ARCHITECTURE AT ZERO 2021-22

A design competition for Decarbonization, Equity and Resilience in California

The *Architecture at Zero* competition challenge is to create housing for farmworker families in California's Central Valley with low carbon emissions. When focusing on building decarbonization and buildings with low carbon emissions, certain design moves make a big difference.

COMPETITION DECARBONIZATION GOALS

In addition to energy efficiency and renewable generation, designers should consider the carbon impact of their fuel choice. One of the primary strategies for achieving zero carbon buildings is electrification of the building's end-uses.

Zero carbon or low carbon buildings also need to be good grid citizens. The specific time that energy is used during the day or year (the "load shape") can have a substantial impact on the overall carbon emissions.

Carefully reducing loads through efficiency and equipment selection has an impact, and loads can be further reduced or shifted through demand response strategies, load shifting strategies, and inclusion of energy storage.

The operational carbon emissions of buildings are generally determined by multiplying the energy use by an emissions factor. The emissions factor varies by fuel, time of year, and time of day, so a number of different strategies must be used to reduce the total carbon emissions of the project, including electrification, energy efficiency, and load shifting.

An "Energy and Emissions" excel spreadsheet tool is provided to visualize results for both energy and emissions from an annual, monthly, and hourly perspective. Note, hourly simulation results are required to output hourly emission load shapes.

There is also increasing attention being paid to the carbon emissions connected to the materials and construction practices of buildings, called the embodied carbon.

WHAT IS ZERO CARBON, AND HOW IS IT DIFFERENT FROM ZERO NET ENERGY?

The New Buildings Institute identifies five foundations of zero carbon building policies:[1]

- Energy efficiency
- Renewable energy
- Building-grid integration
- Building electrification
- Embodied carbon

A zero net energy (ZNE) building project produces at least as much energy from renewable sources as it uses over the course of a year. At its most fundamental level, designing a ZNE building is a balancing act between energy consumption and production. Good ZNE designs address the first two foundations, energy efficiency and renewable energy, and are grid-connected. Fundamentally, designers start by reducing building loads as much as possible to reduce the amount on-site renewable energy required to completely offset the remaining projected energy use.

Zero carbon buildings push these strategies further, still building on the foundations of energy efficiency and renewable energy, but further considering the impact of the building on the grid, reducing emissions by electrifying loads, and considering the embodied carbon of equipment, materials, and construction practices.

All buildings designed as part of the competition must be grid-tied. “Grid-tied” buildings maintain a connection to the electrical grid. For buildings without energy storage, when insufficient energy is generated by on-site renewables to meet the demand from building loads, electricity is drawn from the grid; when on-site renewables generate a surplus of electricity, the surplus electricity is exported to the grid. For buildings with energy storage, the excess may be stored, and the storage energy can be used when needed to meet loads or shift the load shape.

CALIFORNIA CONTEXT

Building decarbonization is a key strategy to achieving California’s aggressive climate goals. California’s Fourth Climate Change Assessment[2] highlights the potential impacts from climate change on California. In 2020, California experienced record-shattering wildfires with widespread smoke and intense, dangerous heat events.

Projects designed and constructed in California must meet certain energy use requirements in the building code. California’s Building Energy Efficiency Standards (Title 24) focus on reducing energy used in new construction and existing buildings.[3]

[1] “Making the Transition from Zero Energy to Zero Carbon Building Policies” - https://newbuildings.org/making-the-transition-from-zero-energy-to-zero-carbon-building-policies/

[2] https://climateassessment.ca.gov/

[3] https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards

The requirements for the latest version of this Title 24 for low-rise multifamily projects, and numerous other resources, can be found at Energy Code Ace.

Building energy codes are still fundamentally based on energy use predicted by energy models. Entrants to this competition are asked to demonstrate or explain how their designs meet the minimum performance standards for buildings in California. This does not require a code compliance model, but may be satisfied with an explanation of the requirements for building systems and how the design meets those requirements. Additional resources and training will be highlighted as part of the competition materials.

TECHNICAL CHALLENGE ENERGY DEMAND TARGETS

Energy Use Intensity (EUI) is a metric that is used to compare the energy consumption of buildings by accounting for Conditioned Floor Area (CFA). It is defined as annual energy consumption divided by conditioned floor area and is most commonly expressed in the units of kBtu/sf-yr.

EUI = Annual Energy Consumption (kBtu) / CFA

Following the first foundation of zero cartoon building policies -- energy efficiency -- participants should use a site EUI target of 19-22 kBtu/sf-yr as a starting point for the competition (including the community space), before accounting for on-site generation.[4] [5]

INTEGRATION OF RENEWABLE ENERGY SOURCES AND STORAGE

Renewable generation is distinct from load reduction, and both are components of a successful low carbon design. Solar photovoltaics (PV) are expected to be the primary source of renewable energy for this challenge. PV with integrated battery storage systems are strongly encouraged.

BUILDING ENERGY MODELING AND SIMULATION

Participants are encouraged to use building energy modeling and simulation tools to optimize their designs to meet the EUI goal. For modeling to be a valuable part of the design process, the team must always ask “Do these results make sense?” and “What are the implications for the building design?”. More information about available simulation tools and resources are included in Energy Modeling Resources under Technical Resources.

[4] NBI Zero Energy Performance Targets for New Construction Projects. See Low-Rise Apartment, ASHRAE Climate Zone 3B.

[5] Transforming New Multifamily Construction to Zero: Strategies for Implementing Energy Targets and Design Pathways. See Table 4 Multifamily in ASHRAE Climate Zone 3B.

DESIGN DOCUMENTATION

The design documentation allows entrants to present their work from both architectural and energy performance perspectives.

REQUIRED DOCUMENTATION

The following elements are required documentation on the submitted board. They are described below in more detail along with successful examples from past competitions and other sources. These are not meant to be prescriptive.

1. Project Narrative
2. Site Plan
3. Floor Plans
4. Perspective Drawing
5. Illustrated Section
6. Mechanical System Summary
7. Annual End Use Summary Table
8. Monthly End Use Energy Consumption Bar Chart
9. Hourly Loads Shapes for Energy and Emissions
10. Details of Renewable Energy Systems
11. Storage Systems (if applicable)

1. Project Narrative

The narrative should clearly outline and summarize the project's context and goals. This text should be a high- level summary. If you would like to include an extended project brief or explanations of assumptions and methodology, please include them in the supplementary documentation. This summary should not exceed 250 words.

2. Site Plan

The site plan should indicate the parcel boundaries, location of the building, and size (kW) and placement of renewable energy sources. Highlight any low carbon strategies or systems shown. Include a north arrow, section marks (as needed), and scale.

Source: "Fog Catcher" – Little; 2016 Competition

Source: "Nexus" – Dialog; 2016 Competition

3. Floor Plans

The floor plans should depict the interior conditions of the building and indicate the total conditioned floor area. Indicate how the space is heated, ventilated, and cooled; how water is heated and delivered; and the design of the natural and electric lighting in the unit.

