FOG CATCHER

ARCHITECTURE AT ZERO

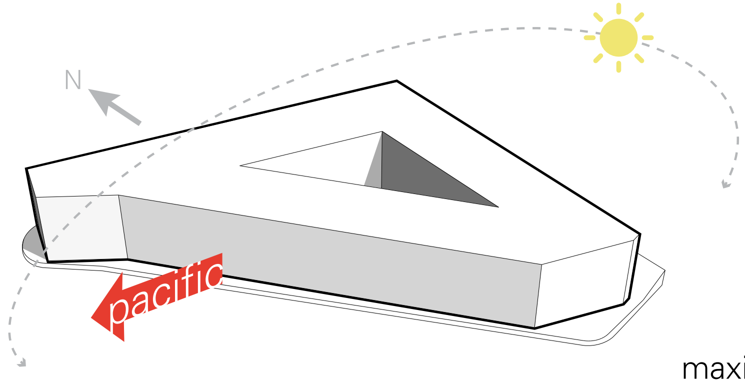
supplementary document

1 project description

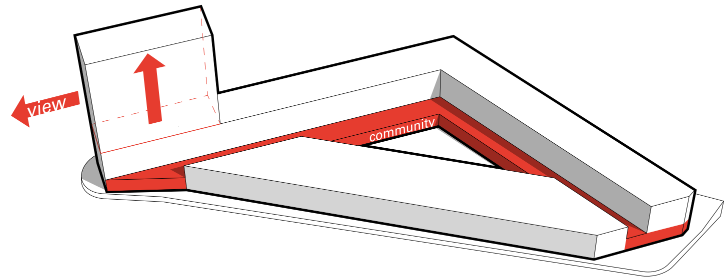
Fogcatcher embraces the specific microclimate of western San Francisco to generate a design that provides **net-positive energy, utilizing no mechanical system for the student housing, relying instead on passive strategies for heating and cooling**. This is accomplished by utilizing a tight and well insulated building envelope and incorporating a **"flipped" tiny living housing concept** with smaller internal sleeping quarters, which supports student's demand for more privacy, and general communal living spaces located on the perimeter, addressing student's desire for more daylight and wellness from their campus residential experience.

The building is enveloped in a "cloud-like" metallic shroud expressive of the natural breezes that enfold the student housing buildings like a perforated, filmy blanket. Addressing California's continued struggles with droughts, the design follows **biomimicry.** Similar to homeohydrous desert plants that collect dew, the design highlights a transparent mesh 'shroud' that collects fog condensation **acting as a fog-catcher**, gathering enough **water from the ambient fog to provide sufficient water for each student annually,** while providing customizable sun shading devices. The cloud-like fog catcher has operable shutters that can be opened or closed depending on the privacy desired or the controllability of sunlight and glare.
LED lighting is incorporated into each **building behind the shroud signifying the energy usage per building**, and creating a dynamic, ever-changing expression while educating the community on the building's energy consumption. Power would be generated by PV's on the roof and wind turbines located in a series of wind parks, capitalizing on the natural breezes to generate energy.

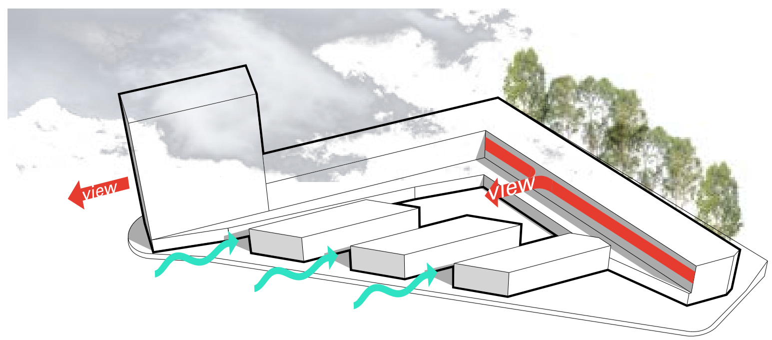
Through the smart, tiny living concept and almost entirely passive strategies, this project requires only 65-75% of typical square footage for comparable student housing and promises to be not just net-zero but actually **Net-Positive** by **18%**. Though we agree with the premise that density is appropriate, we did not support the number of beds proposed for the site. Daylight, natural ventilation and appropriate scale of living drove our design that accommodates **2,168 beds**.



