ENERGY PERFORMANCE DOCUMENTATION

Architecture at Zero 2015

dWELLBEING
San Francisco, CA

dWELLBEING

September 25, 2015

Summary

dWELLBEING addresses a building's impact on and interaction with the environment, while simultaneously improving human health and well-being by integrating high-performance systems with behavioral awareness. The building itself is an interactive environment that enables its residents to understand how individual choices and activities influence consumption and performance through technology, while providing opportunities for occupants to give back via their own actions, behaviors and activities.

This document details the design of the building systems and provides documentation for the anticipated energy performance of the project, dWELLBEING. An integrated design process included early energy modeling using a custom modeling tool, analyzing four HVAC systems and more than 1,000 individual energy conservation measures. These individual energy conservation measures were grouped into Bundles, providing the design team with several energy design options with varying levels of cost effectiveness and energy performance.

With bundled energy performance targets in mind, potential renewable systems were analyzed, taking into account energy generation potential and effectiveness. These renewable systems were designed so as to optimize the overall renewable energy potential on site and bring the annual net building energy use to zero.

18.8	–	18.9	=	-0.1
BUILDING'S TOTAL EUI		RENEWABLE PRODUCTION EUI		BUILDING'S NET EUI

2A. Window-to-Wall Ratio

Striking a balance on window-to-wall ratio can be a very challenging task during design. Early energy analysis allowed for optimization of window size to allow for natural light, views and daylighting controls while minimizing thermal conduction through the window openings. The following table provides a brief summary of window-to-wall ratio by façade. See the Appendix for the completed worksheet.

Orientation	Glazing Surface	Total Façade	Window-to-Wall Ratio
North	10,000	50,200	20%
East	2,200	29,200	7%
South	10,000	33,300	30%
West	5,700	28,300	20%
Total	**27,900**	**141,000**	**20%**

2B. Window Openings and Window Shading

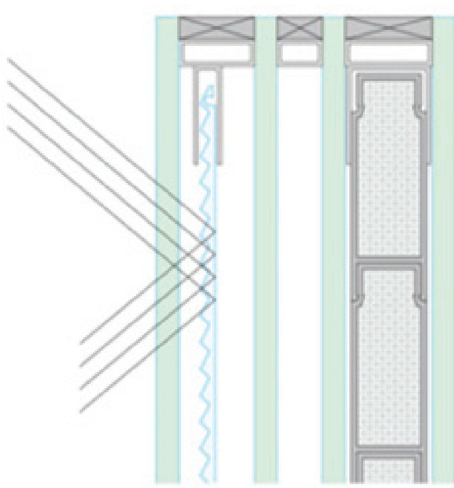
Thermal properties of the windows were studied in an effort to minimize conduction through the window assembly and balance the impact of solar heat gain between the cooling and heating seasons. Triple-pane, clear low-e glazing with argon gas fill was selected as the basis of design for all residential areas, as well as the common spaces, Childcare area and Police office. South and west façades incorporate thermodynamic glazing with prisms and phase-change material. The table below summarizes the performance characteristics of the chosen glass. See the Appendix for completed worksheet.

Orientation	Unit U-Factor	COG U-Factor	SHGC	V-T
North	0.26	0.13	0.32	60%
East	0.26	0.13	0.32	60%
South*	0.24	0.11	0.33 winter 0.24 summer	50%
West*	0.24	0.11	0.33 winter 0.24 summer	50%

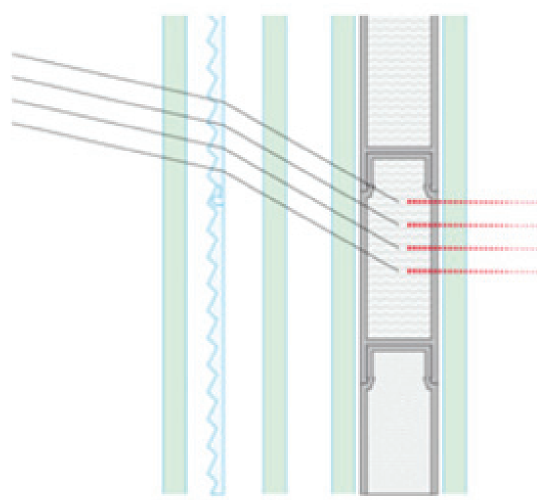
**Note: Properties of glazing on south and west façades is a combination of triple-pane vision glass (2/3) and thermodynamic glazing (1/3).*

In an effort to control solar radiation into the space, especially in the summer, the design team has chosen an advanced, thermodynamic glazing system which includes prisms and phase-change material. Windows on the south and west façades will be made up of 2/3 triple-glazed vision glass as described on the previous page. The remaining 1/3 of the windows utilize GlassX Crystal. GlassX Crystal is a four-pane glazing product which includes a prism plate in one cavity and phase-change material in another cavity. As shown in the images below, the prism is designed to reflect solar radiation at high summer sun angles, but allows solar radiation and lower winter sun angles. The phase-change material will help to delay and reduce thermal conduction into the space.