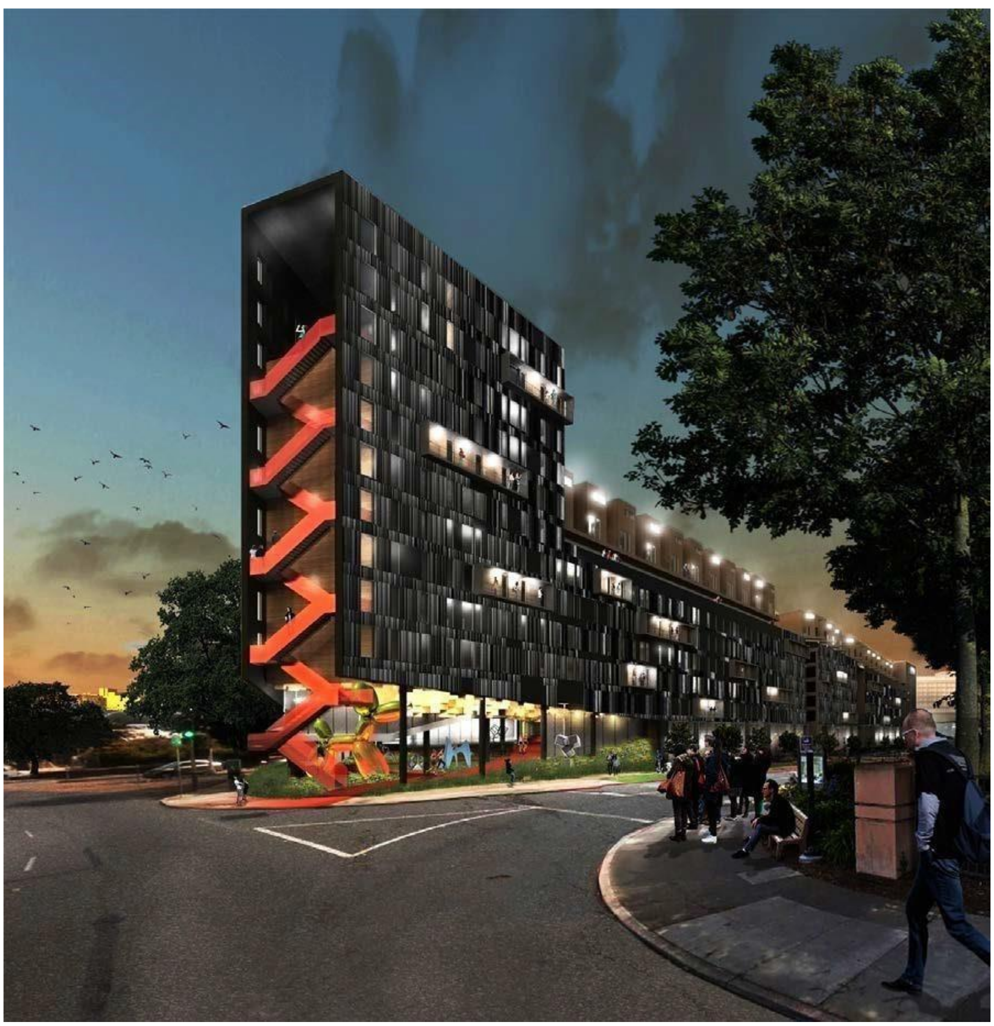
Source: Zero Net Energy Case Study Buildings, Volume 2 (IBEW-NECA JATC Training Center) by Edward Dean

Source: Zero Net Energy Case Study Buildings, Volume 1 (Packard Foundation Headquarters) by Edward Dean

4. Perspective Drawing

The perspective drawing should convey the “big idea” of your design.

Source: “Energized Canopy” - Ecole Nationale Supérieure d'Architecture; 2016 Competition

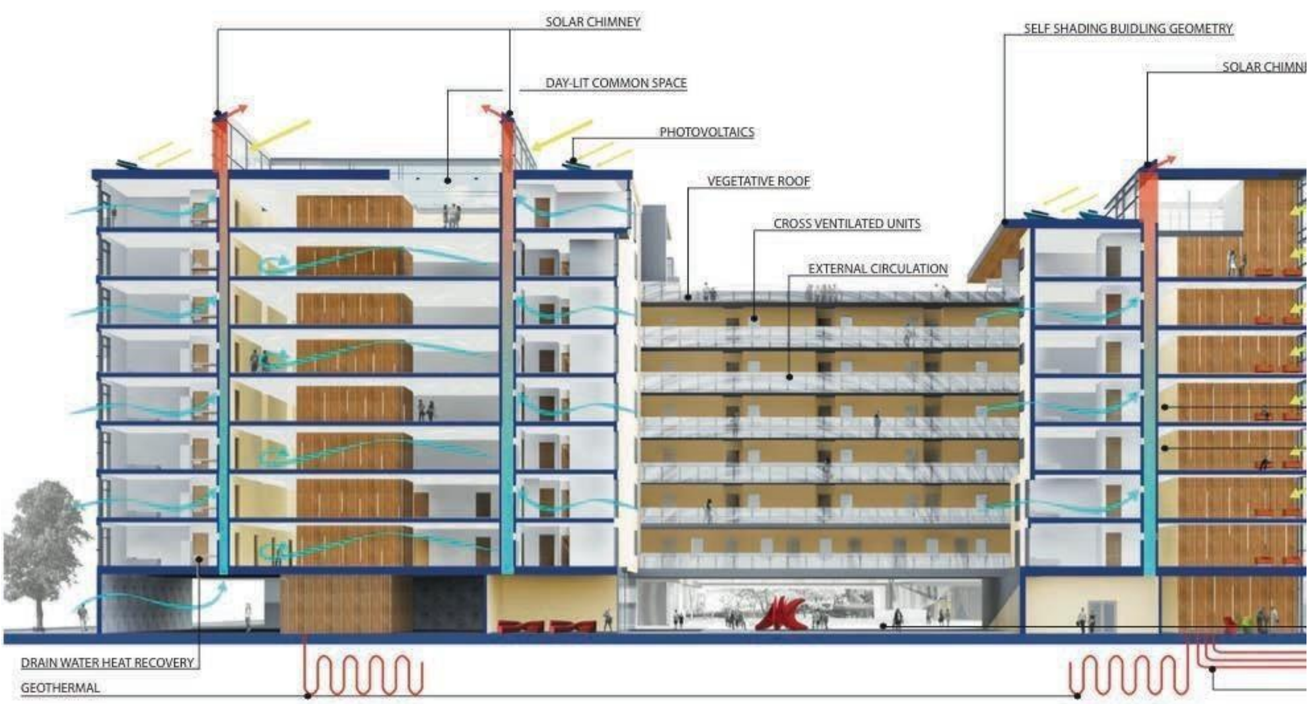


Source: “Piezein Circuit” – Modus Studio; 2016 Competition

5. Illustrated Section

The illustrated section should illustrate principles of passive design and envelope construction that would contribute to the building's low carbon performance. The section should call out daylighting strategies, natural ventilation, air flows, specific materials choices, etc. If arrows are used to illustrate any of these metrics, their intention and direction should be based in reality and physics; they should not be arbitrary. In addition, highlight the energy efficient aspects of the mechanical and lighting systems.

Source: "Conspicuous Consumption" - Weber Thompson; 2015 Competition



Source: "Breeze Block" - Cornell University; 2015 Competition

6. Mechanical System Summary

The summary should include the types of the main mechanical systems used by the building as well as how and why they were chosen. Where applicable, ensure your specifications meet or exceed the Title 24 2019 Building Energy Efficiency Standards.[6]

	System Details
Heating System	10 HSPF Air source heat pump
Cooling System	SEER 22. High thermal mass with night flushing, automatically-operated windows and skylights, air source heat pump backup
Ventilation System	Automatically-operated windows and skylights, outdoor air from the air source heat pump
Lighting System	100% LED (200lm/W) with vacancy control
Domestic Hot Water System	50 gallon heat pump water heater per unit, with 2.35 energy factor
Renewable/Generation System	40 kW (DC) PV on the roof
Lighting System	100% LED (200lm/W) with vacancy control

7. Annual End Use Summary Table

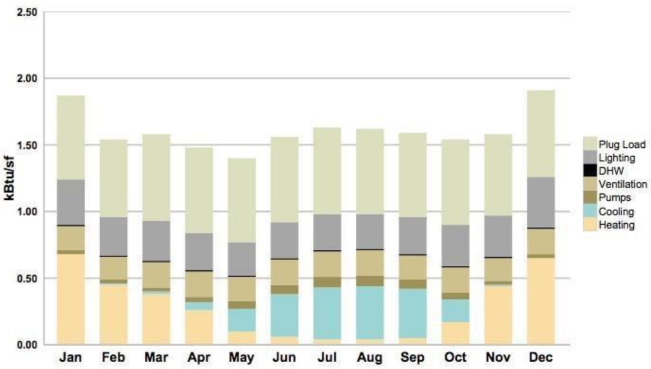
Fill in the table below to provide annual energy use and production broken down by major end uses. Write 1-2 sentences about what you learned from this data.