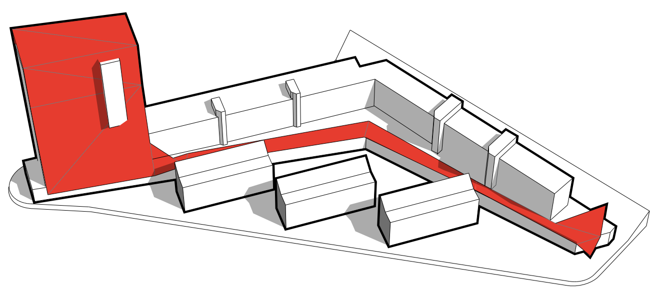
maximize lot coverage



contextual response & public programs



adjust for sustainability



architectural refinement


ecosystem

condensation

collection

architecture


implementation

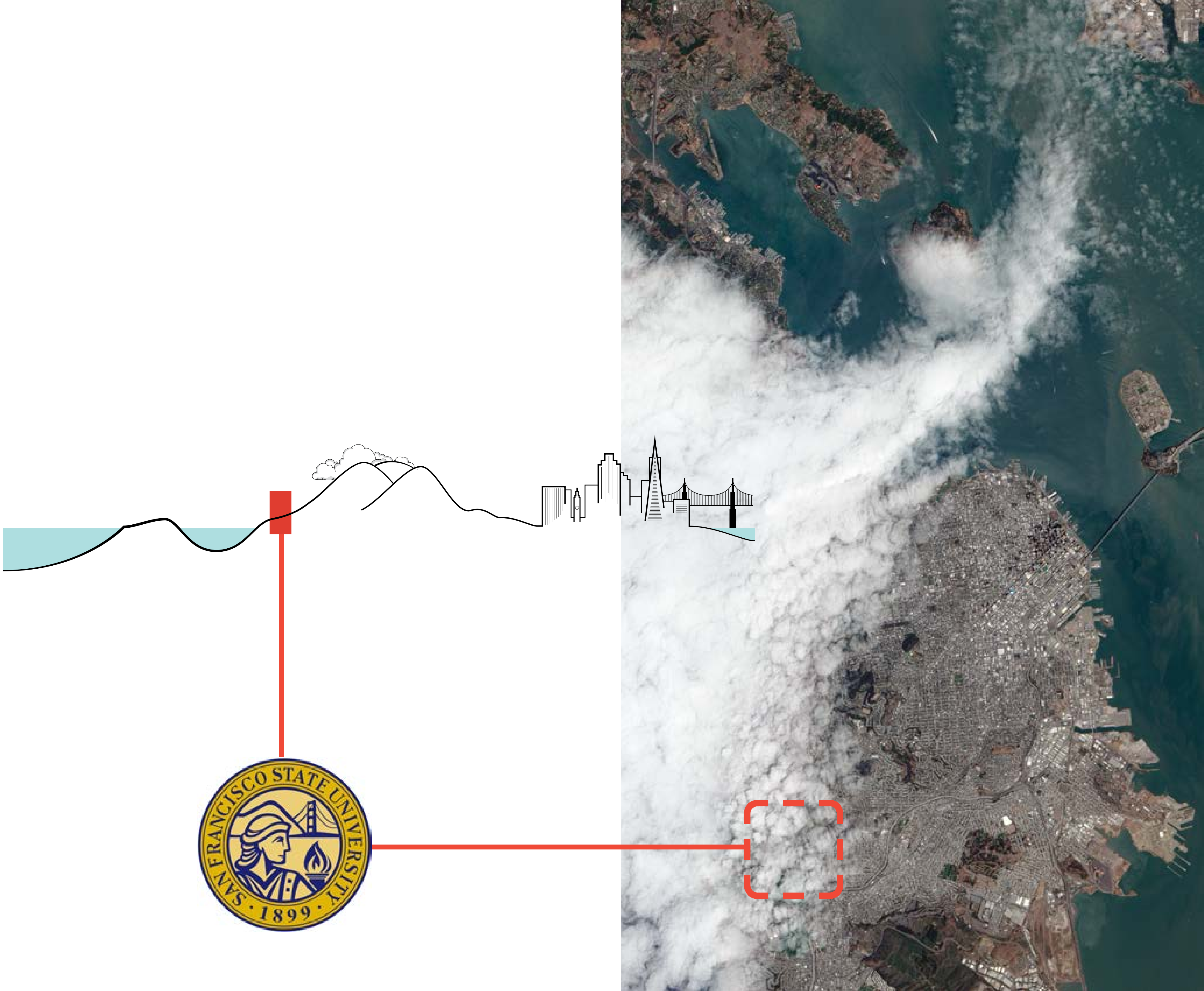
tectonics

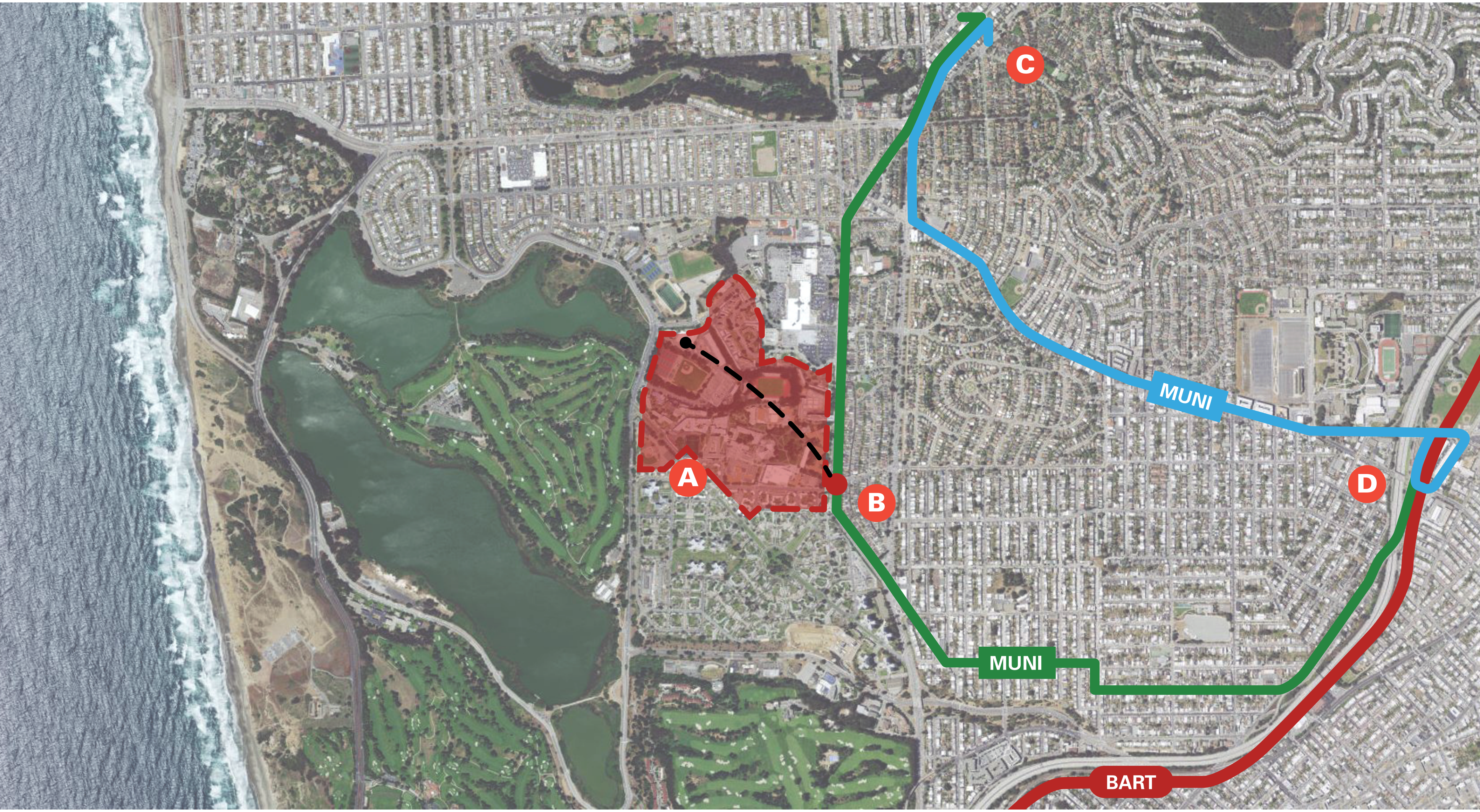
operable

texture

2 site + architecture

The site strategy for **Fog Catcher** creates **interconnected student neighborhoods of 32 students** that foster social and intellectual communities. The freshman and sophomore housing to the north and east are comprised of six-stories over parking that align the edges of the site. Upper division, graduate and married students are located in five-story **buildings oriented east-west, linking triangular wind farms**, generating 12,000 kWh annually, to capitalize on the solar orientation and the prevalent winds. These lower scale buildings allow for natural light in the central outdoor space, which is populated with all of the **public functions aligning the southern edge of the parking deck podium**. A 16-story t**ower, mixing freshman and sophomores, occupies the westernmost portion of the site**, creating an **iconic presence** and offering commanding, **dramatic views** to Park Merced and the Pacific Ocean beyond. Photovoltaic canopies are mounted to the roofs of all of the buildings, generating 2,626,185 kWh annually. Geothermal wells are needed only for the public spaces and are concentrated in the open areas between buildings. All housing units will be passively heated and cooled without a mechanical system. 8,700 gallons of water from the fog-catchers will be collected and stored on every floor of the buildings, providing supplementary water for flushing fixtures for all students and landscaping.


SAN FRANCISCO STATE UNIVERSITY
1899

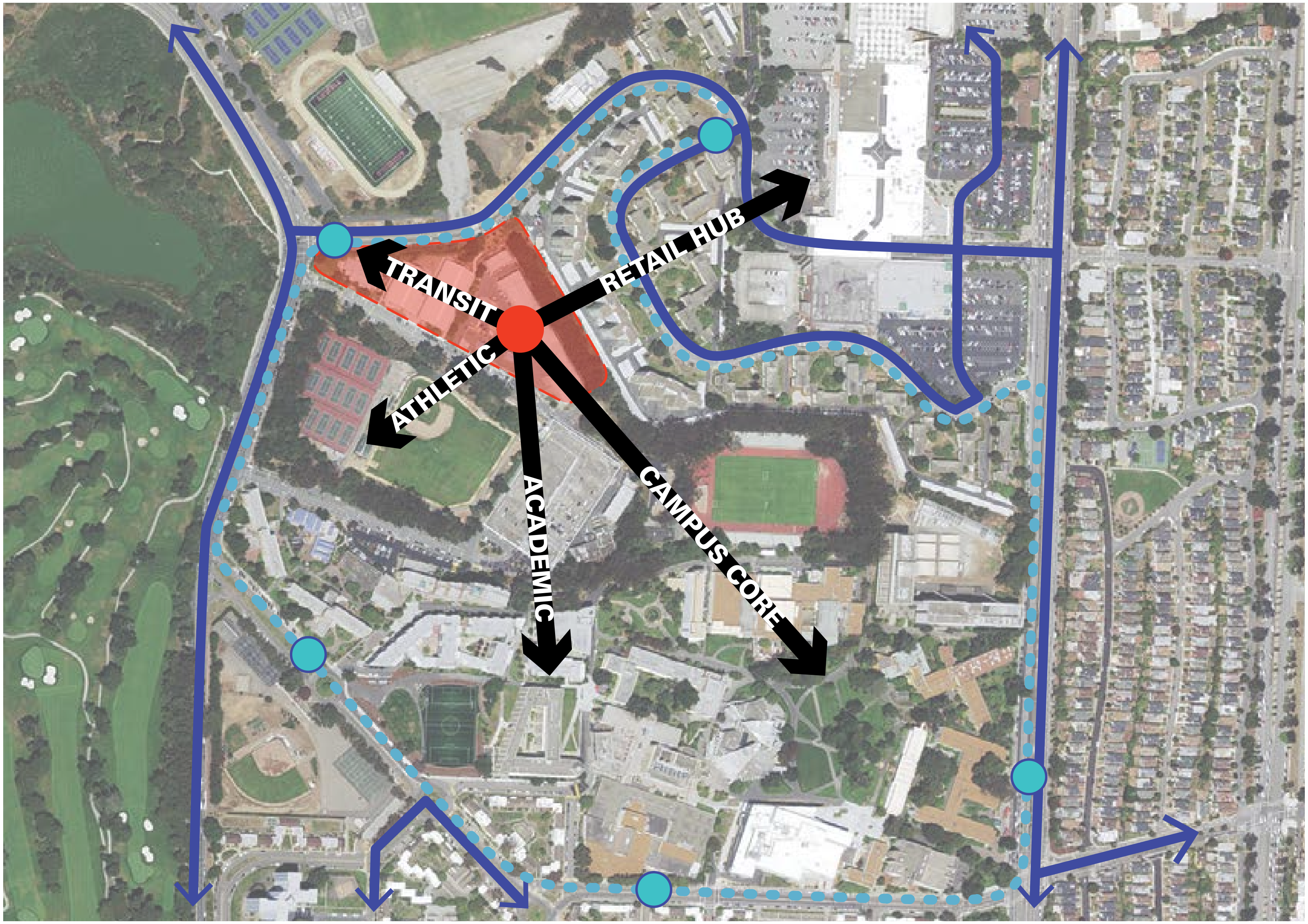


A San Francisco State University Campus

B Rapid Transit Station

C To Downtown San Francisco

D Connection to BART



MUNI Bus Route

Campus Loop Shuttle

Campus Loop Shuttle Stop

Project Site

- **A** Photovoltaic Panels (80,600 s.f.)
- **B** Green Roof System and Urban Farm
- **C** Connection Bridge
- **D** Central Courtyard / Rain Gardens
- **E** Audobon Approved Wind Turbines
- **F** Child Care
- **G** Campus Dining
- **H** Coffee Shop
- **J** Lecture / Meeting Rooms - Ground Floor
- **K** Underground Parking Entry
- **1** First Year Housing
- **2** Sophomores
- **3** Upper Division and Married
- **4** Mixed First Year / Sophomore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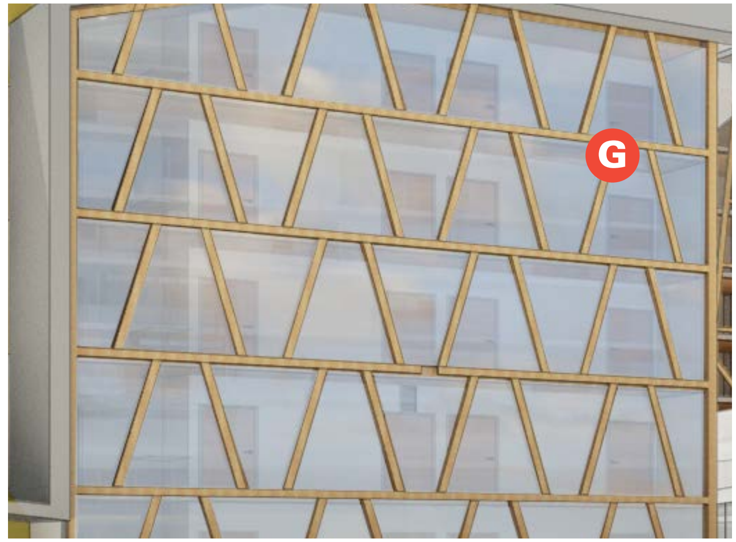


