ConSol
Yale University

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1. Project Progress Report

1.1 Project Introduction

The “right to a city”— a concept first proposed by French philosopher Henri Lefebvre in 1968—places emphasis on protecting urban spaces from the effects of commodification and social and economic inequality. Geographer David Harvey describes the right as “far more than the individual liberty to access urban resources: it is a right to change ourselves by changing the city.” The right to a city is, moreover, a common right since the transformation it entails inevitably depends upon the exercise of a collective power to reshape the processes of urbanization. To us in Yale University Team ConSol—a team that includes several first-generation, low-income students—the freedom to make and remake our cities and ourselves is a precious yet often overlooked right.

We chose Los Angeles for our design location because of the city’s well-known problems with affordable housing and for its large unhoused population. From fragmented planning and sometimes just plain neglect, large urban cities like Los Angeles often marginalize the unhoused population, removing their “rights to a city” and leaving many families without access to housing. Our goal is to ensure that vulnerable populations are protected and given opportunities to thrive in their environment. With its moderate, sunny climate, Los Angeles is a desirable setting for affordable housing based on modern solar technology. Several organizations addressing homelessness in greater Los Angeles—including our design partner, Union Station Homeless Services—have provided the team with the information needed for a well-designed and practical solution.

Our design creates a model of sustainable, low-cost urban single-family housing for the unhoused and low-income populations—housing which, we believe, can provide a stepping stone for members of the community to find their footing and realize their potential.

1.2 Project Summary

We designed our residential unit with low-income populations in mind. Affordable housing in the United States is often designed to maximize occupancy in a given physical space, which tends to create housing units with limited area for comfort. Affordable housing can also ignore aesthetics and community-building, with a side effect that the stereotypical affordable housing complex ends up creating increased feelings of isolation, not community. We want our design to reinvent the narrative around low-income housing.

The built environment is a reflection of a society and its values. Sprawling urban landscapes are intended to promote productivity, but many factors—including a series of recessions and shifting demographics, and, now, a global health crisis—have left gaps in today’s urban environments. The city of Los Angeles has hundreds of empty lots, thousands of disintegrating buildings, and millions of people who have been made unwelcome in their home city. This population deserves a chance to live in safe, affordable, and comfortable housing.

Urban sprawl in Los Angeles has left behind neighborhoods destitute and gentrified, especially in minority and low-income communities. Despite many efforts, the city has not made great progress in reducing housing insecurity. Here are the numbers:

- Los Angeles has about 22,000 vacant lots, about 10 percent of which are owned by the city.
- Los Angeles also has more than 792,000 publicly- and privately-owned empty properties within its boundaries. About 14,000 properties are owned by six major public entities, including the City, LAUSD, State, County, Metro, and Federal. Many of the empty parcels can be repurposed for affordable housing.

Last year, the city launched a new initiative to transform these vacant lots into accessible public spaces; yet chronic homelessness in LA County is predicted to nearly double in the next four years. Los Angeles has space for everyone but will need more political will and determination to ensure equity. Team ConSol’s design is intended to provide a path for short-term action, with potential to shape long-term changes in the city. Our design builds around key features of shipping containers—modularity, ease of transport, and adaptability to different environments. A basic housing unit consists of two containers, merged to create a coherent floor plan with ample space for a family of four to live and grow. The arrangement provides enough roofing area for solar PV panels to satisfy the electricity demand of all the occupants while backup battery storage ensures resilience. In addition, the design includes necessary measures to comply with local codes and to mitigate natural disaster risks such as earthquakes and wildfires; some of these measures include the addition of a sprinkler system and the avoidance of natural gas systems or connections.

1.3 Team Information

The ConSol team is composed of motivated individuals who possess a drive and passion for sustainability and accessibility. While we may not be experts, we are a team with many life experiences that influence our design process and decisions. Our team structure reflects a collaborative approach without a strict leadership hierarchy. Because we are a small team with limited resources and support, each member was involved in every aspect of the design process.

Mary Chen (Upper Left) – Geology & Geophysics and Political Science

Sena Sugiono (Upper Right) – Environmental Studies

Queenie Lam (Bottom Left) – Undecided

Asher Ellis (Bottom Right) – Economics

1.4 Additional Information

We worked with the following individuals or groups to help provide more realistic feedback for our design process:

Yale College Students:
Elias Silver (Architecture)
Shan Gunasekera (Finance)
Theo Haaks (Policy)
Thembi Gausi (Mechanical Engineering)

Non-Students / Organizations:
Union Station Homeless Services (Local Design Partner)
Eli Gould (Architecture)
Kyle Yoshida (Plumbing)
Michael Oristaglio (Yale Faculty Advisor)

2. Target Market and Design Constraints

2.1 Target Market, Location, and Setting

Team ConSol's proposed design aims at providing modular, affordable, sustainable, and comfortable housing for families who cannot afford existing housing in urban and suburban settings. Unfortunately, more and more families find themselves forced into homelessness because of soaring housing and rent costs and resistance from communities to allow construction of affordable housing in their neighborhoods. We believe that our design can help reverse this trend by reducing construction costs and creating a pathway for affordable, aesthetic, and practical housing which can fit and fit in anywhere.