	Calculated Site Energy Use (kBtu/sf-year)
HVAC	
Lighting	
Appliances and Plug Loads	
Domestic Hot Water	
Gross EUI	
Renewable Production	
Net EUI	

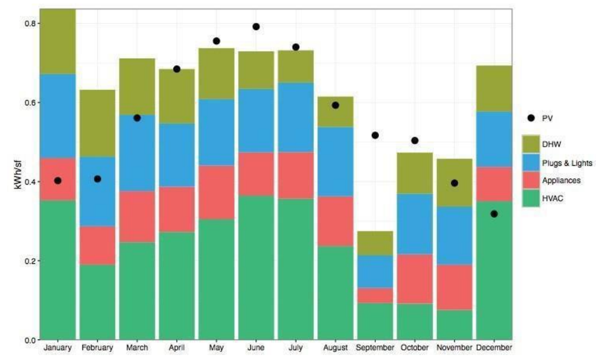
[6] https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2019-building-energy-efficiency

8. Monthly End Use Energy Consumption Bar Chart

Show the energy consumption by end use and production of the building on a monthly basis. Please use energy units consistent with the annual end use summary table.



Source: *Zero Net Energy Case Study Buildings, Volume 1 (Packard Foundation Headquarters) by Edward Dean*

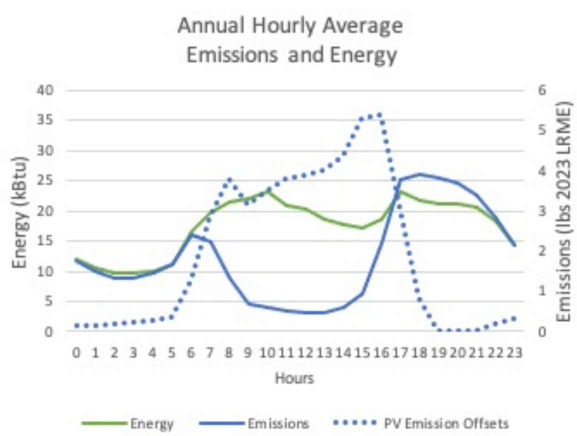


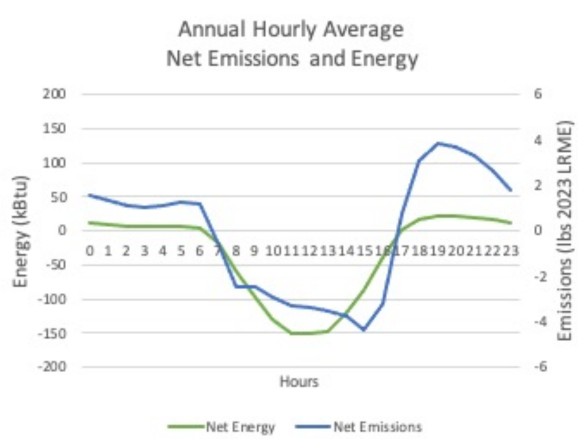
Source: Margaret Pigman, Resource Refocus LLC

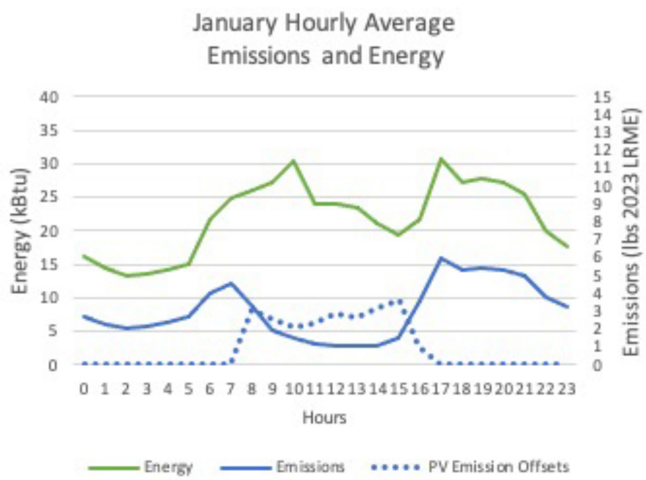
9. Hourly Load Shapes for Emissions

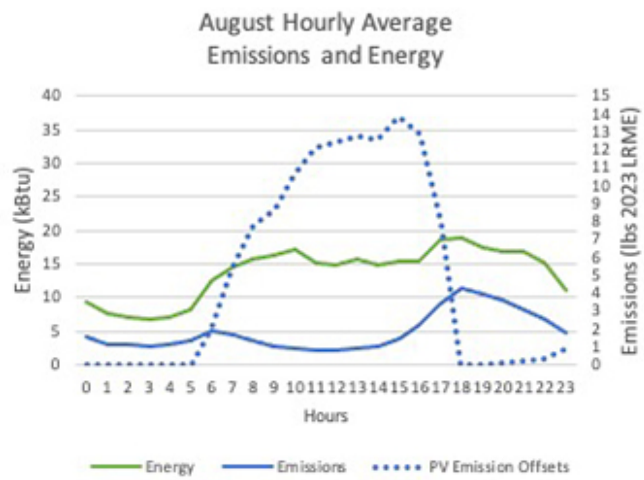
Use the "[Energy and Emissions]" excel workbook to show hourly load shapes for emissions in 2023. Note, hourly energy simulation results are required to generate hourly emission results.

To calculate the emissions generated, the "Energy and Emissions" workbook multiplies the modeled hourly energy use by an hourly emission factor. It's important to note that these emission factors vary by season and by the time of day. Emission factors are the lowest in the middle of the day, when ample photovoltaic supply allows for a cleaner grid mix. As a result, even if energy use is high during the middle of the day, the resulting emissions may be relatively low, as illustrated below. Shifting energy use from hours with higher emission factors to those with lower emission factors can help your design meet zero carbon targets. Using the load shapes in January and August, identify times when load shifting would be beneficial and illustrate how your design implements load shifting strategies for the heating and cooling seasons, respectively.