- **A** Fog Harvesting Screen System
- **B** Photovoltaic Panels
- **C** Wind Park
- **D** Green Roof System
- **E** Water Reclamation
- **F** Greywater Irrigation
- **G** Sun Shading Device
- **H** Vertical Pocket Park

- **A** Fog Harvesting Screen System
- **B** Greywater Irrigation
- **C** Vertical Pocket Park
- **D** Upper Division Housing
- **E** Geothermal Field
- **F** Freshman / Sophomore Tower
- **G** Campus Dining


F
C
D
A
E
G
B

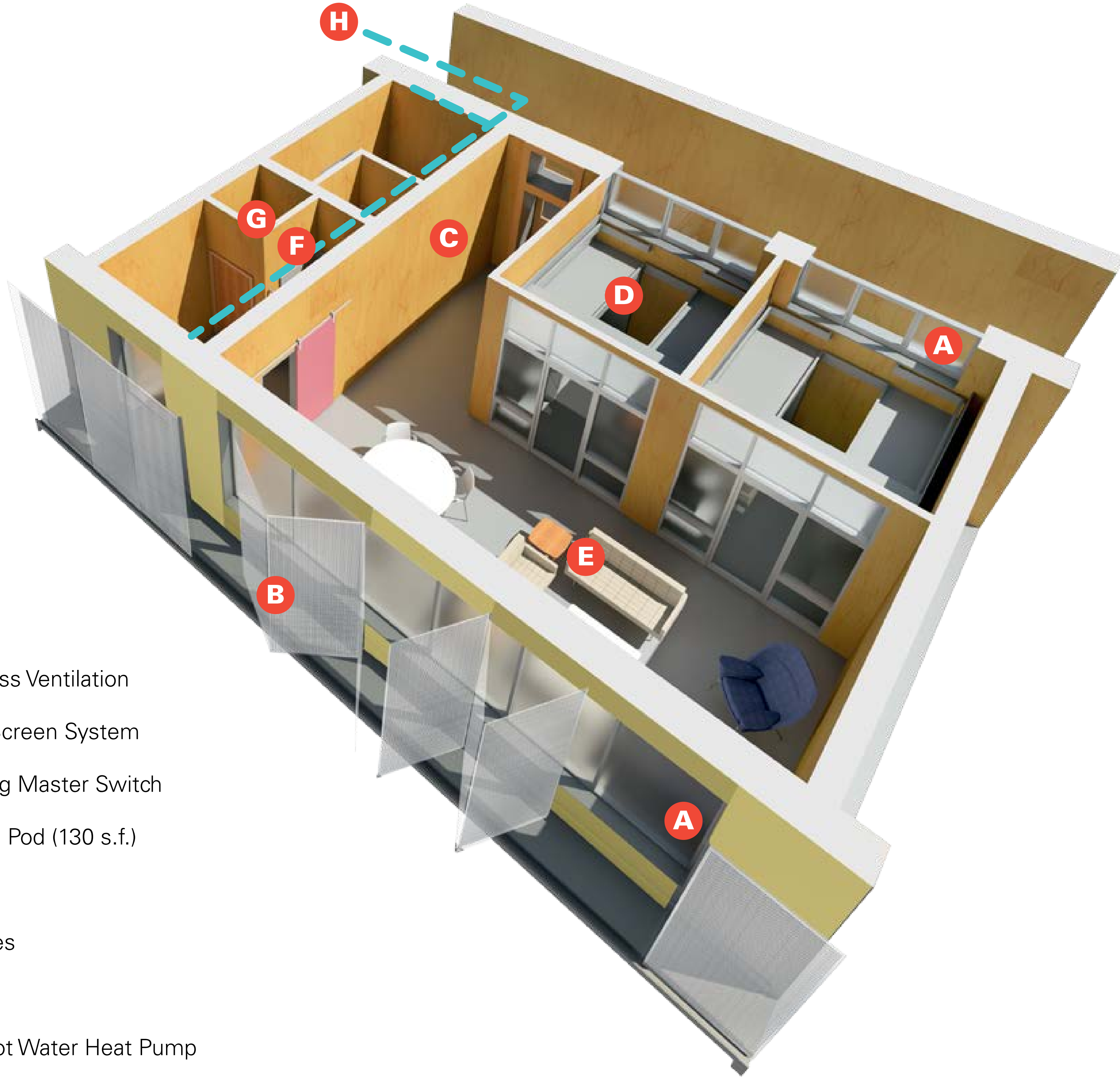
3 unit plans

The organization of the living units are **"flipped"** from the conventional dormitory typology for multiple reasons. **Locating the sleeping and private study quarters on the interior** wall of the suites and apartments **creates greater thermal comfort**, capitalizing on the natural climate conditions and **eliminating the need for mechanical systems**. In the winter, the warmer sleeping quarters will recirculate air to help temper the cooler perimeter public zone of the units. In the warmer summer months, the units will utilize the natural ventilation throughout the entire unit, connecting air flow to the "open' corridors. During cooler days, the corridors can be enclosed through temperature reading automation, while still being properly ventilated.

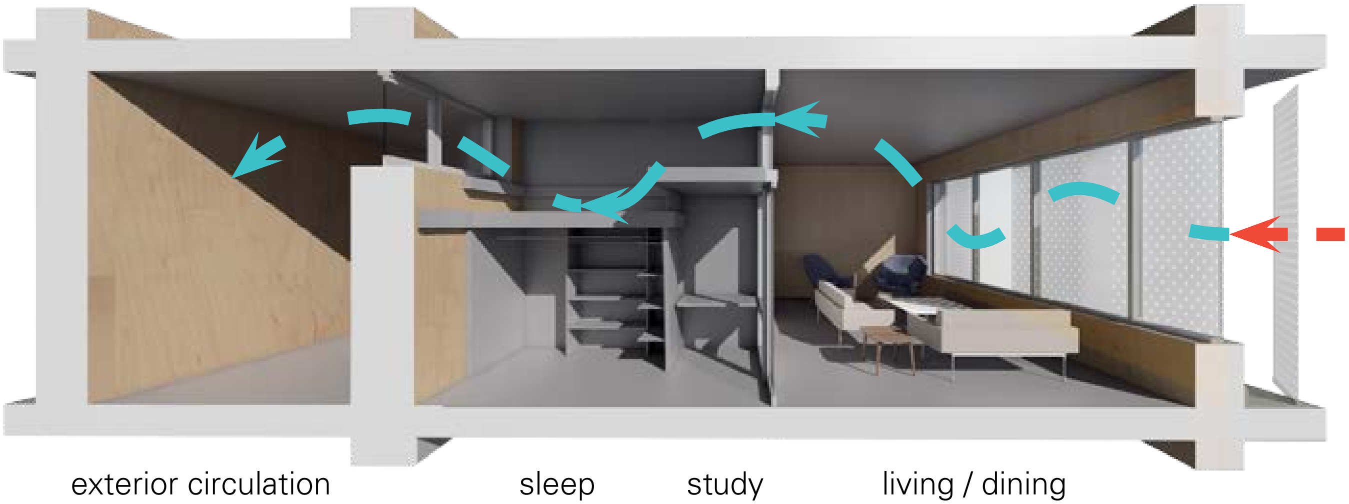
Typical apartments and suites on college campuses average 250-350 NSF per student. This concept of utilizing **Tiny Living principles is 190 NSF** per student, reducing materials by nearly half and significantly reducing energy consumption beyond the regional benchmark by 82% This typology is not just about reducing materials and cost: This **flipped concept** with minimal sleeping and study quarters focuses more on volume over area, **allowing for generous, open, well-lit living and dining spaces promoting greater social and intellectual collaboration**.

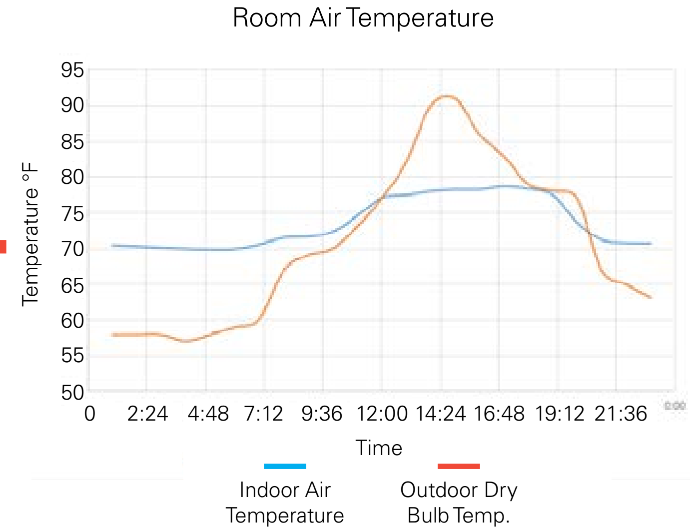
Energy Strategies

The cooling of the living spaces is accomplished with **natural ventilation only**. The building design uses operable windows and a orientation that takes advantage of the wind patterns in the area to introduce fresh air and **maintain a comfortable space temperature**. Heat pump water heaters provide domestic hot water Heat rejection from the water-cooled VRF to the ground source loop preheats incoming city, adding additional energy savings. Energy use is greatly influenced by the residents. A key card inserted in a reader within the space cycles the room into occupied mode, energizing receptacles, the ERU system, and lighting. The fog catchers also act as external shading devices to reduce direct sun exposes shading devices to **reduce direct sun exposure**.