Summer: Sun high in the sky >40^0
Solar-Heat-Gain-Coefficient
(G-value) = 6-9%



Winter: Shallow winter sun <35^0
Solar-Heat-Gain-Coefficient
(G-value) = 33-35%



Source: http://www.glassxpcm.com

2C. Building Enclosure Details

Wall Details

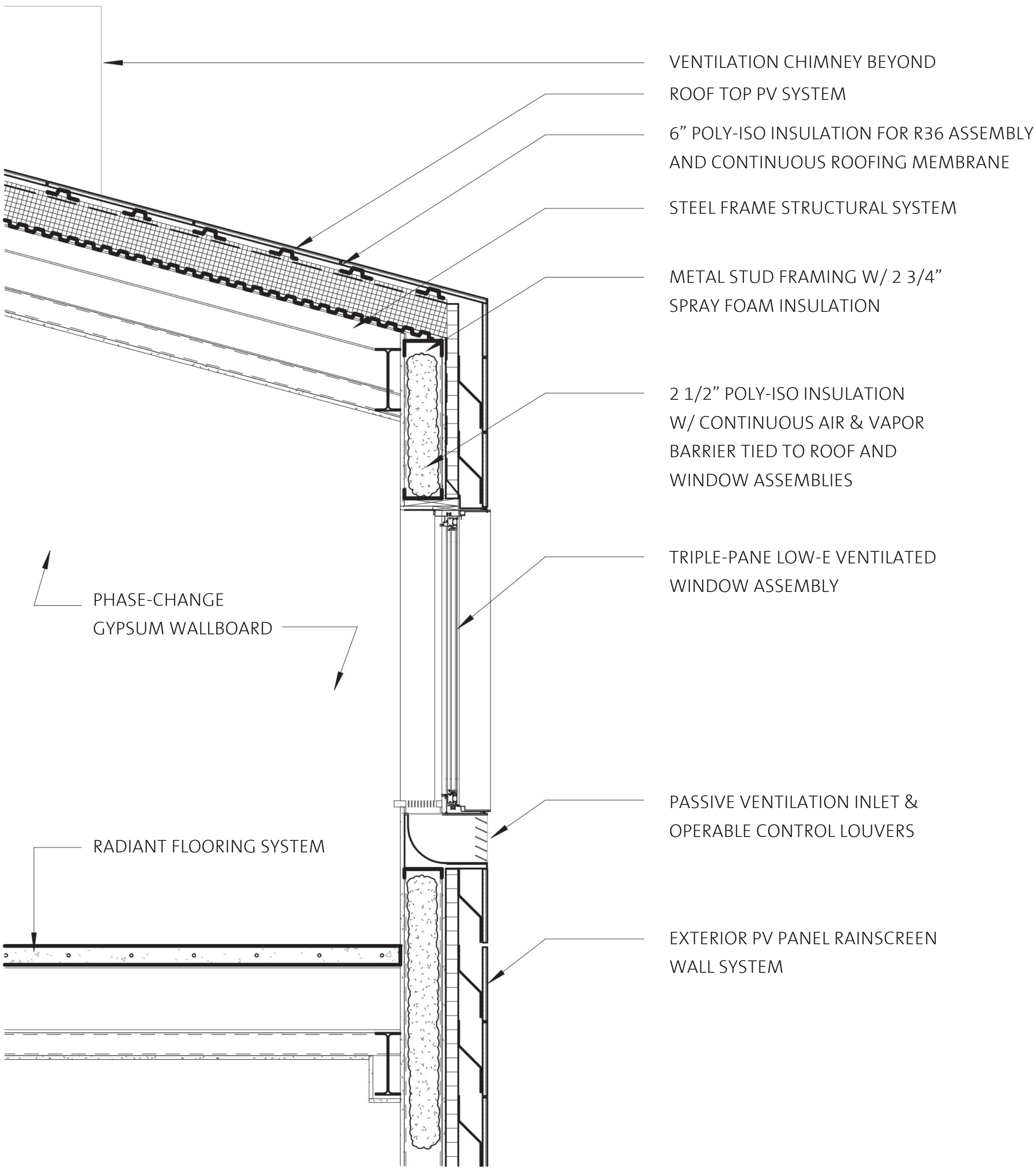
The exterior walls are made up of steel studs (2”x4”), spaced 16” on center. Spray foam (2 ¾” deep) provides insulation between the studs and acts as an air barrier to reduce infiltration. Extruded poly-iso insulation (2 ½” thick) is added interior of the studs, bringing the total assembly insulation value to R-24 (U-0.041). Phase-change wallboard increases the heat capacity of the wall assembly, delaying heat gain into the space into the evening and night. Total assembly insulation value of R-24.

Roof Details

The roof is steel frame with 6” of insulation above deck, providing a total assembly insulation value of R-36 (U-0.028). Phase-change wallboard increases the heat capacity of the roof assembly, delaying heat gain into the space into the evening and night.

Rainwater Collection

Understanding the importance of water conservation along the west coast, a rainwater harvesting system will be installed. This system will collect rainwater from the roof and store it as a way of controlling run-off and for use on site. With annual precipitation of approximately 24 inches for the San Francisco area, rainwater collection will result in harvesting nearly 600,000 gallons of freshwater.



EXTERIOR WALL SECTION

NOT TO SCALE

2D. End Use Breakdown

The Bundle of energy conservation measures selected by the team (and outlined below) achieves an expected total annual energy use of 18.8 kBtu/sf. The table below summarizes the energy consumption by end use and key design assumptions.

	Design Load		**Calculated Energy Use (Btu/sf/year)**
End Uses			
HVAC	--------------------		2,165
Lighting	Residences: 0.08 Commons: 0.69 Childcare: 0.51 UCFS Police: 0.63	*W/sf*	540
Appliances and Plug Loads	Residences: 0.58 Commons: 0.50 Childcare: 0.88 UCFS Police: 0.75	*W/sf*	9,625
Domestic Hot Water	Residences: 18.0 Commons: 0.26 Childcare:0.61 UCFS Police: 1.0	*gal/per/day*	6,499
Total			**18,830**
Renewable Production	---------------------	----------------	18,950
Net EUI	---------------------	----------------	-120

List of Selected Energy Conservation Measures

The following pages include a summary list of the selected strategies. Savings are shown compared to an ASHRAE 90.1-2010 Baseline model. These energy conservation measures reduce the total building energy use to 18.8 kBtu/sf/year.

Building System Category	Energy Reduction from Baseline
Insulation	1.9%
Glazing	5.1%
Lights	16%
HVAC	25.6%
Service Water Heating	1.1%
Plug and Process Loads	4.3%
Total	**54%**

Energy Conservation Measure	% Energy Savings Contribution
R-24 total wall assembly	2%
R-36 total roof assembly	<1%
Optimized window-to-wall area ratio	<1%
Triple-pane clear low-e glazing with argon fill in thermally broken aluminum frames and thermodynamic glazing on south and west façades	8%
Automatic dimming daylighting controls; apartment living spaces, common areas, Police, Childcare	5%
Vacancy sensor control of electric lights in common areas and Police	1%
Lighting power in Apartments reduced to 0.08 W/sf	20%
Lighting power in Childcare reduced to 0.69 W/sf	1%
Lighting power in Common areas reduced to 0.51 W/sf	1%
Lighting power in UCFS Police reduced to 0.63 W/sf	< 1%
Mechanical system: Common areas, Childcare, UCFS Police: Ground-coupled water to air heat pumps. Apartments: Hot water heat with natural ventilation	10%
<30% increased heat pump COP; Childcare, common areas, UCFS Police	<1%
30% increased heat pump EER; Childcare, common areas, UCFS Police	<1%
95% efficient condensing gas boiler system, aggressive temperature reset	1%
Beyond premium efficiency fan and pump motors	<1%
Apartment radiant heating	28%
Common area, Childcare, Police fan system power at 0.27 Watts/CFM	<1%
VFDs on ground-coupled heat pump loops, hot water heating loop	<1%
Occupancy sensor control of zone ventilation and temperature; apartments, common areas, Childcare, UCFS Police	<1%
95% efficiency service water heaters	4%
WaterSense low-flow showerheads	2%
ENERGYSTAR-rated appliances; clothes washers, dishwashers, refrigerators	8%
Occupancy sensor control of office equipment; Childcare, UCFS Police	<1%
Programmable thermostats in apartments	3%