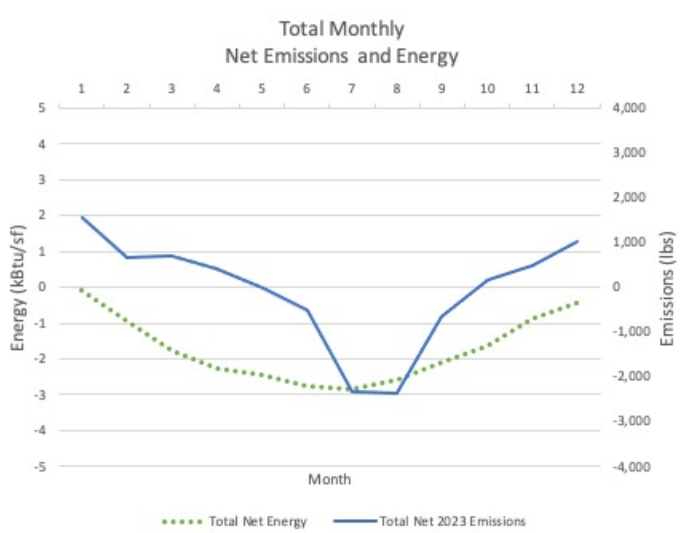


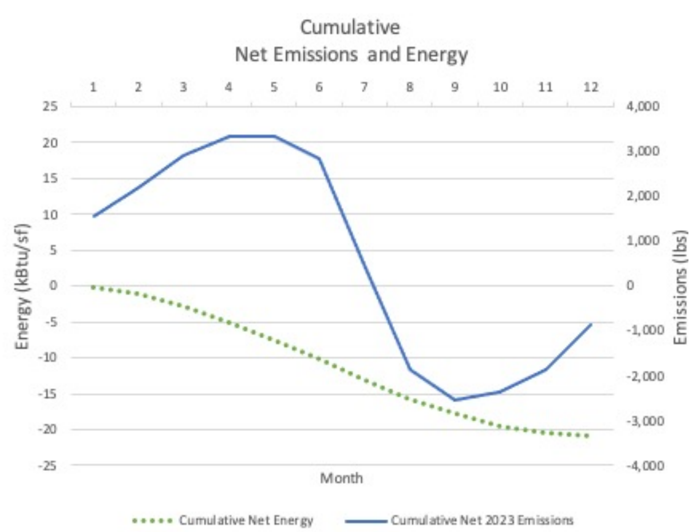




Illustrate monthly total and cumulative net energy and emissions in the year 2023.

Note that hourly emission factors will change over time as more renewables are added to the grid mix. Additional analysis of load shapes using 2030 and 2050 hourly emission factors is included below in the Optional Documentation section.





10. Details of Renewable Energy Systems

Provide information about renewable energy systems, including sizing and installation location. For designs that include sources of renewable energy other than solar and wind, provide an example of an existing installation of the system showing the same performance. This information does not have to be on the presentation board but must be included in the submission.

11. Storage Systems (if applicable)

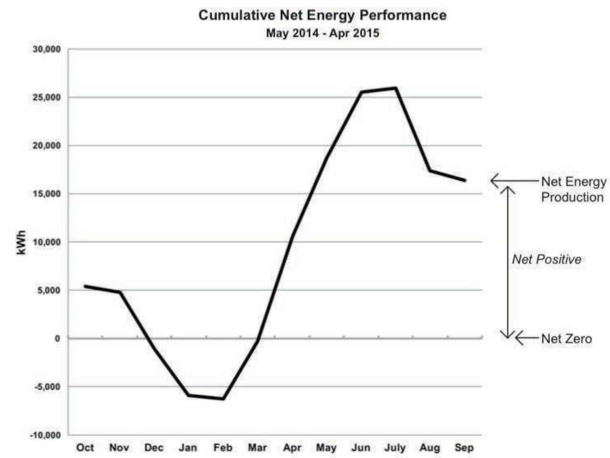
If applicable, include information about energy storage systems included in the design.

OPTIONAL DOCUMENTATION

Entrants may submit supplemental documentation to elaborate on their zero carbon design and the process around it. Examples of some of the possibilities are shown below as inspiration; other elements may be included.

Zero Carbon Narrative

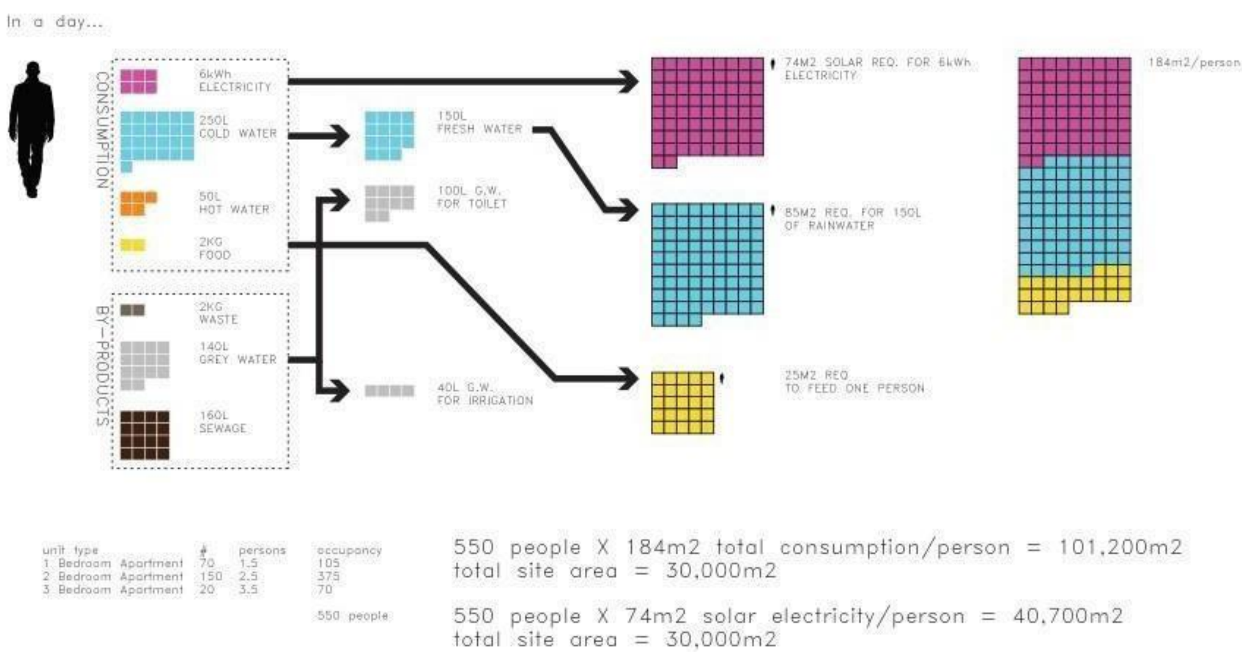
Does your design reach Zero Carbon performance? What are the major reasons why it does or does not? Describe your iterative energy and emission design process.



Source: Zero Net Energy Case Study Buildings, Volume 2 (Speculative Office Building at 435 Indio Way) by Edward Dean

"While this building only offsets 70% of its emissions, the deep energy efficiency measures such as the high-performance envelope, geothermal heating and cooling, and solar hot water reduce the EUI by 50% compared to a typical multifamily building. In order to maximize the outdoor space available to occupants, the building footprint was reduced, and the roof area cannot accommodate the PV required to offset 100% of the emissions due to building consumption."