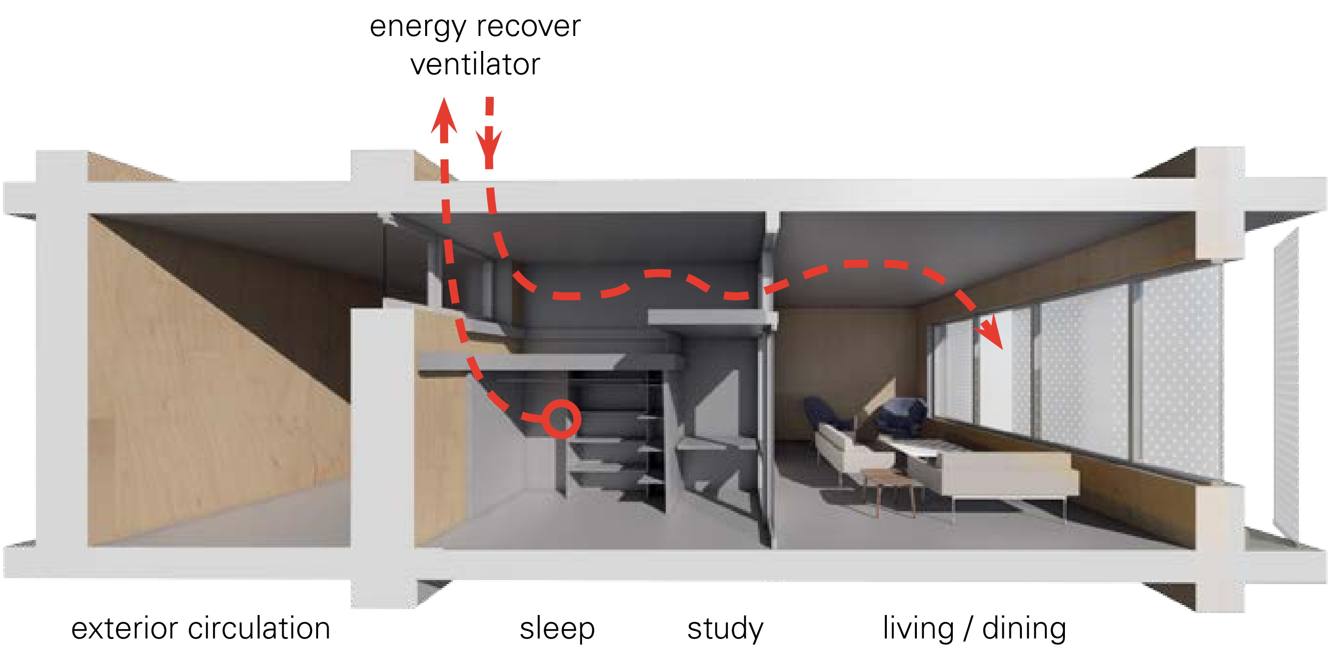


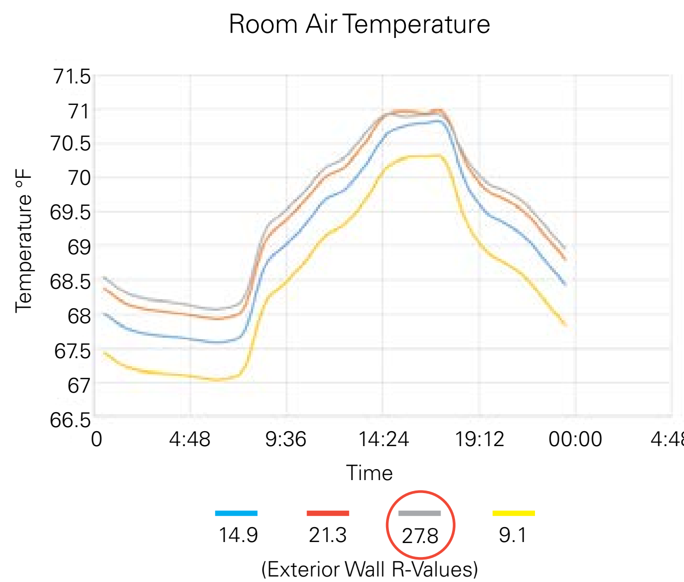
- **A** Operable Windows for Cross Ventilation
- **B** Operable Fog Harvesting Screen System
- **C** Occupant Key Card Lighting Master Switch
- **D** Tiny Living Lofted Sleeping Pod (130 s.f.)
- **E** Exterior Facing Living Area
- **F** Low-Flow Plumbing Fixtures
- **G** Greywater Water Closets
- **H** Domestic Hot Water via Hot Water Heat Pump



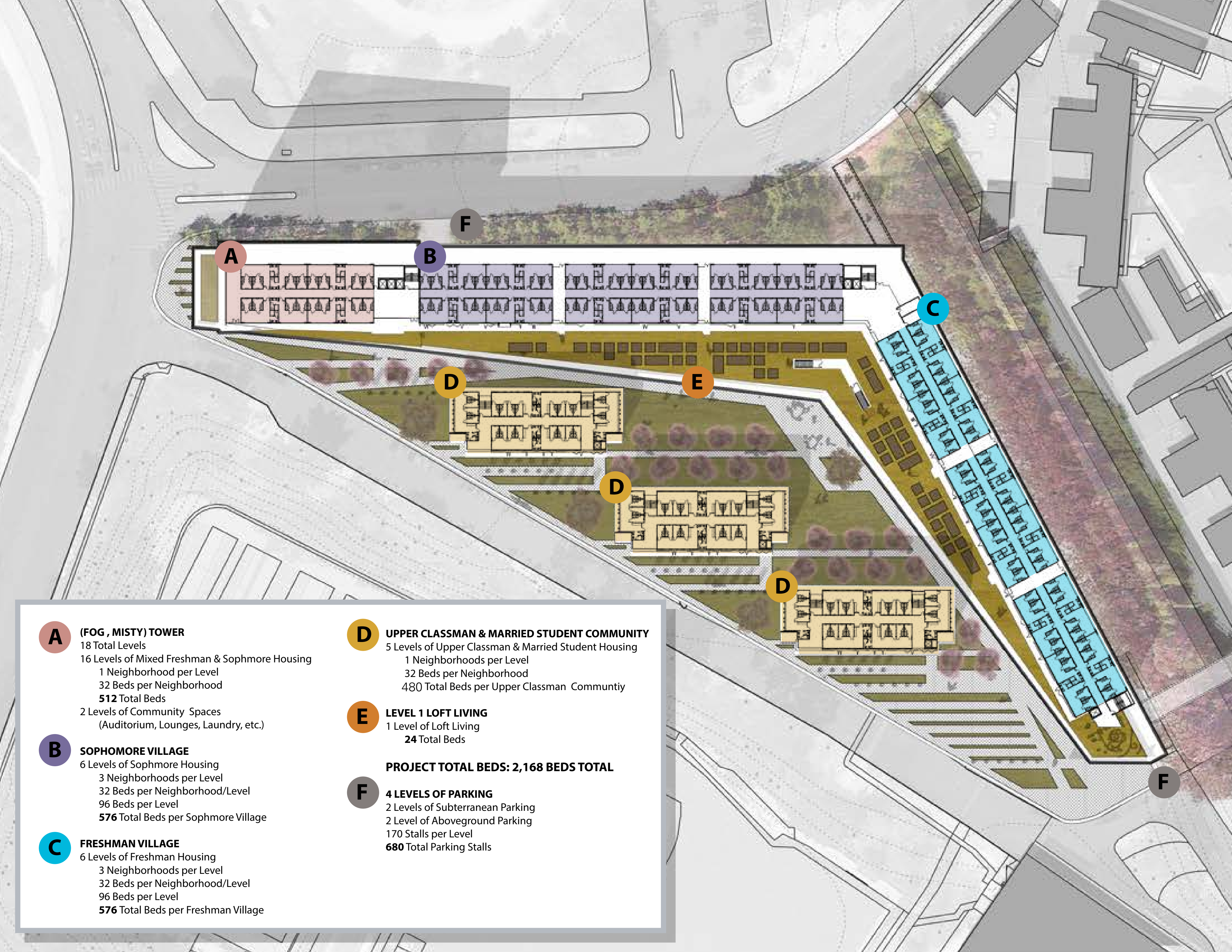


Air Circulation - Summer





Air Circulation - Winter



A **(FOG , MISTY) TOWER**
18 Total Levels
16 Levels of Mixed Freshman & Sophmore Housing
1 Neighborhood per Level
32 Beds per Neighborhood
512 Total Beds
2 Levels of Community Spaces
(Auditorium, Lounges, Laundry, etc.)

B **SOPHOMORE VILLAGE**
6 Levels of Sophmore Housing
3 Neighborhoods per Level
32 Beds per Neighborhood/Level
96 Beds per Level
576 Total Beds per Sophmore Village

C **FRESHMAN VILLAGE**
6 Levels of Freshman Housing
3 Neighborhoods per Level
32 Beds per Neighborhood/Level
96 Beds per Level
576 Total Beds per Freshman Village

D **UPPER CLASSMAN & MARRIED STUDENT COMMUNITY**
5 Levels of Upper Classman & Married Student Housing
1 Neighborhoods per Level
32 Beds per Neighborhood
480 Total Beds per Upper Classman Communtiy

E **LEVEL 1 LOFT LIVING**
1 Level of Loft Living
24 Total Beds

PROJECT TOTAL BEDS: 2,168 BEDS TOTAL

F **4 LEVELS OF PARKING**
2 Levels of Subterranean Parking
2 Level of Aboveground Parking
170 Stalls per Level
680 Total Parking Stalls

4 net-positive strategies

When first exploring the design, we studied how to reduce energy demand before jumping into selecting renewable resources. Our solution does this by employing **passive design strategies** and incorporating **tiny living concepts**.