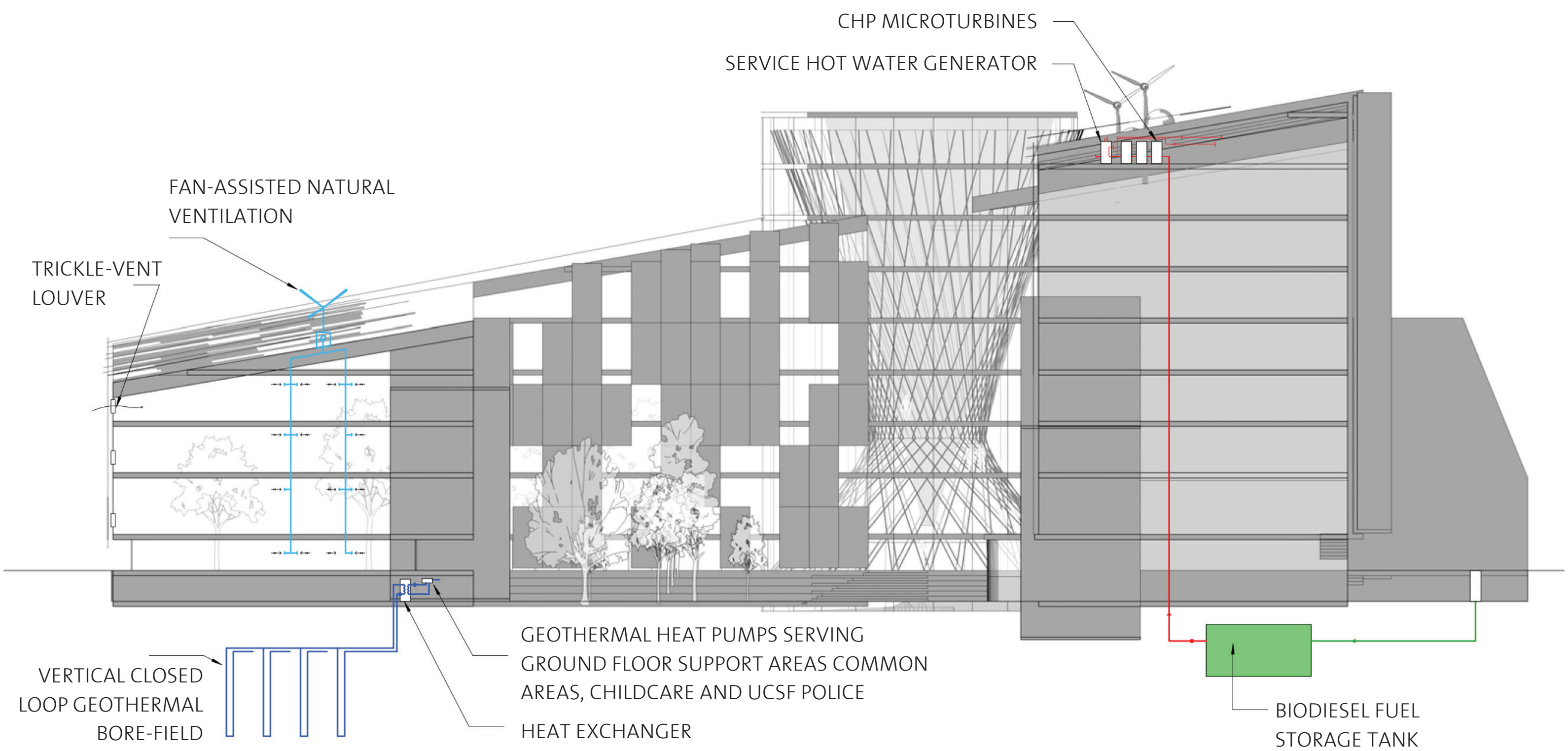
2E. Description and Diagram of Whole-Building Heating and Cooling System

Heating and cooling for the ground-floor community and support spaces, including the Childcare and UCSF Police offices, is provided by distributed ground-coupled geothermal heat pump units. The heat pump units include ECM motors for increased energy efficiency. A closed-loop vertical borefield installed under the native plantings landscaped area takes advantage of the constant ground temperatures and high water table to dissipate or capture heat for the heat pump water loop. A heat exchanger separates the borefield ground loop and the building water loop and pumps equipped with VFDs circulate water in each loop. The heat exchanger, pumps and ground-loop manifold are located in a ground-level mechanical room for facility staff to easily service and maintain.