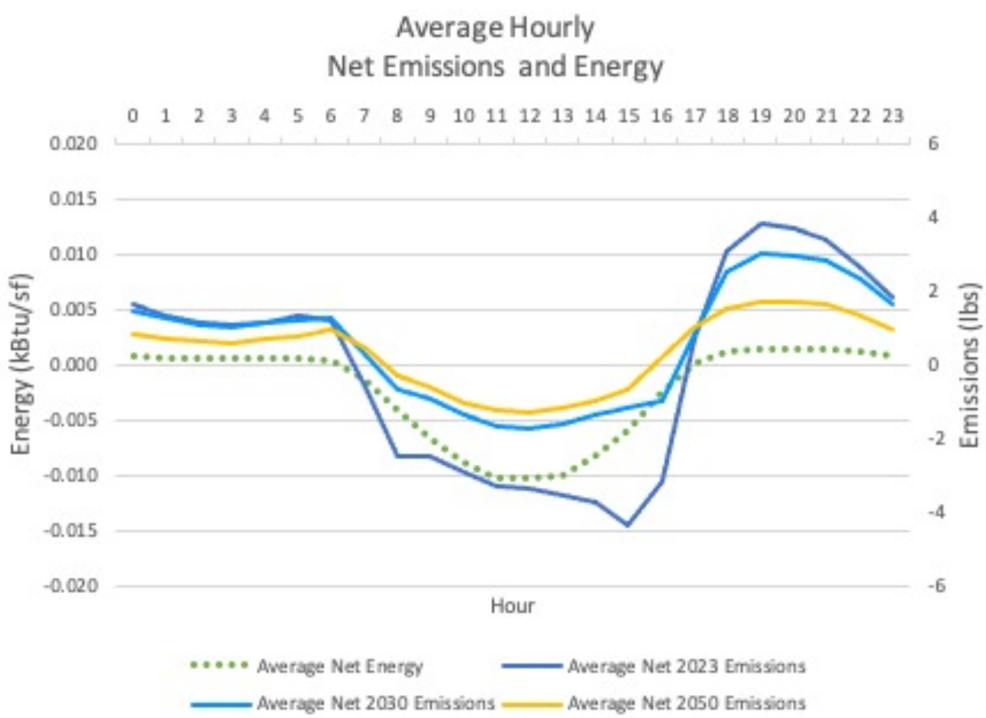
Source: Margaret Pigman

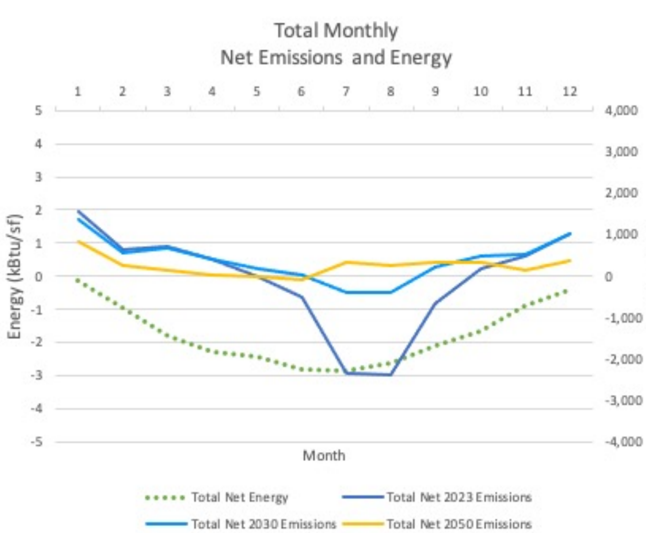


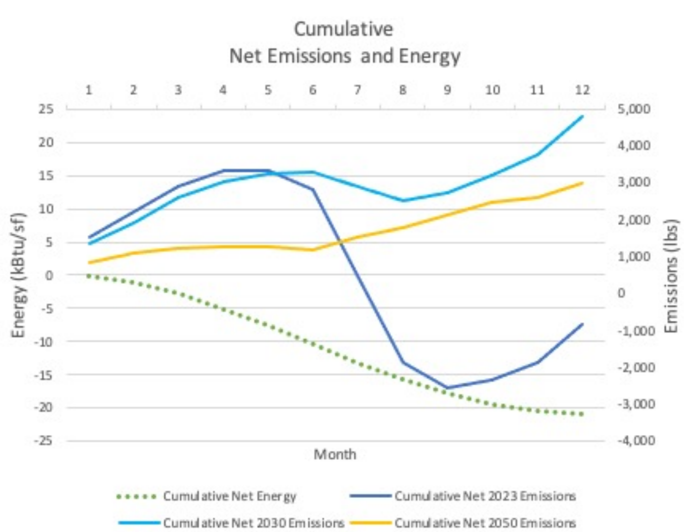
Source: "Chimera" - Tom Tang; 2011 Competition

Emissions 2023-2050

Hourly emission factors will change over time as more renewables are added to the grid mix. Illustrate net average hourly, monthly total, and monthly cumulative energy and emissions in the years 2023, 2030, and 2050 using the "Energy and Emissions" workbook.







Performance Characteristics Table

A table, like the example below, can quickly and clearly show the performance-related characteristics of a building and demonstrate how the low carbon goal is being met. As with the required mechanical documentation, where applicable, ensure your specifications meet or exceed the Title 24 2019 Building Energy Efficiency Standards.

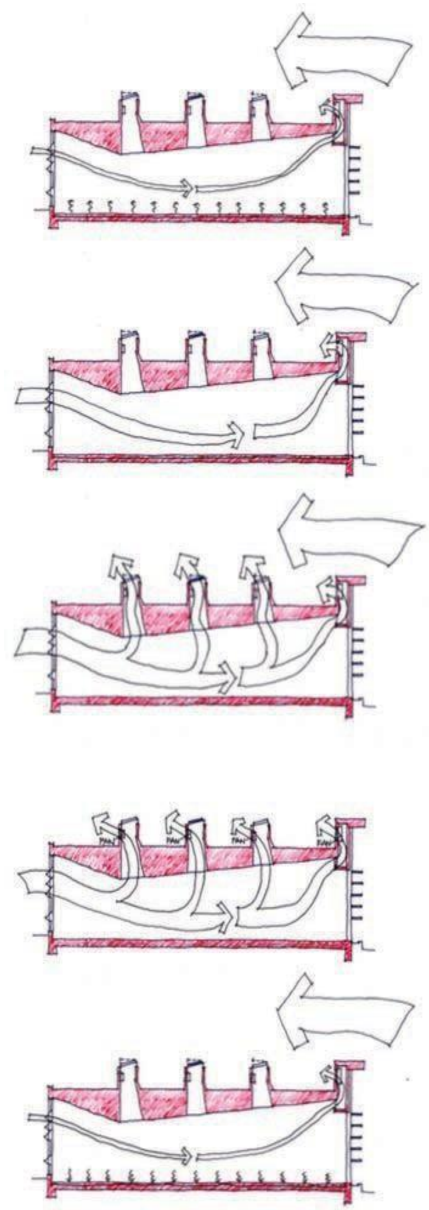
	Example 1	Example 2
Modeling Software	OpenStudio 2.8	eQuest 3.64, SketchUp
Building Envelope		
Wall R-value	R-21	R-30
Window to Wall Ratio	80%	40%
Window U-value, SHGC	0.22, 0.2	0.3, 0.25
Roof R-value	R-42	R-30
Space Conditioning		
Heating System Type	condensing boiler	ground source heat pump
Heating System Efficiency	0.96 EF	4.2 COP
Cooling System Type	natural ventilation	ground source heat pump
Cooling System Efficiency	N/A	4.2 COP
Ventilation Strategy	natural ventilation	ERV
Water Heating		
Water Heating System Type	solar thermal, condensing boiler	heat pump water heater
Water Heating System Efficiency	boiler 0.96 EF	3.2 COP
Domestic Hot Water Demand (gal/person/day)	15	20
Lighting, Appliances, and Plug Loads		
Lighting Type	LEDs	LEDs
Lighting Power Density (W/sf)	0.7	1

Lighting Controls	occupancy sensors	daylight dimming
Appliance and Plug Load Power Density (W/sf)	0.7	0.8
Plug Load Controls	none	smart power strips
Renewables		
Renewable System Type	PV	PV, micro vertical axis wind turbines
Renewable Capacity (kW)	6,000 kW	4,000 kW PV; 1,000 kW wind

Annotated Diagram of HVAC System

A diagram depicting the major components of the HVAC system or systems serving spaces can be at the unit or building level.