Passive Strategies:

Solar orientation, natural breezes and fog greatly shaped the site design approach, as well as the overall building planning. We really wanted to explore the notion of not needing a mechanical system. By flipping the housing typology to internalize the sleeping quarters and pushing the public spaces to the perimeter, we have been able to create a balanced, passive approach that relies only on the recirculation of air to create the appropriate comfort levels year-round. We also understand the water shortage in CA and in addition to gray and black water systems we have incorporated fog catchers into the building envelope to capture enough water to store and use for the suite or apartment restrooms.

Health and comfort rooted in natural conditions can only lead to healthier and happier students who are more connected to the natural environment.

Tiny Living:

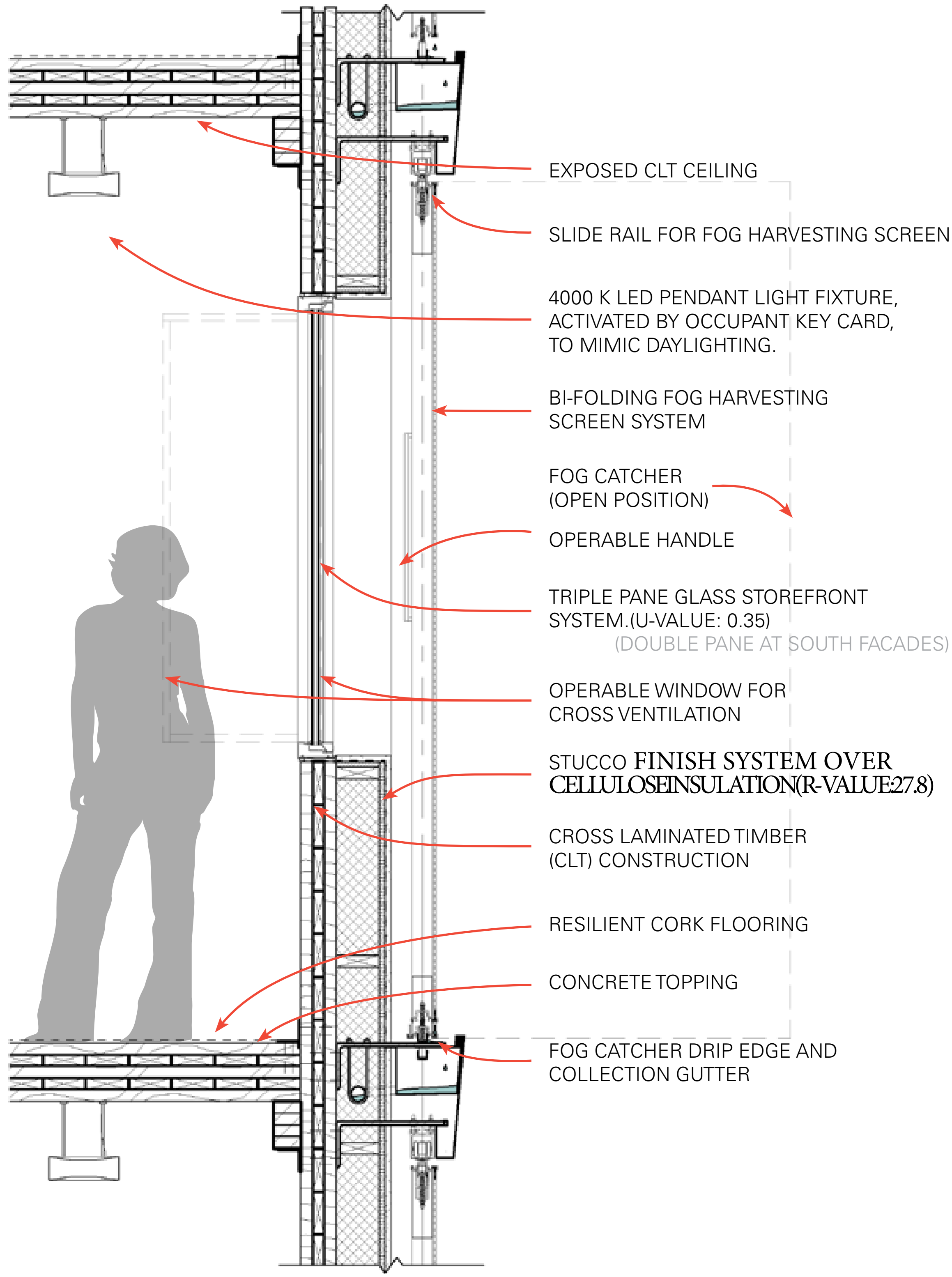
We have created intentional, smaller environments where every cubic inch is considered and carefully designed, while also considering the quality of the overall environment. For example, according to the program that was provided, a typical freshman or sophomore living unit would be approximately 350 GSF/student. We have designed our freshman/sophomore housing at 2,65 GSF/student. This is an overall GSF reduction of 25%. 25% less material. 25% less exterior surface area, and 25% less area to heat and cool.

We have provided 1,664 beds for freshman and sophomore student housing, totaling 425,000 GSF. That is 135,000 GSF less than the typical model equating to 17% energy demand reduction.

We took the tiny living model to the apartments as well, providing private tiny singles, compartmentalized bathrooms, a kitchen and a large, well-lit living space. The program provided in the original outlined brief for upper residents was approximately 430 GSF/student and we have provided a design that is 360 GSF/student. This is a 17% reduction.

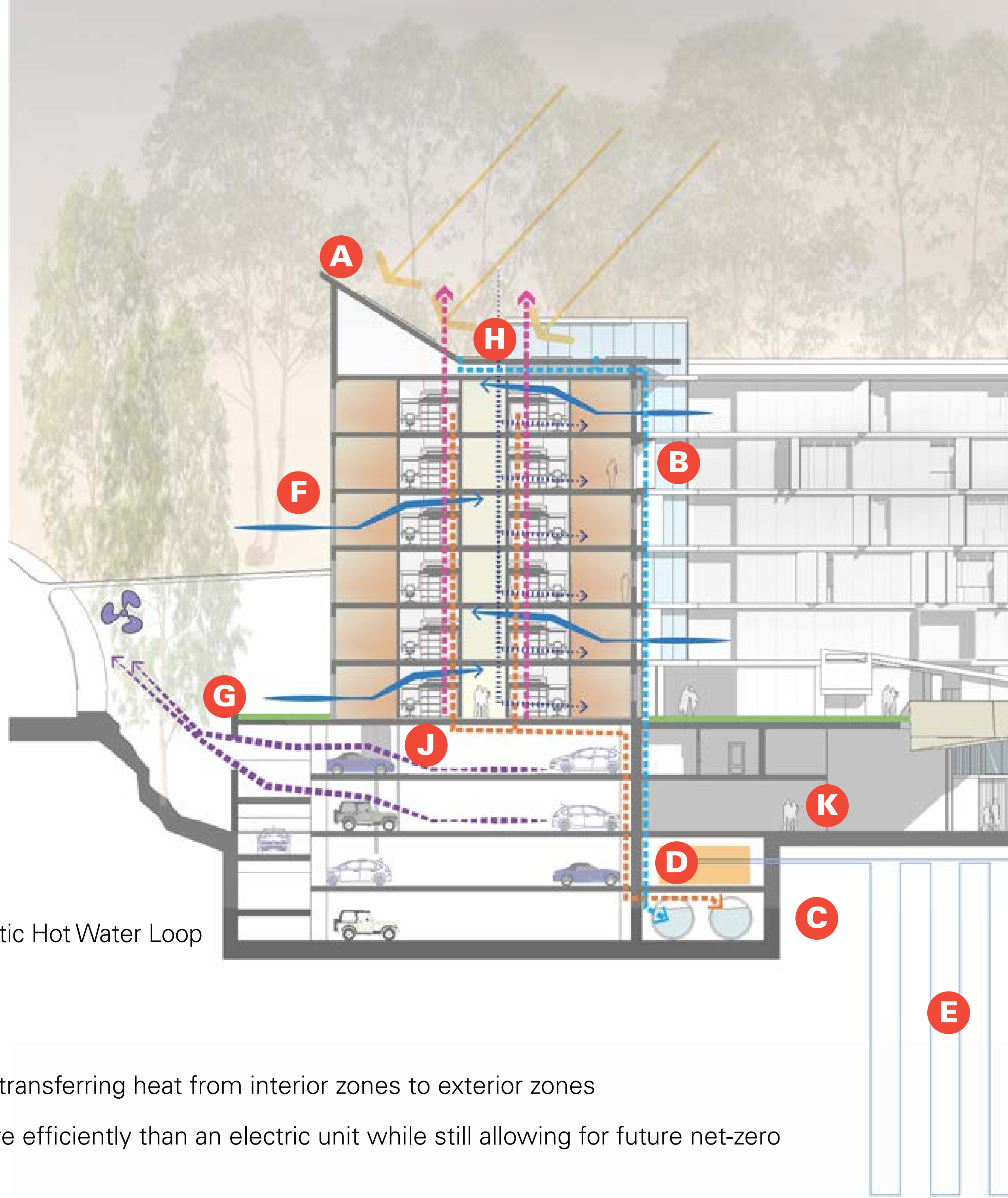
We have provided 480 beds for upper division students, married students and graduate students, totaling 130,000 GSF. That is 25,000 GSF less than the typical model, equating to 17% energy demand reduction.