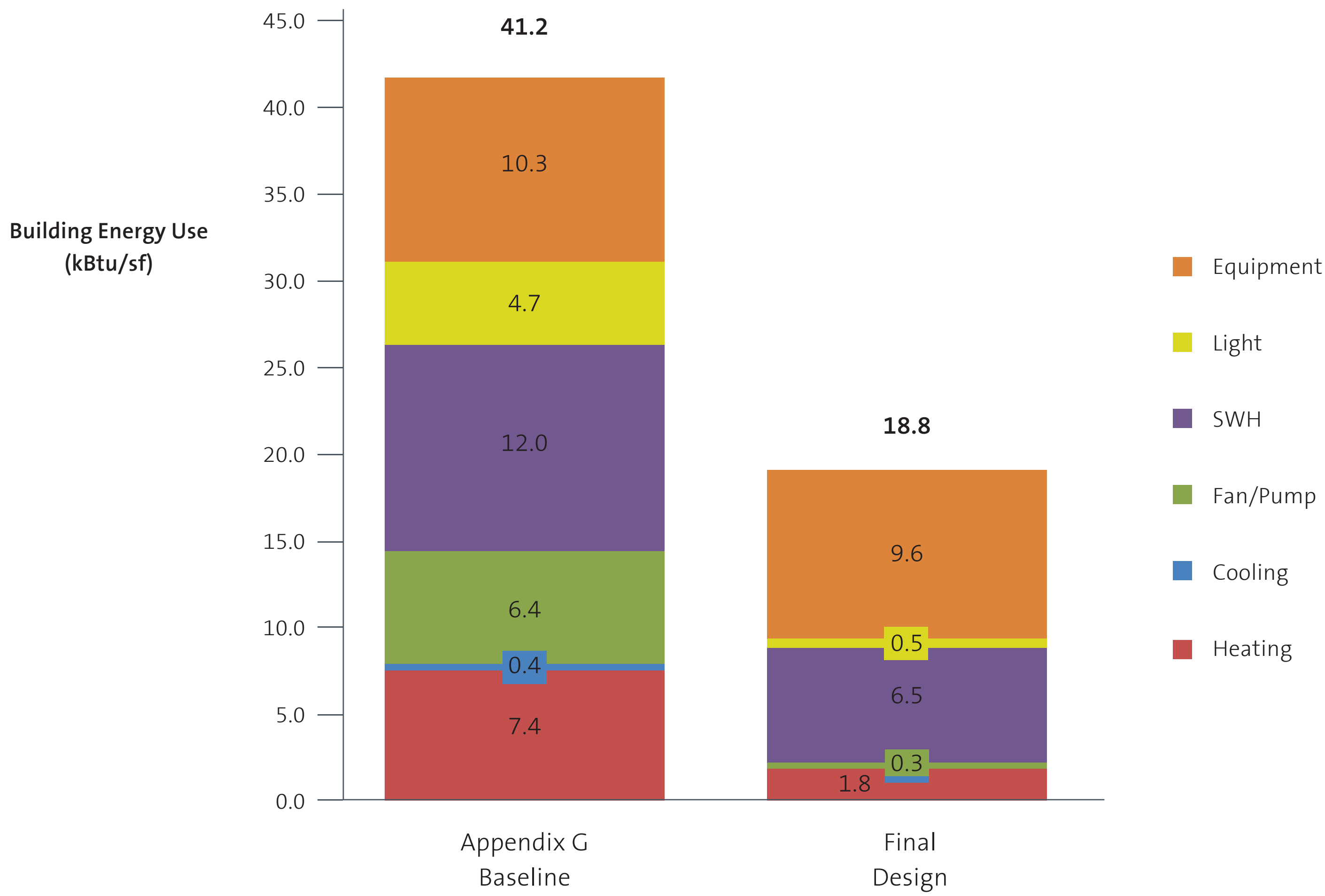
Ventilation air is directly ducted to each heat pump unit to ensure optimal indoor air quality for healthy living. Distributed heat pump units allow occupants to control comfort levels for each area served. Programmable thermostats and occupancy sensors limit operation of units to when the areas are in use, further contributing to energy savings.

The north-facing façade integrates photobioreactors for microalgae production. The north façade provides sufficient light levels for algae growth while protecting the photobioreactor from excess heat due to direct solar exposure. The building's wastewater system is interconnected to the medium broth circulated through the photobioreactors, providing needed nutrients to enhance algae growth. This has an additional sustainable benefit in that the returning waste water is delivered to the municipality in a cleaner state, requiring less treatment to purify the water. Contributing to green job creation, a third-party service contract will be established to maintain the system and harvest the microalgae for biodiesel generation. This same service provider will be contracted to supply the building with biodiesel fuel to feed seven (7) 65kW CHP microturbines serving the building's heating and service hot water needs and generating electricity.

Rainwater will be captured from the roofs and stored in cisterns located within the attic voids. The captured rainwater is treated and reused to reduce the demand on the municipality-recycled water needed for toilet flushing, irrigation and make-up water for the heat pump system.


CHP MICROTURBINES
SERVICE HOT WATER GENERATOR
FAN-ASSISTED NATURAL VENTILATION
TRICKLE-VENT LOUVER
VERTICAL CLOSED LOOP GEOTHERMAL BORE-FIELD
GEOTHERMAL HEAT PUMPS SERVING GROUND FLOOR SUPPORT AREAS COMMON AREAS, CHILDCARE AND UCSF POLICE
HEAT EXCHANGER
BIODIESEL FUEL STORAGE TANK

EUI Comparison



2F. Description and Diagrammatic Sketch of Residential Unit Systems

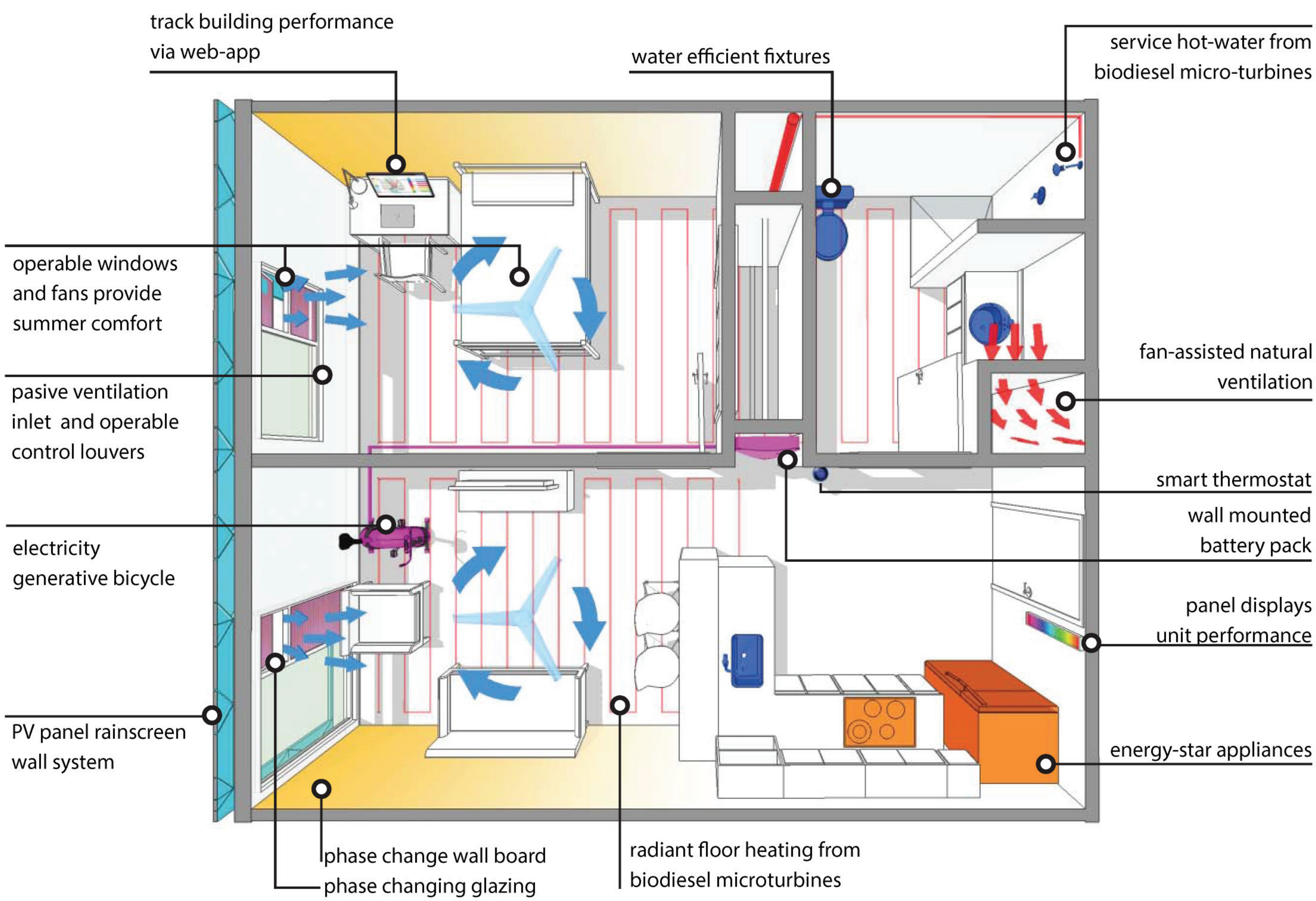
The residential units are heated via a hydronic radiant floor system providing optimal comfort. The radiant heating system delivers a higher mean radiant temperature, allowing occupant comfort at reduced space thermostat settings, which further contributes to energy savings. The heating hot water is provided by the seven (7) 65kW CHP microturbines serving the building.