The following diagrams are examples from entries from sources not connected to this competition and are meant to be for reference only.



Mode 1: Heating Season

Mode 2: Swing Season

Mode 3: Cooling Season / Good Wind Conditions

Mode 4: Cooling Season / Poor Wind Conditions

Mode 5: Peak Cooling Events

Mode 1. Heating Season Operation. In this mode, the radiant heating system is on and the passive ventilation system admits the minimum amount of outdoor air as required by code.

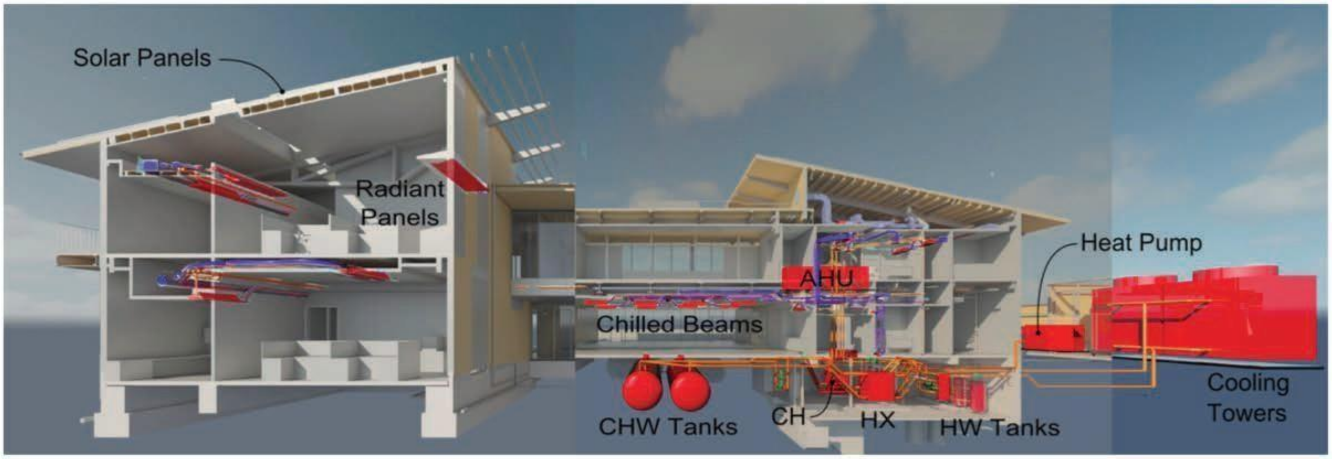
Mode 2. Swing Season Operation. No heating required and the amount of outdoor air required for fresh air and (at times) cooling varies. The wind chimney drives the air flow through the building spaces.

Mode 3. Cooling Season Operation – Good Wind Conditions. Increased amounts of outside air are required for cooling purposes. Designated skylights open to allow movement of larger volumes of outdoor air.

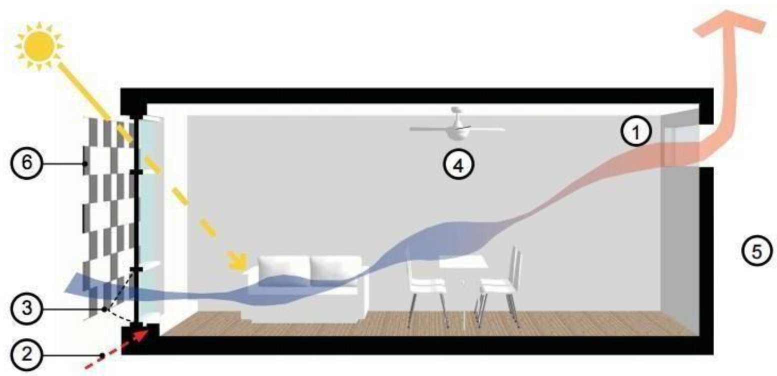
Mode 4. Cooling Season Operation – Poor Wind Conditions. System design includes backup fans at skylight shafts to engage and ensure air flow under poor wind conditions and for **night purging** ***using cool night air. (Skylights are closed)***

Mode 5. Operation in Peak Cooling Events. Outdoor air is too warm for cooling, so full cooling mode with radiant slab cooling via heat pumps engages. The passive ventilation system admits the minimum amount of outdoor air as required by code.

Source: Zero Net Energy Case Study Buildings, Volume 2 (West Berkeley Library) by Edward Dean



Source: Integral Group, taken from Zero Net Energy Case Study Buildings (Packard Foundation Headquarters) by Edward Dean



1. ***PASSIVE STACK EXHAUST: Single loaded corridor combined with operable windows allows for natural cross ventilation throughout the unit and on those occasions with warmer or hot weather in San Francisco, the window placement aids night flushing of the unit for greater occupant comfort.***
2. ***HYDRONIC BASEBOARD RADIATOR: Part of a shared solar thermal domestic hot water loop which uses water as a highly efficient means to transfer heat from the centralized solar thermal panels. Placement beneath the window helps to temper any radiation of cold which may be felt by the occupant.***
3. ***OPERABLE WINDOWS: Allows for natural ventilation. Using low/high placement of operable panes, in combination with operable panes at the opposite side of the unit, permits occupants a high degree of control, expanding the comfort range and improving Indoor Air Quality (IAQ) contributing to increased occupant comfort and wellness.***
4. ***CEILING FANS: Very low energy devices providing increased air movement and greater occupant control for an expanded comfort range, improved Indoor Air Quality (IAQ) and contributing to increased occupant comfort and wellness.***
5. ***LIGHT WELLS: Opening up the circulation side of the traditional double-loaded corridor allows for cross ventilation of units, provides more natural light over more of the interior (greater day-light autonomy) and helps balance the daylighting for a higher quality of light.***
6. ***SHADING SCRIM: Translucent, lightweight and durable panels, suspended on cables in front of the south and west facades, the density of the scrim directly responds to the annual solar insolation falling on the façade, allowing all units to maintain a maximum amount of glass while still maintaining a comfortable interior environment. On the north and east façades, the solar insolation is lower so the scrim is not required and the interior comfort can be maintained with a high performance envelope and glazing.***

Source: "Zero Emission" - BAR Architects; 2015 Competition

Occupant Behavior

Ultimately, it is the behavior of the occupants that determines a building's energy consumption and emissions. How does the design account for and influence occupant behavior?

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

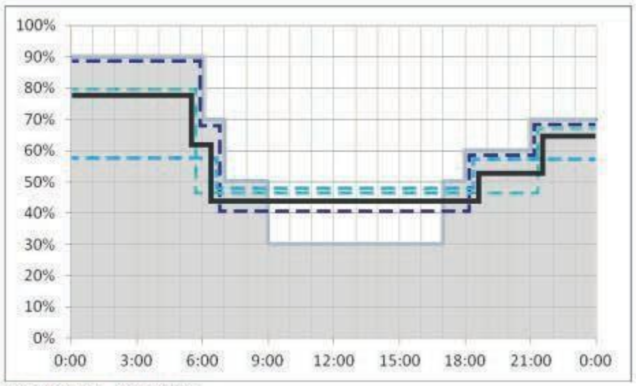
- ***How an individual resident's apartment and end uses use energy, including near-real time, historical usage, and usage relative to net zero "budget" that is weather-normalized. Residents would be able to view (anonymously) their own apartment's normalized energy usage within their "neighborhood" as a benchmark to privately see how they are performing compared to their neighbors.***
- ***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.***
- ***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.***
- ***Renewable energy production would be displayed in real time, as well as over the last week, month, and prior 12 month period.***
- ***Residents may optionally configure the app to "push" energy alerts 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 smartphone 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."***