Both of these housing typologies not only reduced square footage but they foster the kind of environment that encourages community on many levels, creating a healthier living situation which leads to greater success at the University level.


EXPOSED CLT CEILING
SLIDE RAIL FOR FOG HARVESTING SCREEN
4000 K LED PENDANT LIGHT FIXTURE, ACTIVATED BY OCCUPANT KEY CARD, TO MIMIC DAYLIGHTING.
BI-FOLDING FOG HARVESTING SCREEN SYSTEM
FOG CATCHER (OPEN POSITION)
OPERABLE HANDLE
TRIPLE PANE GLASS STOREFRONT SYSTEM.(U-VALUE: 0.35)
(DOUBLE PANE AT SOUTH FACADES)
OPERABLE WINDOW FOR CROSS VENTILATION
STUCCO FINISH SYSTEM OVER CELLULOSEINSULATION(R-VALUE:27.8)
CROSS LAMINATED TIMBER (CLT) CONSTRUCTION
RESILIENT CORK FLOORING
CONCRETE TOPPING
FOG CATCHER DRIP EDGE AND COLLECTION GUTTER

The building is a hybrid solution using a concrete podium for the parking, public spaces on the ground floor and the vertical core. Glulam and **CLT (cross laminated timber) construction** is use for the primary vertical structure, walls and flooring.
We know that natural materials are appealing but we now understand the neuroscience behind why. Our natural human response to nature and natural materials has been shown to reduce blood pressure and stress hormones in our bodies, allowing for the best conditions to relax, learn and engage with others. We have used **natural materials, finishes and colors to reinforce these biophilic benefits** on the occupants, allowing them to focus on creating new relationships and learning.
Additionally the total environmental impacts of CLT proved to outperform the more conventional construction systems.

- This system produces less greenhouse gas emissions than conventional construction.
- CLT stores carbon emissions and provides a temporary carbon credit.
- Carbon emissions to produce steel and or concrete are far greater than what is needed to produce wood.
- CLT has a lower life cycle impact than conventional construction.
- Wood can be harvested locally reducing transportation impacts.
- It is a renewable material.
- There are no adverse effects on the indoor environmental air quality contributing to the students' health and well-being.
- The material is re-usable.
- The thermal mass of the panels helps reduce heating and cooling loads.
- This pre-manufactured panelized system minimizes construction waste and any waste produced can be fed into the manufacturing plant's biofuel plant for carbon neutral energy.



- **A** Solar Energy
- **B** Captured Rainwater and Fog
- **C** Greywater, Rainwater, and Fogwater Storage Tanks
- **D** Water-Cooled Variable Refrigerant Flow Serving Community Zones
- **E** Ground Source Loop with Heat Exchange to Domestic Hot Water Loop
- **F** Passive Cooling through natural Ventilation
- **G** Code Required Exhaust Fans
- **H** Energy Recovery Ventilator providing fresh air and transferring heat from interior zones to exterior zones
- **J** Heat Pump Water heaters providing hot water more efficiently than an electric unit while still allowing for future net-zero certification by not using combustion.
- **K** Daylighting controls automatic reduction of artificial lighting within the community zone spaces. A daylighting study was included in the energy simulation to reflect the energy savings.

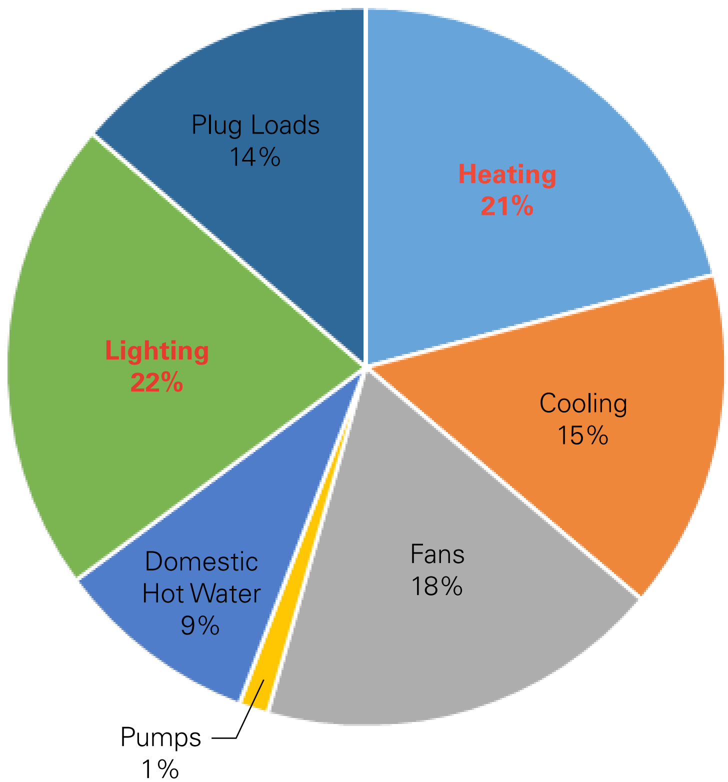
5 end use summary

Aggressive energy efficiency measures proposed for Fog Catcher contribute to a design that **surpasses regional benchmark energy use intensity (EUI)**. Going beyond the 2030 Challenge's to reduce energy consumption by 70% over comparable buildings in the region, the proposed site achieves an **EUI of 9.1 kBtu/sf/yr**, an 82% energy savings over the benchmark. Additionally, the site **generates 118%** of the required energy through photovoltaic panels and wind turbines. This energy production fuels the surrounding community through not only clean energy production but also as a social catalyst.

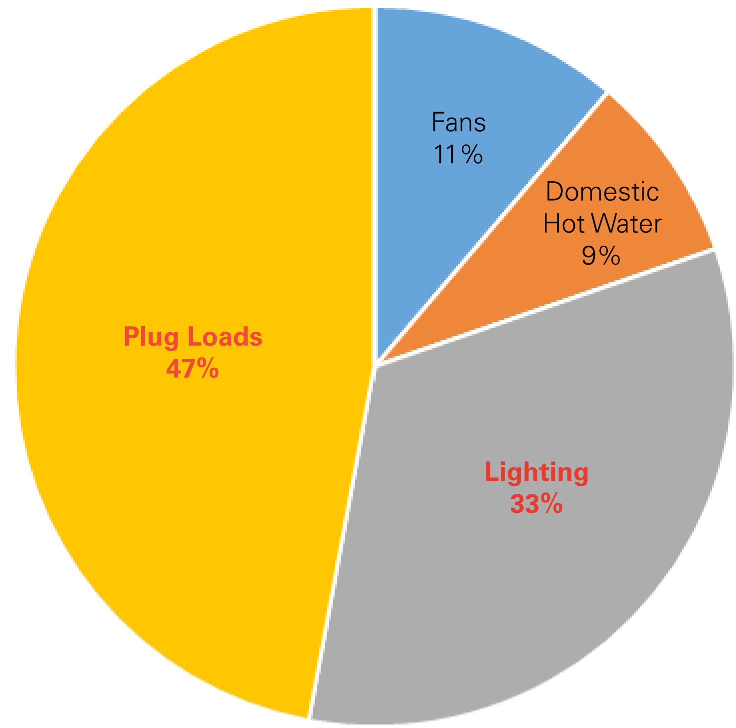
The energy goals are achieved primarily through providing over 2,000 beds in a **tiny living concept with passive heating and cooling**. Tight construction and a super-insulated design keeps heat from internal gains inside the building during cooler months and heat from entering spaces during warm summer days. This insulated design also provides a high level of comfort as interior surface temperature varies little in response to outdoor temperature changes, allowing for residential units to **forgo mechanical heating and cooling** for a large energy savings. Resident key cards that activate lighting and select electrical circuits in units, incentives for low consumption, and active monitoring by building occupants through energy consumption feedback provide savings on resident plug loads.

Additionally, access to **natural views and daylighting keep lighting energy consumption low** while maintaining appropriate lighting levels. Along with heat exchange through a ground source water loop, heat pump hot water heaters, and heat recovery between exhaust air and incoming fresh air, the design ensures occupant comfort with minimal energy consumption.

