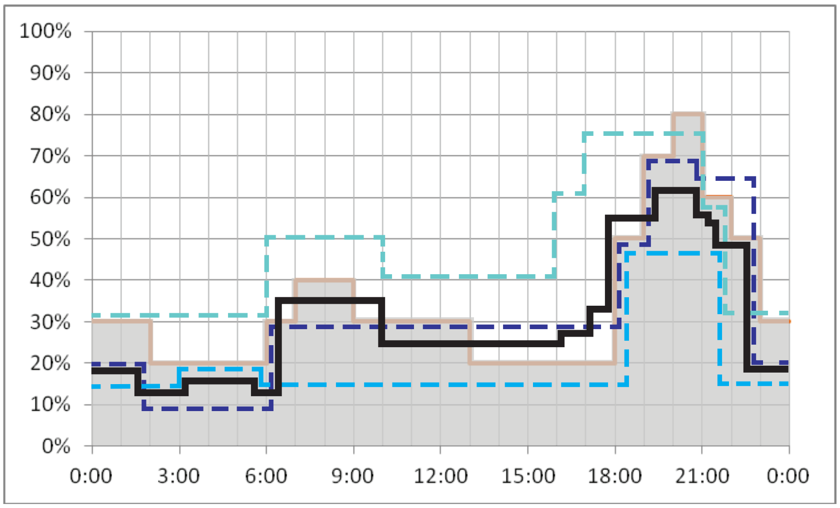
OCCUPANT BEHAVIOR



Lighting – Weekday



Lighting – Saturday



Lighting – Sunday

OCCUPANT BEHAVIOR

Enabling Building Occupants to Achieve the Smallest Energy Footprints

Ultimately, achieving ultra-low energy use during operation relies on the residents who require – and influence – the amount of heating, lighting and domestic hot water used. The residents further consume varying amounts of energy for food production/storage and to power anything they plug into wall receptacles. While it is challenging, if not problematic, to accurately estimate in advance the energy use of each individual, for a multi-family project with a (statistically) understood demographic we are able to draw reasonably close to the mark in predicting the energy use patterns of the average occupant. We have carefully reviewed the programmatic data, visited the site and spoke to students. We concluded there could be a significant variation in user influenced energy use based on whether the demographic resolves into either primarily foreign national students that may likely include some multi-generational living scenarios or one where the majority of students are U.S. born Generation Z.

Regardless of the demographic, research has shown that residents' "energy-unaware" behavior results in as much as twice the energy consumption as the minimum that can be achieved. For this reason, we propose to provide occupant feedback on their energy consumption in a manner that promotes conservation. The core infrastructure would include an advanced interval energy meter data acquisition system, with information storage and a dynamic reporting system. The system would include the ability to track overall usage of individual apartments, occupied defined "neighborhoods" (i.e. floor) within the development, and the overall development, as well as:

1. Energy use of primary heating and domestic hot water systems

2. Energy use of common areas, broken down by usage category (lighting, receptacle, ventilation, elevator, etc.)

3. Energy use of each apartment, and potentially sub-metered by usage category.

Recognizing that Generation Z lives on-line and smart phones and other devices that enable it are ubiquitous, energy information feedback would include an app that provides:

1. How an individual resident's apartment and end uses use energy, including near-real time, historical usage, and usage relative to net zero "budget" that is weather-normalized. Residents would be able to view (anonymously) their own apartment's normalized energy usage within their "neighborhood" as a benchmark to privately see how they are performing compared to their neighbors.

2. How the individual's "neighborhood" within the building is using energy, again considering near-real time, historical usage, and relative to net zero "budget." Competition between floors is encouraged by clearly identifying the high-performing floors within the building.

3. How each building is using energy at any given time. Residents would again be able to view each building's normalized energy usage relative to the net zero budget. Competition between buildings can be encouraged by identifying the high-performing building(s) within the project.

4. Renewable energy production would be displayed in real time, as well as over the last week, month, and prior 12 month period.

OCCUPANT BEHAVIOR

5. Resident's may optionally configure the app to "push" energy alerts to them to them when they are wasting energy relative to their budget, or they achieve exemplary performance relative to the budget and benchmarks.

A key aspect to encourage competition and drive occupancy behavior to better efficiency, is to publicly display performance levels in addition to the smart phone app for the individual. Between "neighborhoods" (floors within the building), a visual display on centrally located walkways in the open courts will indicate the top three efficiency leaders. Similarly, between the three apartment buildings within the project, a portion of the exterior of the building will identify the highest-performing building (relative to the zero-energy budget) to the broader campus through colored LED lighting.

A public energy information center website would also be available that provides the residents, school, and the public, to see how the overall development is doing relative to the Net Zero goal. Residents can log-in at this site to access the private "view" of energy data found on the app.

The objective of this enabling energy information system is to educate occupants on building energy use and to guide them to make choices to reduce energy use by (e.g.) simply turning off lights and appliances when not in use. A low-technology, simple "Master Switch" is proposed for each apartment at each entrance that allows occupants to conveniently turn off equipment, lighting and appliances plugged into identified non-essential receptacles.

In addition, "intelligent building" technology is proposed that will enable the Building to know and optimally respond to occupant chosen preferences and needs with regard to comfort and health and further reducing energy waste. In individual apartments, thermostats will be used that are programmed to learn user preferences and their normal schedules and maintain temperatures at comfortable conditions based on (1) occupied and awake, (2) occupied but asleep, and (3) unoccupied.

A second, emerging, future-ready technology again relies on smart phones or other devices that occupants carry with them and a wireless network within the development that is able to recognize distinct occupant locations at a much higher granularity than GPS, down to individual spaces within the building. In individual apartments, while this technology could potentially be used to provide full energy management, we are proposing initially it just be used to increase or decrease ventilation rates to each unit based on the number of current occupants. In common amenity/study spaces, the technology would enable ventilation quantities to be managed based on total occupancy. In addition, the heating would be optimized for comfort and energy efficiency based on a "vote" by current occupants of their preferences. The app enables occupants to "vote" whether to shut off ventilation and heating to a space entirely when outdoor conditions indicate opening windows would be effective to efficiently maintain comfort in a space. The "vote" of preferences changes over time as individuals enter and leave the space.