Phase-change wallboard and ceiling board enhance comfort during the summer months by absorbing heat gain during peak hours, keeping the space cooler. As temperatures drop during the evenings, the material will undergo a phase change and release the energy as heat to the space, which will help to maintain comfort.

A fan-assisted ventilation system ensures optimal air quality in each residential unit. Constant-volume toilet exhaust is sized to meet each unit's ventilation air requirements. This same exhaust system draws air from the corridors to induce ventilation air. The exhaust ducts are routed vertically through the building and combined at the top floor level to a series of roof-mounted fans located in chimneys. Ventilation air is provided during the winter months by trickle-vent louvers within the window system. During the summer months, residents have control over operable windows and switch-operated ceiling fans to increase air movement according to their comfort needs.

All permanently installed light fixtures include LED lamps. Fixtures near the perimeter include automatic daylight dimming controls to further reduce energy. Residents are encouraged to use LED lamps to meet their additional lighting needs. All installed appliances are Energy Star rated. Residents are encouraged to purchase Energy Star-rated equipment to contribute to the building's low energy needs.

Service hot water is generated by the waste heat from the seven (7) 65kW CHP microturbines. Plumbing fixtures are low flow, meeting EPA's WaterSense program to reduce water demands. Flush fixtures are served by the municipality's recycled water system, as well as the on-site rainwater collection/reuse system.


track building performance
via web-app
water efficient fixtures
service hot-water from
biodiesel micro-turbines
operable windows
and fans provide
summer comfort
pasive ventilation
inlet and operable
control louvers
fan-assisted natural
ventilation
smart thermostat
wall mounted
battery pack
electricity
generative bicycle
panel displays
unit performance
PV panel rainscreen
wall system
energy-star appliances
phase change wall board
phase changing glazing
radiant floor heating from
biodiesel microturbines

2G. Renewable Energy

The project will incorporate solar PV on site, microturbines using biofuels delivered to the site, and small wind turbines to produce enough energy on site to meet the net-zero energy goals of the project. The table below shows the different renewable energy sources and their contribution to the total goal.

Renewable Energy Source	% Renewable Contribution
Microturbine	38%
PV	59%
Wind	3%
Total	**100%**

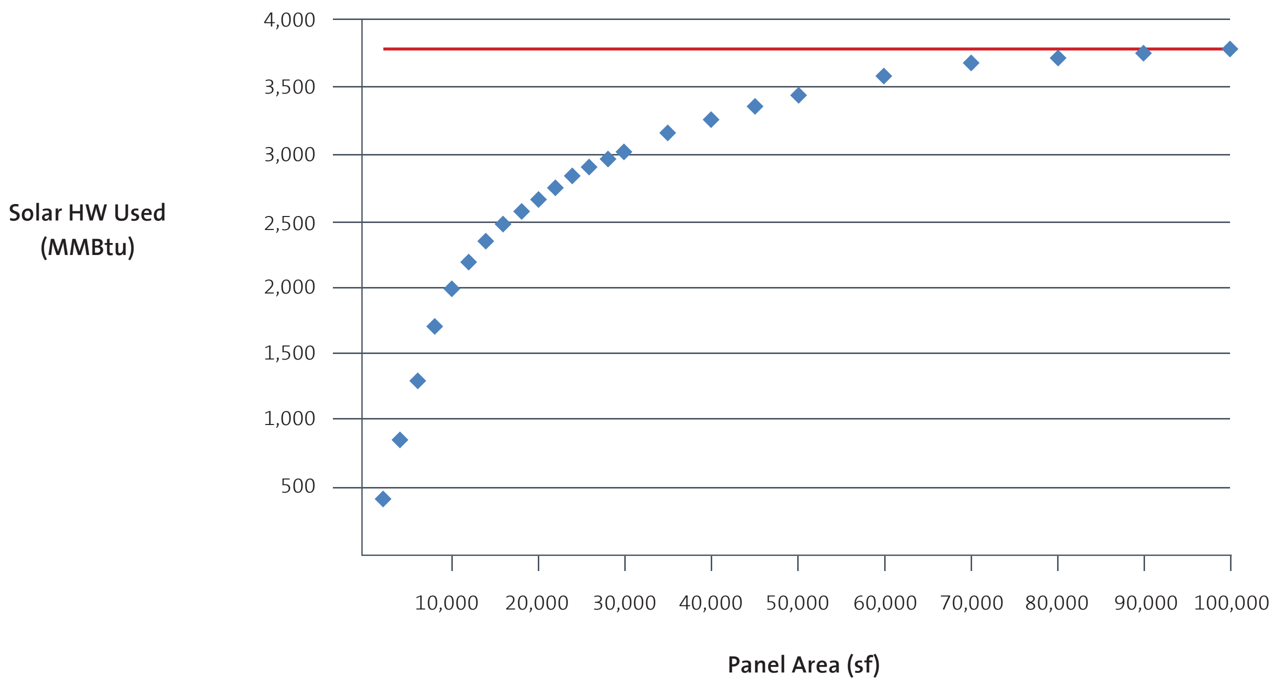
Renewable Systems Analyses

Hot water loads in residential buildings can be significant, especially if space heating systems utilize hot water as the heating medium. The proposed HVAC system was analyzed in order to understand the level of hot water loads in the building and how much solar hot water panel area would be needed to offset building loads.