Source: "Conspicuous Consumption" - Weber Thompson; 2015 Competition

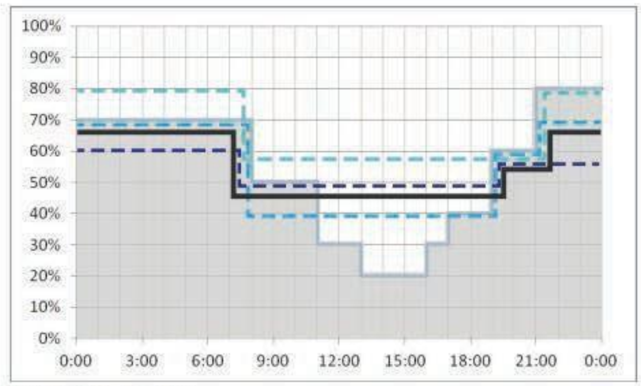
"As building's set lower resource use goals and employ active strategies to achieve those goals the role of occupants is critical. There is an opportunity to address how high-performance buildings affect occupants (comfort) and how occupants can in-turn affect building performance (engagement). Occupant is defined as anyone inhabiting a building full or part time, visitors and maintenance staff. People are now a vital building "system". The following strategies are market-ready solutions to affect occupant-controlled energy use and behavior:

- ***Sustainable Practices Guidebook:*** *Each unit has a manual with best practices graphically illustrated*
- ***Operable Windows:*** *occupants instructed with red light / green light signal next to panel*
- ***Smart Thermostat / Monitoring:*** *Programmable thermostats with continuous energy use dashboard*
- ***Instructional Signage:*** *Common spaces have educational signage installed throughout*
- ***Site Planning:*** *Bike parking is located adjacent to and within proximity of external stairs. The intent is to encourage use of stairs over elevators as there is a load demand from multiple elevator cores within the project."*

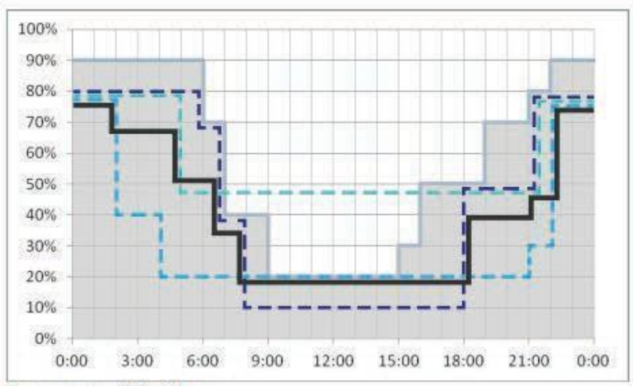
Source: "Breeze Block" - Cornell University; 2015 Competition



Occupancy – Saturday



Occupancy – Sunday



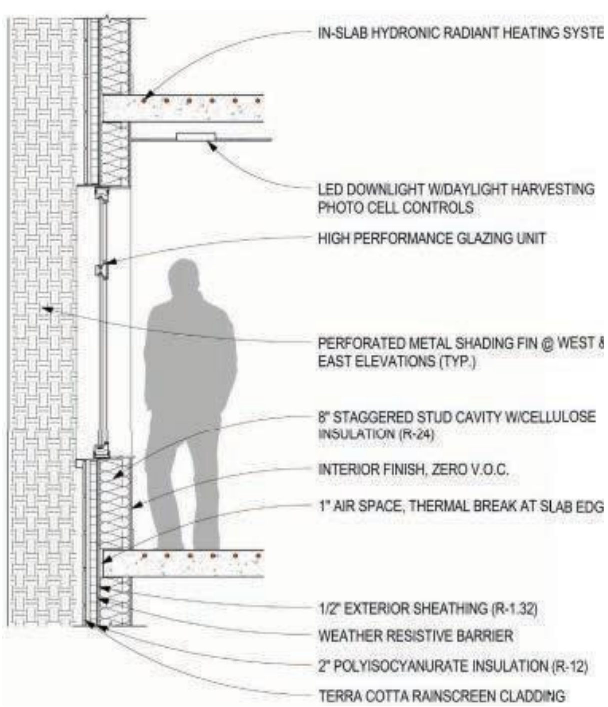
Occupancy – Weekday

DEFAULT Residential Use
PROFILE 1: PHD, Masters, DDS, PharmD students (50%)
PROFILE 2: MD, Nursing students (33%)
PROFILE 3: Faculty & families (17%)
AVERAGE OF UCSF PROFILES 1-3

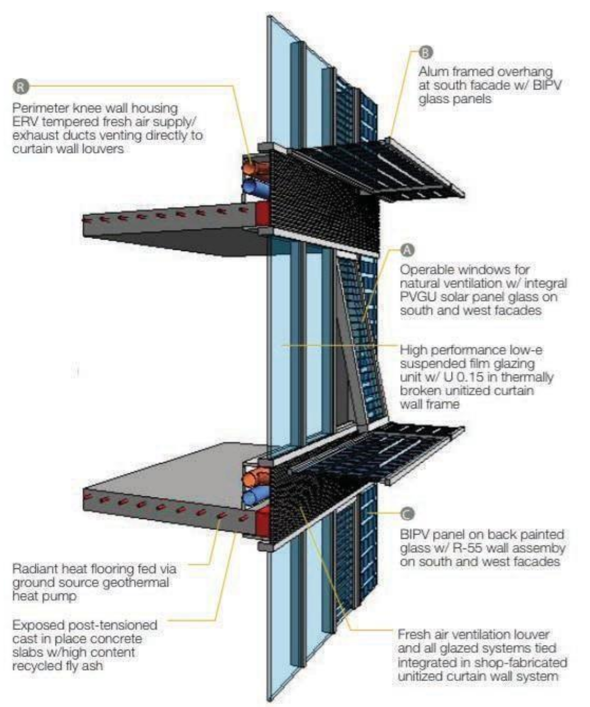
Source: "Conspicuous Consumption" - Weber Thompson; 2015 Competition

Wall Section

Highlight decarbonization, equity, and resiliency design considerations in section drawings.



Source: "Estuary" - Mithun; 2015 Competition



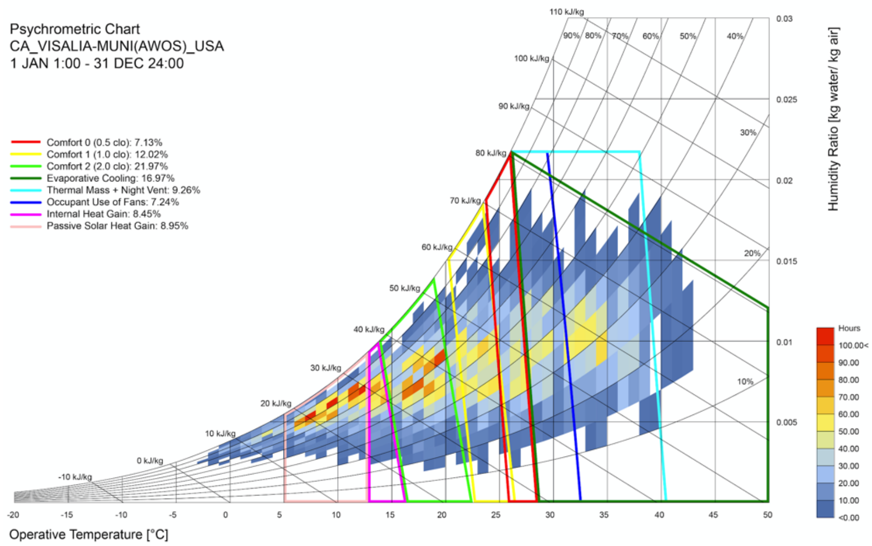
Source: "Catalyst SF" - Booth Hansen; 2013 Competition