Community Zones End Use Consumption



Housing End Use Consumption



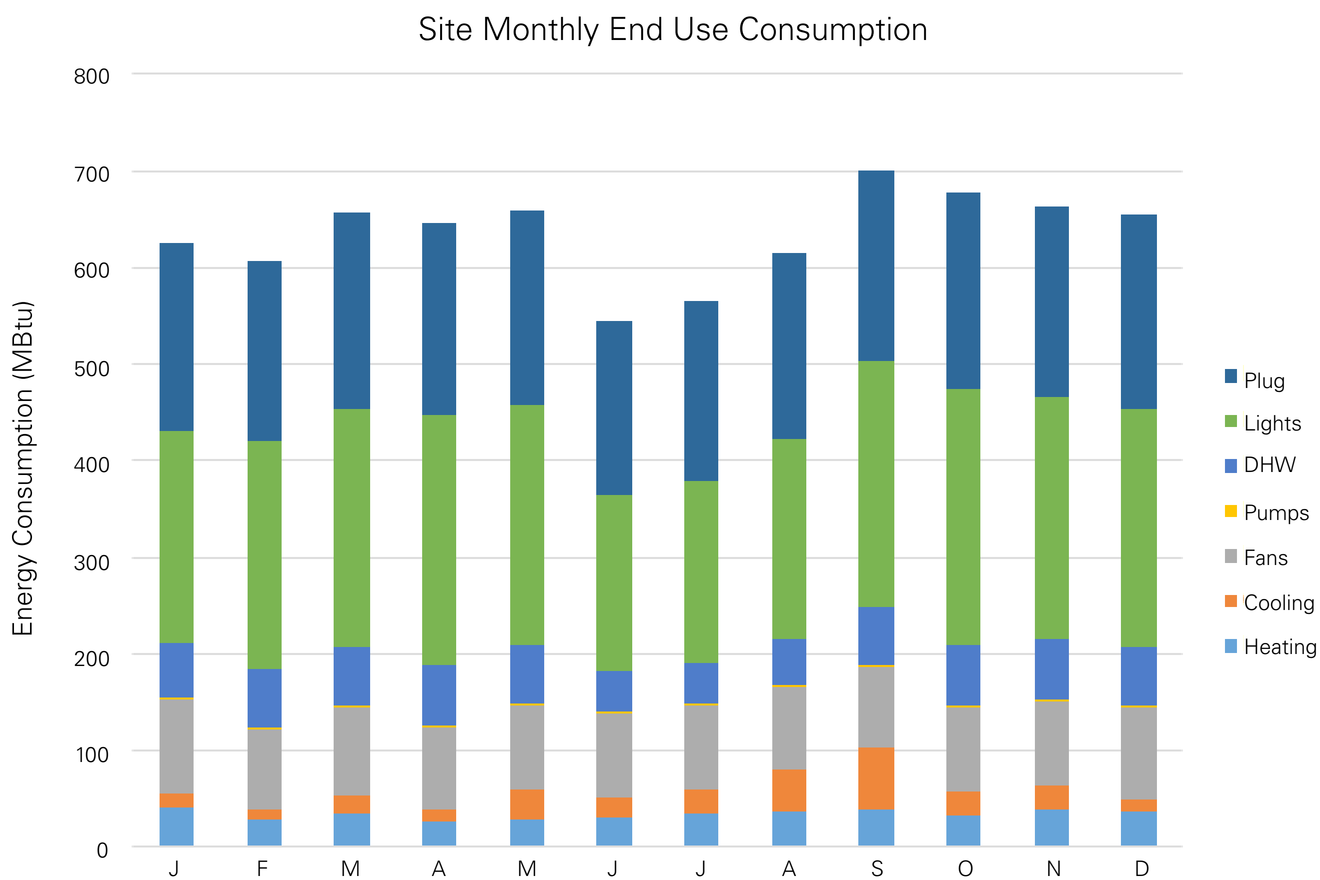
Community Zones		Lighting (W/sf)	Plug Load (W/sf)	Hot Water (gal/h/person)
	Lecture	0.4	1	0.045
	Dining/Kitchen	0.4	0.15	0.145
	Laundry	0.4	1.5	0
	Childcare	0.4	1	0.045
	Recreation	0.4	.25	0.023

Housing		Lighting (W/sf)	Plug Load (W/sf)	Appliances (kWh)	Hot Water (gal/h/person)
	Upper division	0.3	0.25	1080	0.023
	Lower division	0.3	0.25	215	0.023

Housing plug loads based on a minimum (4) laptops, (4) desk lamps, (4) phones, (2) tablets, (1) microwave, (1) TV, (1) refrigerator for a 4-person suite and (1) stove/ oven in the upper division apartments.

Building Envelope		
	WWR	40%
	Glazing - North	U-0.26, SHGC-0.25, VLT - 48%
	Glazing - East	U-0.26, SHGC-0.25, VLT - 48%
	Glazing - West	U-0.26, SHGC-0.25, VLT - 48%
	Glazing - South	U-0.26, SHGC-0.25, VLT - 48%
	Exterior Wall Insulation	R-28
	Roof Insulation	R-30

Results		EUI (kBtu/sf/year)
	Heating	0.49
	Cooling	0.36
	Fans	1.26
	Pumps	0.03
	Domestic Hot Water	0.81
	Lighting	3.37
	Plug Loads	2.81
	Total	9.13
	PV and Wind Offset	10.79



Site Monthly End Use Consumption
Energy Consumption (MBtu)
800
700
600
500
400
300
200
100
0
J
F
M
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J
J
A
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N
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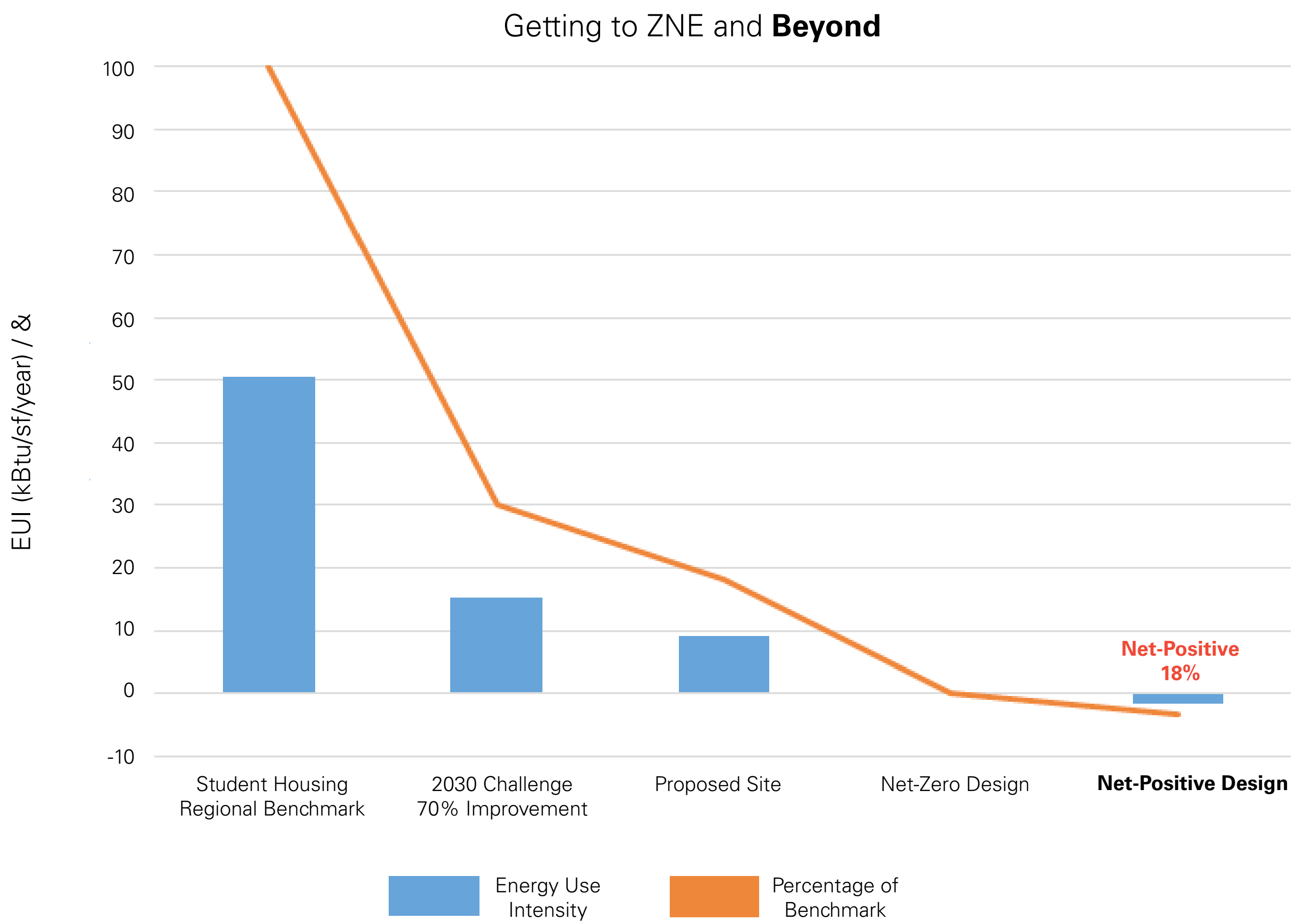
Lights
DHW
Pumps
Fans
Cooling
Heating



Getting to ZNE and **Beyond**
EUI (kBtu/sf/year) / &
100
90
80
70
60
50
40
30
20
10
0
-10
Net-Positive
18%
Student Housing Regional Benchmark
2030 Challenge 70% Improvement
Proposed Site
Net-Zero Design
Net-Positive Design
Energy Use Intensity
Percentage of Benchmark

Renewable Resources

Photovoltaic Panels by the Numbers

The site's primary source of renewable energy is solar. SunPower's X22-360-COM panels tied to the electric grid were used as the basis design to produce enough energy for a net positive site. Available roof space is loaded with 2,830 horizontal panels covering **49,674 sf** and 1,763 panels angled at 22° covering **30,937 sf** The total production is **2,626,185 kWh/year**, approximately **118% of the site's total energy consumption**.

Rethinking Wind Energy

36 vertical axis wind turbines spread across three concentrated wind parks contribute approximately **12,000 kWh** of energy to the sites renewable resources. While their energy productions is not a large percentage of the site's consumption, the wind turbines are not only a peaceful and sculptural contribution to the landscaping but also a reminder to residents and students of the university's dedication to sustainability.