It was noted in the initial site and weather analysis that the highest heating loads occur during times with the least solar radiation. This results in diminishing returns as the panel area is increased, as shown in the chart below.

Chart 1

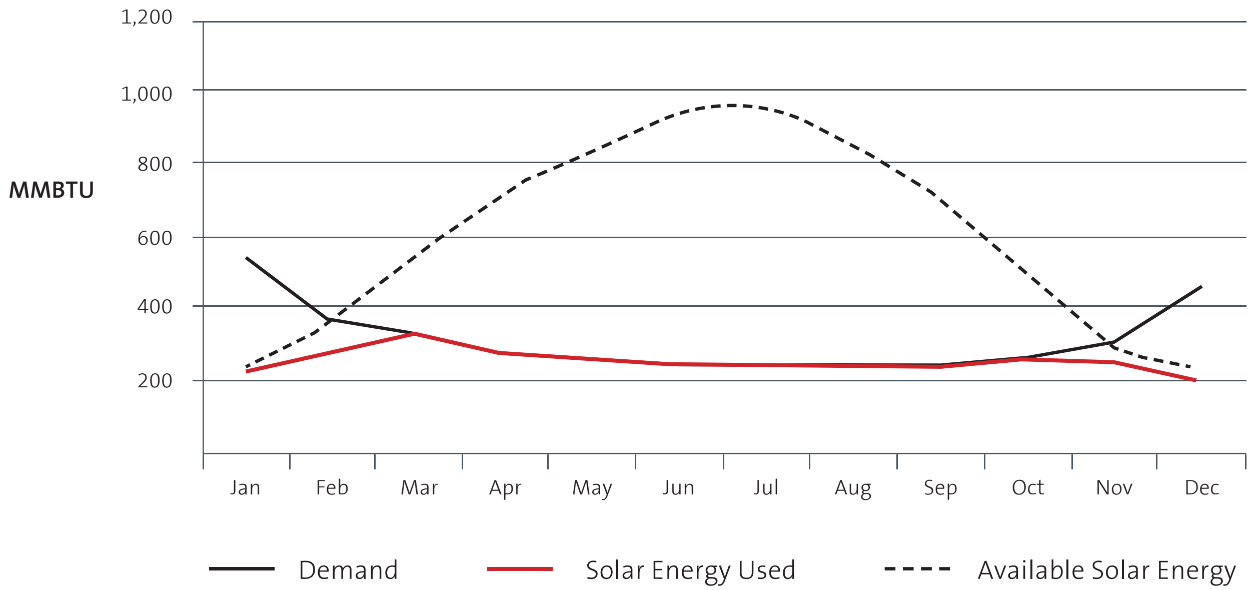
Solar hot water used for varying panel sizes



The hot water systems analyzed are assumed to be evacuated tube with design supply temperature of 140°F. Hot water storage systems are sized at two gallons per square foot of panel area.

Chart 2

Solar hot water system performance; 30,000 sf (80% loads met)



Key Points

- Hot water loads are met for eight months of the year (March through October)
- 30,000 sf of solar hot water panels produces about 3,006 MMBtu, offsetting about 7.23 kBtu/sf of the building EUI

Photovoltaic (PV) systems were also analyzed for the building and site, initially focusing on available roof area for PV installation. Accounting for other equipment on the roof and space between panels for maintenance, the roof area allows for approximately 40,000 square feet of PV panel. PVWatts® Calculator from NREL estimates a PV system oriented south at a 10° tilt to produce 1,465 kWh per rated kW. Scaling that result up to 40,000 sf of panel area results in a PV system that produces approximately 562,653 kWh annually.

Knowing the area of the site and the panel area required to achieve net zero, it quickly became apparent to the design team that other renewable system options would need to be considered, including wind and biofuels.

There was simply not enough area on the site to support a solar hot water system and a photovoltaic system. The program System Advisor Model (SAM) from NREL was used to further investigate wind turbines, finding that while the generation potential was relatively small, there was still opportunity on site for some small-scale wind turbines.

Biofuels were considered as an alternative to solar hot water as a way to meet the building heating water loads without requiring significant site area for solar collectors. The team decided on using biodiesel-fueled microturbines as a combined heat and power (CHP) system. Local biofuel suppliers will be contracted to deliver biofuel to the site and to harvest the algae from algae panels for future biofuel production.

The microturbines are sized and controlled to meet the building's hot water loads for space heating and service water heating. As the CHP system produces hot water for the building, it also generates electricity, giving the system a total efficiency above 80%. An additional potential benefit of the microturbines is that they are demand responsive, providing resiliency for the grid and supporting the new Utility 2.0 paradigm of grid flexibility. If needed, the microturbines can be operated at peak times to reduce the building's peak energy use – a feature that is very valuable to utilities. For the purposes of the net-zero calculation, it is assumed that the microturbines will only be operated in a combined heat and power mode, meaning they will track the building hot-water loads as described above.

Other energy-generating systems being considered include kinetic pavers and energy-generating fitness bikes. These cutting-edge, constantly improving technologies will enhance the resident's experience, giving some ownership and control over renewable energies. These systems will be relatively small overall and have not been accounted for in the net-zero calculation.