Climate Analysis

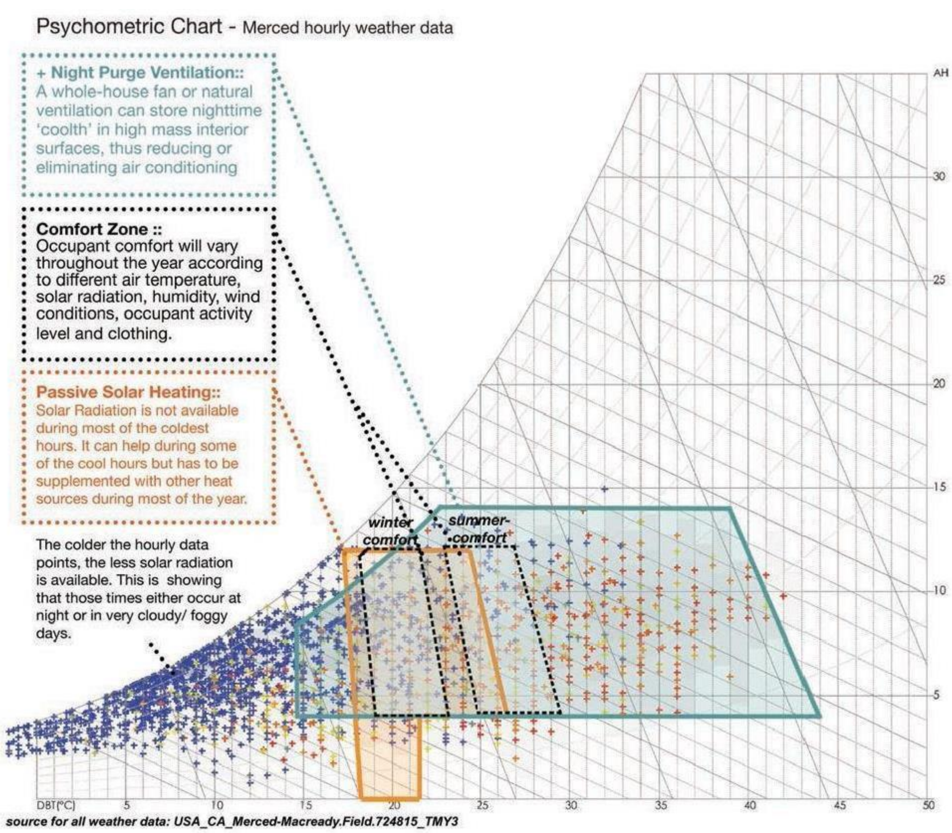
How does the particular climate of the site inform the building design? How have passive strategies been incorporated into the design? How will these strategies perform under extreme weather events?

Source: Elizabeth Gilman, Resource Refocus 2021

Visalia, CA



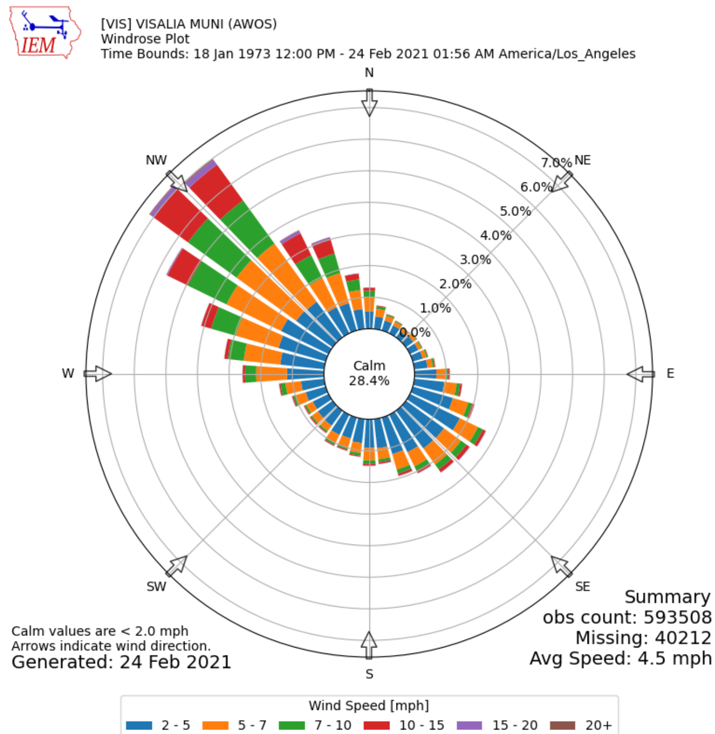
Psychrometric charts are graphic depictions of the physical and thermodynamic properties of air, such as dry-bulb temperature, wet-bulb temperature, enthalpy, relative humidity, humidity ratio, and dew-point temperature, and their relationship to comfort zones. The charts are used to inform the inclusion of passive design strategies based on their effectiveness to the given, specific location. Autodesk provides reference articles[7] to help understand and utilize psychrometric charts.



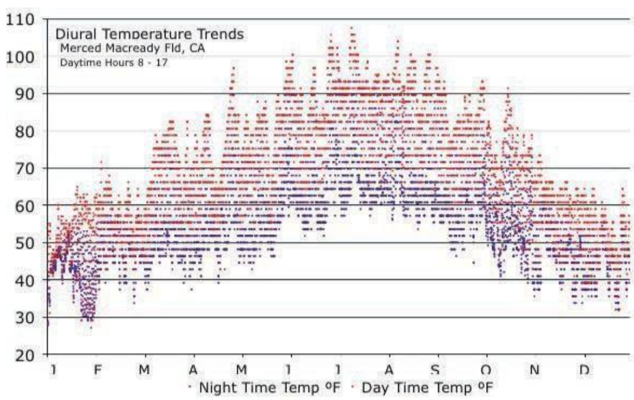
Source: "Silver Streak" - Loisos + Ubbelohde; 2012 Competition

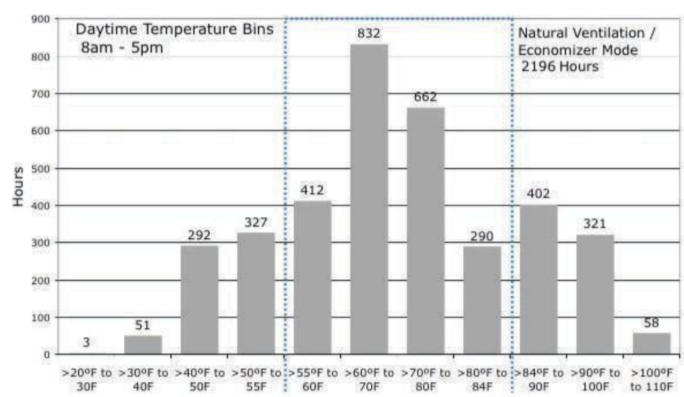
[7] Autodesk Psychrometric Chart guides, Part-1 and Part-2

Wind roses graphically represent the frequencies of wind direction and speed, allowing for quick interpretations and understanding of dominant wind patterns. While the image provided gives a summary for the average wind speeds in Visalia, CA throughout the year, Iowa State University also provides monthly breakdowns for the wind data.[8]



Source: "Wind Roses" - Iowa State University, Iowa Environmental Mesonet 2021





Source: "Homeostasis" - Wei Yan, Edward Clark; 2012 Competition

[8] Iowa State University: Iowa Environmental Mesonet - Wind Roses