Water Reuse

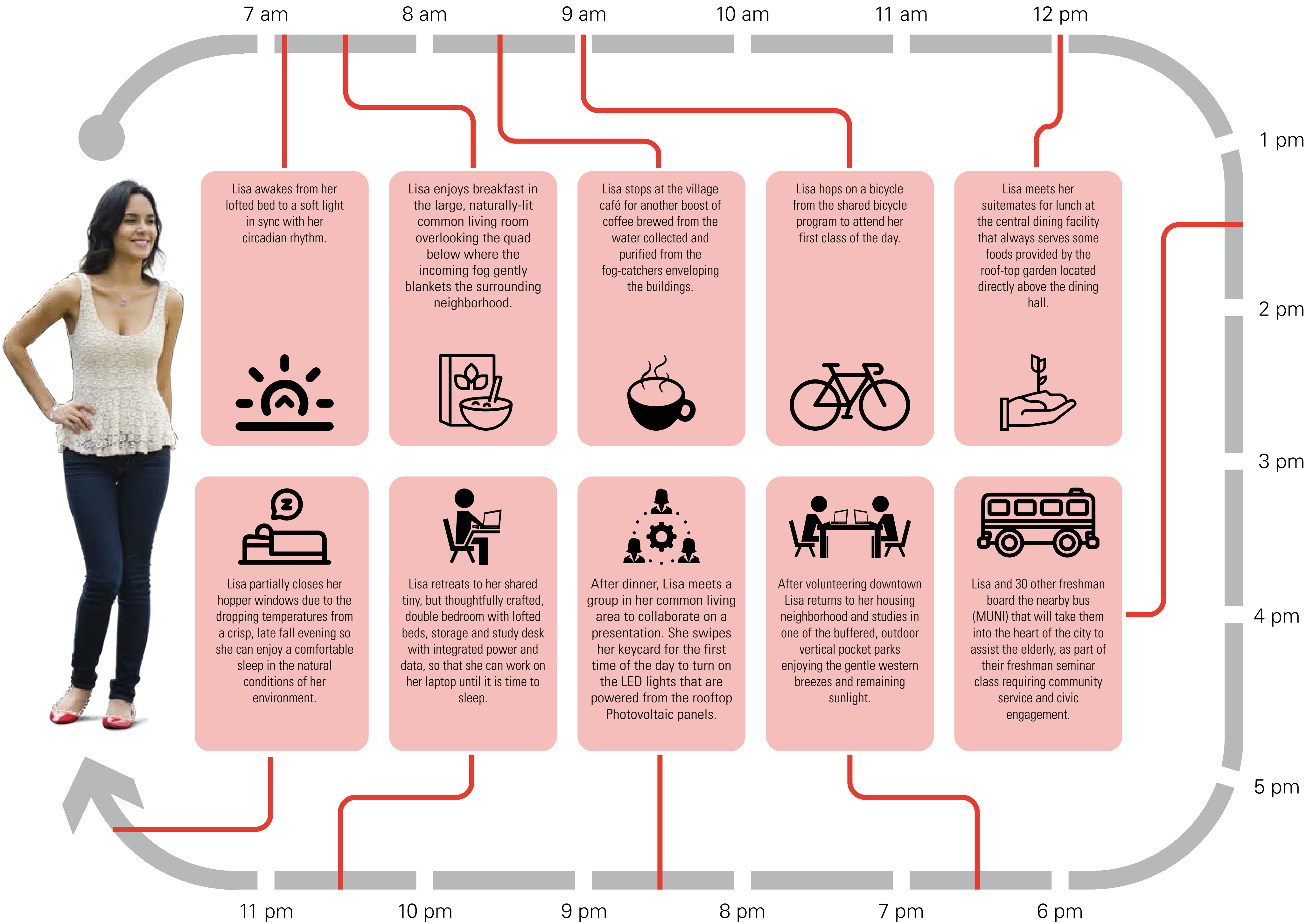
An on-site treatment system makes use of rainwater, greywater, and water captured through the innovative fog catcher system to reuse water for use in low-flow flushing fixtures, laundry, and landscaping. As drought conditions continue and California residents are faced with the challenge to conserve water, innovative solutions and investments in water technology are key to reining in water consumption.

In reviewing the design with vendors, such as Aquanomix, the annual rainfall is estimated at 20.1". With **142,000 sf** of roof surface, we can expect to collect approximately **1.5MM gallons of rainwater** annually for use in flushing fixtures with overflow used for landscaping.

With the number of students being served, we have calculated that up to **50,000 gallons per day of greywater** will be available. We are designing for a 50,000 gallon storage tank and a filtration system (2-stage filtration and UV treatment) sized for 80 gpm which would be the peak demand on the greywater system. We have not chosen a black water system because of the cost of the system, the amount of chemicals needed to treat the wate, and the state and local regulations for this treatment. Greywater offers a substantial benefit to the project without the increased cost and chemical use of a black water system.

Mesh screens blanketing the building facades **capture wind-blown fog droplets**. As fog drifts in from the ocean, the harvesting system pulls fog out of the air, condenses it into water, and funnels the collected water towards the rainwater system. Based on data from researchers, approximately 0.1-0.2 gallons/ft^2 is captured daily, totally a daily contribution of approximately **8,700 gallons** to the water reuse system.

6 a day in the life ...


7 am
8 am
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11 am
12 pm
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10 pm
11 pm
Lisa awakes from her lofted bed to a soft light in sync with her circadian rhythm.
Lisa enjoys breakfast in the large, naturally-lit common living room overlooking the quad below where the incoming fog gently blankets the surrounding neighborhood.
Lisa stops at the village café for another boost of coffee brewed from the water collected and purified from the fog-catchers enveloping the buildings.
Lisa hops on a bicycle from the shared bicycle program to attend her first class of the day.
Lisa meets her suitemates for lunch at the central dining facility that always serves some foods provided by the roof-top garden located directly above the dining hall.
Lisa and 30 other freshman board the nearby bus (MUNI) that will take them into the heart of the city to assist the elderly, as part of their freshman seminar class requiring community service and civic engagement.
After volunteering downtown Lisa returns to her housing neighborhood and studies in one of the buffered, outdoor vertical pocket parks enjoying the gentle western breezes and remaining sunlight.
After dinner, Lisa meets a group in her common living area to collaborate on a presentation. She swipes her keycard for the first time of the day to turn on the LED lights that are powered from the rooftop Photovoltaic panels.
Lisa retreats to her shared tiny, but thoughtfully crafted, double bedroom with lofted beds, storage and study desk with integrated power and data, so that she can work on her laptop until it is time to sleep.
Lisa partially closes her hopper windows due to the dropping temperatures from a crisp, late fall evening so she can enjoy a comfortable sleep in the natural conditions of her environment.

12 pm 11 am 10 am 9 am 8 am 7 am

1 pm 2 pm 3 pm 4 pm 5 pm

William awakes to the sound of the early morning breezes and calls from his daughter in the room next door.

Willam and his daughter, Olivia, enjoy breakfast in the large, naturally-lit common dining room, overlooking the courtyard and the daycare center employees turning on the lights, getting ready for the day.

William takes Olivia to the day care center as the building's facade lights begin to change, signifying the energy demand beginning to rise. He then crosses the pedestrian bridge through Eucalyptus Trees to take the shuttle to the BART station.

After leaving his internship at the Peace Corps, William stops by child care to see Olivia before heading to the lecture hall beneath the western tower. Through the mist, William can see the water condensing on the fog harvesting screen.

After leaving the community outreach lecture, William heads up the stairs, past the bustling laundry-lounge and cafe which are both supplied by the fog harvesting screen system. On the tower's top floor lounge, WIlliam takes in a moment of peace looking out at the Pacific.

After picking up Olivia, William meets with his neighbors in the graduate student housing where they share a meal in their large living/dining space. The large space is the result of the 'tiny-living' bedrooms, giving space to the common areas.

After dinner, William takes Olivia acroos the street to the recreation fields to play before bed. After putting Olivia to bed, William opens the windows to create a breeze and finishes up some work to prepare for tomorrow.

Willaim gets into bed in his, internal, darkened bedroom which allows for optimal circadian rhythm minimizing sleep disruption in order to wake rested and re-energized.

6 pm 7 pm 8 pm 9 pm 10 pm 11 pm

C conclusion

This project was conceived and designed in a truly integrative manner where each decision informs and responds to multiple other factors critical about the design. Energy strategies, social organization and aesthetic expression are woven together in an integrated manner to create Fog-Catcher.

Energy related design

- **Net positive 118% - 18% positive**
- No mechanical system for the student housing using passive systems design and proven through the planning and mathematics/physics
- Renewable energy PV/Fuel cells?/Geothermal/wind farms
- Fog catchers capturing water for re-use
- Cross laminated timber construction to minimize overall environmental impact
- Tiny living principles to reduce sf, save materials, reduce energy needs, improving the quality pf living.
- Flipped housing to provide open well-lit living spaces for everyone
- Technologies to reduce consumption, keying lighting, occupancy sensors, photo sensors

Social design

- **Multi-layered communities**
- Village of 2000 students
- Sophomores of 800 students
- Freshmen of 800 students
- Upper division and married student housing of 400 students
- Neighborhoods of 32 students throughout
- Lounges between neighborhoods to bring people together.
- Suites and apartments of 4 with common living areas
- Rooms of 2 (freshmen and sophomores)
- Dining, café, laundry lecture halls, meeting rooms, childcare all easily accessible on the ground floor.
- Outdoor quadrangle
- Vertical pocket parks

Aesthetic Design

- **We intentionally expressed elements** that contribute to the building achieving Net-Positive energy
- Simplicity of construction expressed
- Living rooms on the perimeter expressed
- Fog-catchers and sun shading expressed
- Vertical pocket parks for social and natural ventilation expressed
- Tower as icon and place to view Merced Park and the ocean expressed
- Exposed wood panels on interior from CLT panelized construction expressed
- Energy usage through lighting expressed


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ARCHITECTURE AT ZERO
supplementary document