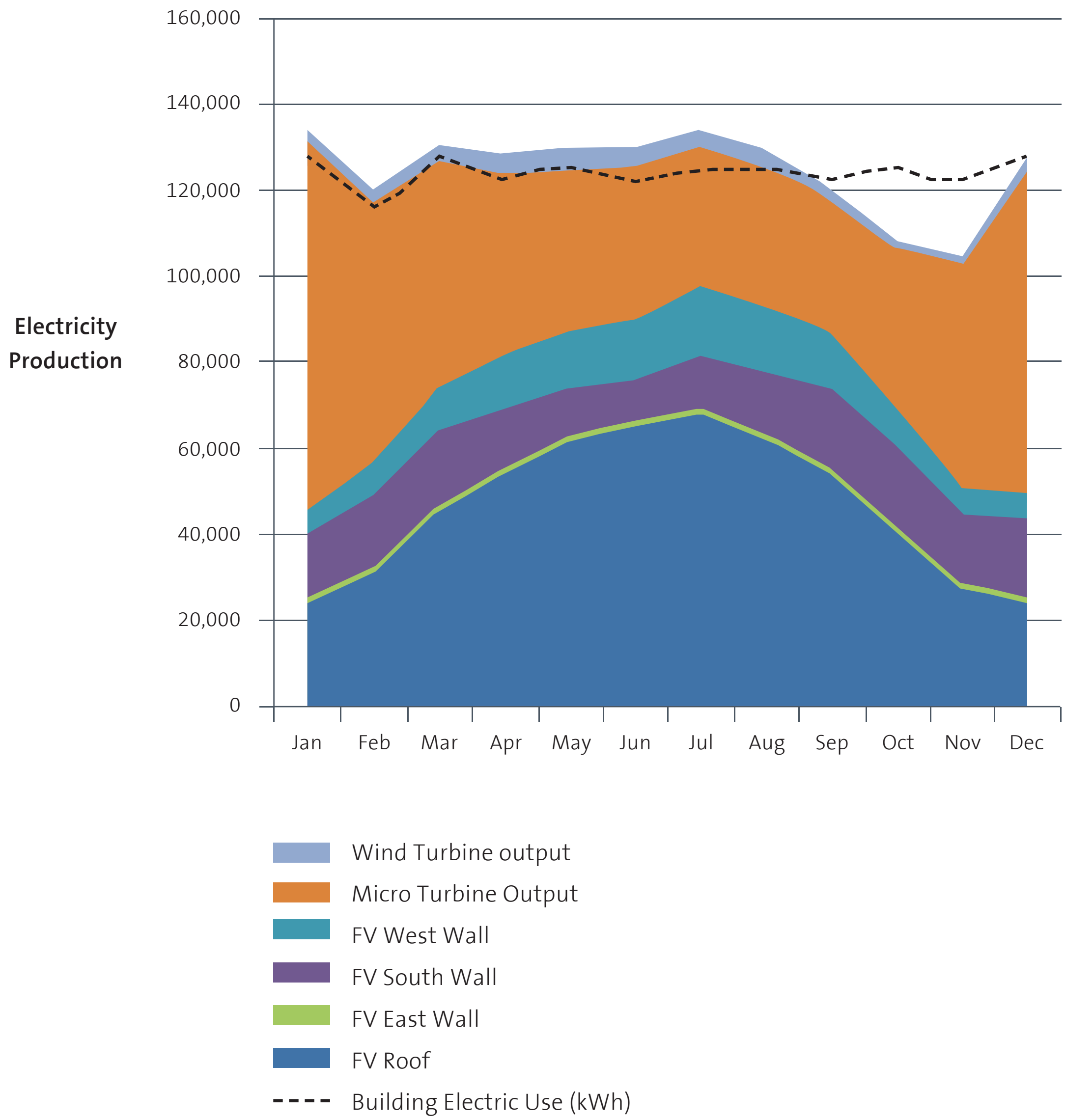
Renewable Energy System Design

The final renewable energy systems design for the building includes photovoltaics, biodiesel-fueled microturbines (as a CHP plant) and wind turbines. The table below summarizes the installed capacity and annual energy generation of each system. The renewable energy systems outlined below will generate enough electricity and hot water annually to offset all building energy use, bringing the building to net zero.

System	Installed Capacity	Annual Energy Generation
PV Roof	384 kW (40,000 sf)	562,653 kWh
PV South wall	198 kW (20,600 sf)	187,790 kWh
PV East wall	12.5 kW (1,300 sf)	9,093 kWh
PV West wall	159 kW (16,600 sf)	127,479 kWh
Wind	16.8 kW (7 turbines, 2.4 kW each)	39,957 kWh
Microturbine	455 kW (7 microturbines, 65 kW each)	571,200 kWh electricity 3,619 MMBTU hot-water

Note: PV and wind generation estimates are from System Advisor Model (SAM) from NREL. Microturbine generation estimates are based on a conservative assumption of 28% electricity generation efficiency and 52% hot water generation efficiency.

The following graph shows the overall renewable energy electric performance by month as it relates to the monthly building electric load.



2H. Occupant Behavior

Net Zero is more than just smart building technology – it's a thoughtful approach to resources and a new way of thinking about home.

Inspired by the new wave of wearable fitness trackers, the dWELLBEING project gives users an interface to monitor the health of their home. Easily accessible from personal electronic devices, this fun front-of-mind format will encourage smarter choices and establish sustainable habits. Residents can get an awareness of the total building energy performance through metered consumption and renewable energy generation. For example, someone would be able to understand how last week's cloudy days actually affected the amount of energy the PV panels produced.

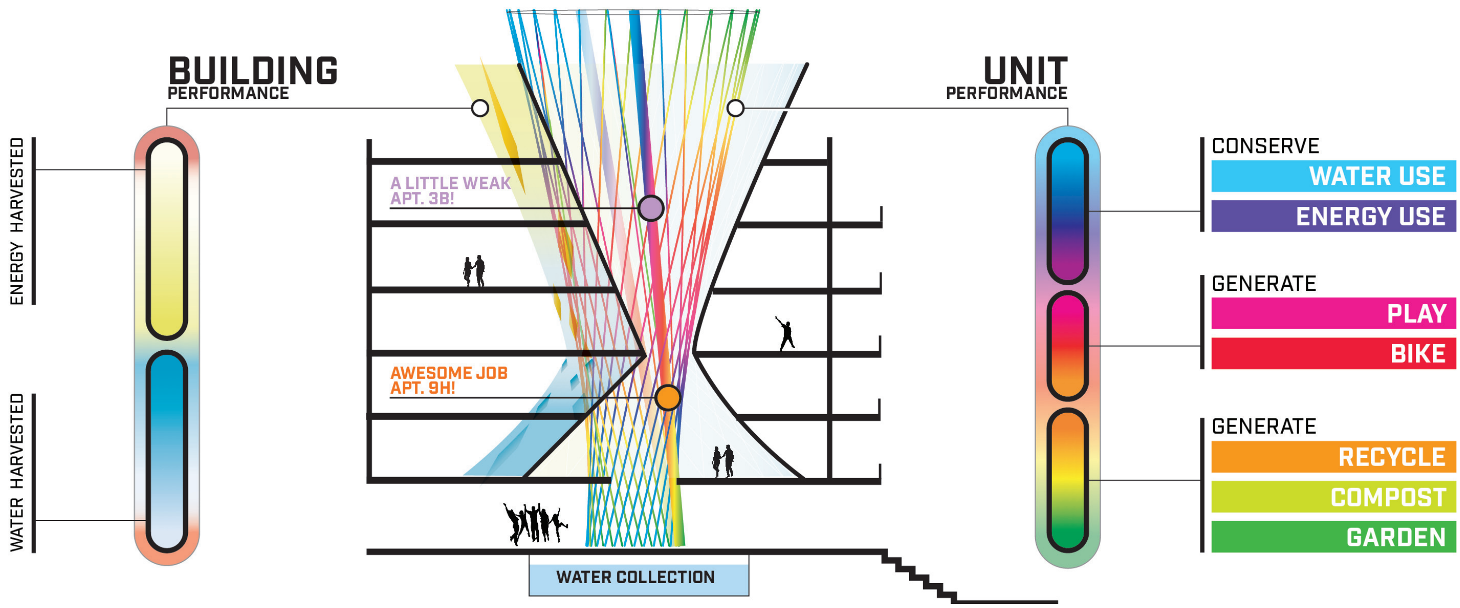
Custom benchmarking software monitors each residential unit as well – allowing a community of inclusion and (friendly) competition between neighbors. Instead of focusing only on consumption – dWELLBEING places an emphasis on how people can contribute and earn points in this energy market. There are three main categories for contribution:

- Conservation
  -Water Conservation (shorter showers, etc.)
  -Energy Conservation (taking the stairs instead of the elevator)

- Generation
  - Kinetic Pavers (playing a game of basketball on the kinetic court)
  - Bicycle Generators (taking a spin class at the gym)

- Community
  - Recycling Programs
  - Composting
  - Helping out at the edible green wall

Prominent between the two residential bars is a multi-story community installation displaying the real-time health of the building.



(Image included for reference)

Since the success of this building relies on both occupant engagement and the availability of renewable energy, the form consists of two nested shapes. The outer shell displays the amount of energy renewables and water collection. The inner cone consists of LED cables, each one illuminated in a different color to reflect the specific energy performance (positive or negative) of the electrical, heating and/or water usage of that particular residential unit as compared to a targeted baseline. Stepping back, one can see an overall snapshot of collective success. Ultimately, net zero is not possible without occupant engagement.

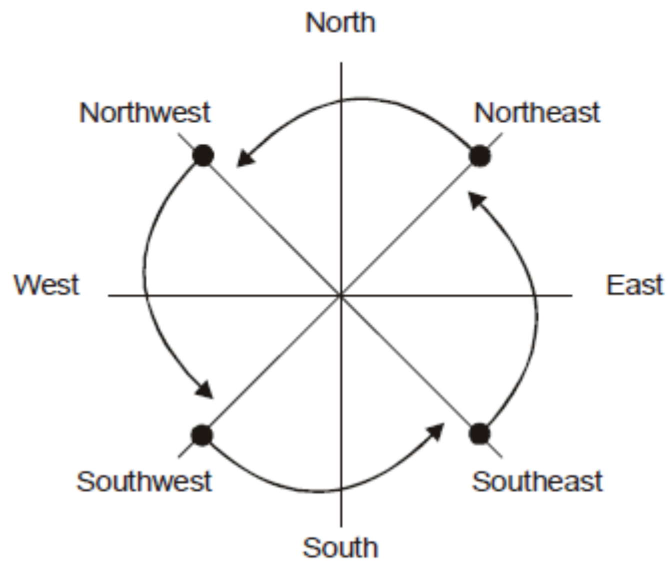
Appendix.

2A. 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° of true north, east, south, or west should be assigned to that orientation. If the orientation is exactly at 45° 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: 10,000ft^2

Step 2: Total area of north façade: 50,000ft^2

Window-to-wall ratio of north façade = number from step 1 / number from step 2 = 0.20

East

Step 1: Total area of light transmitting glazing surfaces on east facade: 2,200ft^2

Step 2: Total area of east façade: 29,200ft^2

Window-to-wall ratio of east façade = number from step 1 / number from step 2 = 0.07

South

Step 1: Total area of light transmitting glazing surfaces on south facade: 10,000ft^2

Step 2: Total area of south façade: 33,300ft^2

Window-to-wall ratio of south façade = number from step 1 / number from step 2 = 0.30

West

Step 1: Total area of light transmitting glazing surfaces on west facade: 5,700ft^2

Step 2: Total area of west façade: 28,300ft^2

Window-to-wall ratio of west façade = number from step 1 / number from step 2 = 0.20

Total Building Window-to-Wall Ratio

Step 1: Façade area$_{total}$ = step one$_{north}$ + step one$_{east}$ + step one$_{south}$ + step one$_{west}$ = 27,900ft^2

Step 2: Light transmitting glazing$_{total}$ = step two$_{north}$ + step two$_{east}$ + step two$_{south}$ + step two$_{west}$ = 141,000ft^2

Total window-to-wall ratio = number from step 1 / number from step 2 = 0.20

2B. Window Openings 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 transmittance.

Type of window and glass:

Vision Windows: Triple pane, clear low-e with argon fill and aluminum frame.

South and West thermodynamic glazing: Quadruple pane, low-e with argon fill, prism and phase change material inserts/

East facing
U-factor: COG: 0.13 Unit: 0.26; SHGC: 0.32; Visible Transmittance: 60%

South facing
U-factor: COG: 0.11 Unit: 0.24; SHGC: Win: 0.33 Sum: 0.24; Visible Transmittance: 50%

West facing
U-factor: COG: 0.11 Unit: 0.24; SHGC: Win: 0.33 Sum: 0.24; Visible Transmittance: 50%

North facing
U-factor: COG: 0.13 Unit: 0.26; SHGC: 0.32; Visible Transmittance: 60%

If you included a projecting shading device(s) or a window reveal, include a diagram of a representative residential window on the south and the west elevations showing shadows cast at the dates and times shown below. These studies should be for ”solar time’ rather than “clock time.” (In solar time 12 noon represents the moment when the sun is due south and at the highest point in the sky it will reach that day.) Impose a 1’-0” grid on the window to make it possible for jurors to see the percent shading achieved at each time.

While there are a number of software tools that can be used to accurately cast shadows, it is straightforward to do this analysis in SketchUp, a free software tool.

South Elevation:

- December 21: 9 am, 12 noon, 3 pm
- March/September 21: 8 am, 10 am, 12 noon, 2 pm, 4 pm
- June 21: 9 am, 12 noon, 3 pm

West Elevation:

- December 21: 3 pm
- March/September 21: 2 pm, 4 pm
- June 21: 3 pm, 5 pm

dWELLBEING II