To find the best location, we explored an interactive mapping software, created by LA Controller Ron Alperin and his technology and innovation team. The tool compiled a visual map of nearly 14,000 properties in the City, owned by six major public entities, including 7508 properties owned by the city itself. We explored a variety of parcels of lands and investigated each parcel's information using the Assessor Identification Number (AIN) through the LA County Assessor Portal.

We settled on a building site in San Fernando Valley as a typical site where our design could work. This site is in the Sylmar neighborhood of Los Angeles, with an elevation of 1,159 feet from sea level and minimal sloping (aerial photo from Google Maps at left below). According to a 2017 estimate from the LA Department of City Planning, Sylmar has a population of 82,298, with about 6,678 people per square mile. The neighborhood experienced a 4.4% growth in population from 2013–2017. Other demographic statistics are:

- The median household income was about $66,000 in 2008.
- Average household sizes for renters and owners are about 3.99 and 3.79 people, respectively.
- 64% of the population own homes; 36% rent.
- 14% of the population fall below the poverty line—higher than the 2017 national poverty rate of 12.3%.

FIG 1 | (LEFT) Aerial photograph of site chosen as the type location for Team ConSol's design (from Google Maps). (RIGHT) USGS earthquake hazard map of the U.S.

The site's precise geographic location is 34°17'54.6"N 118°27'23.4''W. The vacant lot is made up of five parcels identified by their AIN (Appendix B). We identified a rectangular plot of land that is roughly 366 by 300 feet in size (Figure 1), with enough space to create 24 units of our basic design housing up to 96 individuals. The lot resides behind residential houses, in a secluded setting; access to the property would of course need to be negotiated with the local community. This is especially important given that neighborhoods in Los Angeles have often been hostile towards construction of new affordable housing. The plot of land is, however, owned by the City, which should allow for more flexibility in permitting and construction. There is limited pathway access to the lot from the main street, San Fernando Road. The lot does not have any trees or other obstacles that need to be removed, with the exception of the wild grass that has grown in the vacated, uncared plot.

We believe that such a location would be ideal for families with children. Local public schools include the El Dorado Avenue Elementary School, which is less than a mile away, and Osceola Street Elementary School, about 2.3 miles away. Two hospitals—Olive View Medical Center and Providence Holy Cross Medical Center—are also within close proximity. Similarly, supermarkets and shopping centers are also located nearby, and Sylmar's public transportation system will allow increased mobility and convenience for low-income occupants with children.

The Los Angeles County Metro provides bus services, and Metrolink provides commuter rail services on Antelope Valley Line at the Sylmar/San Fernando station, which is less than a mile away from the proposed location. Metro Local bus lines run through various streets in the Sylmar community. As the neighborhood continues to grow, Metro Local plans to open the East San Fernando Valley Transit Corridor light rail project at the Sylmar/San Fernando station. For families with motor vehicles, Sylmar is serviced by several freeways, including nearby Interstate Highways I-5, I-405, and I-210.

Other Sites:
We have identified other locations in Los Angeles where our housing unit can transform and adapt to the surrounding built environment. While the team understands that many neighborhoods will not be welcoming—and may even be hostile—to affordable complexes, which may help to change minds. Our design emphasizes comfort, efficiency, aesthetics, and community-building. Overcoming ingrained assumptions and attitudes is, however, a large challenge, as demonstrated in localities such as Echo Park, where recent protests destroyed homeless encampments. Other potential locations include a vacant lot at 34°12'43.3"N 118°27'24.1"W (AIN 2210025900), which is in Van Nuys, the most populous neighborhood in central San Fernando Valley. This is one of many locations the Los Angeles City Council is proposing for one of their homeless shelters. Another potential location is near 1353 Elysian Park Drive, Los Angeles, CA 90026, with coordinates of 34°04'26.2"N 118°14'58.5" W (AIN 5406011900). More information on these sites is in Appendix B.

2.3 Local Climate

The Sylmar region is in climate zone 3A (CA climate zone 9) and has an average humidity of 50–70%. To prepare for potential rainfall, roofs are slanted at 45° to prevent the buildup of rain or debris. Shipping containers are expected to have minimal rust issues in most dry climates such as Southern California, but our proposed location is about 30 miles from the ocean, so there is potential for fog and moisture to blow in from the coast. Therefore, rusting in a humid climate is a concern. Several preventive measures will be implemented to minimize rusting on the container which provides the exterior support structure. A layer of galvanizing paint will be applied to all outer walls. There is also the risk of ground moisture buildup, as the plot is primarily soil. To protect against ground moisture, the pier foundation elevates the unit and a capillary break is included in the foundation.

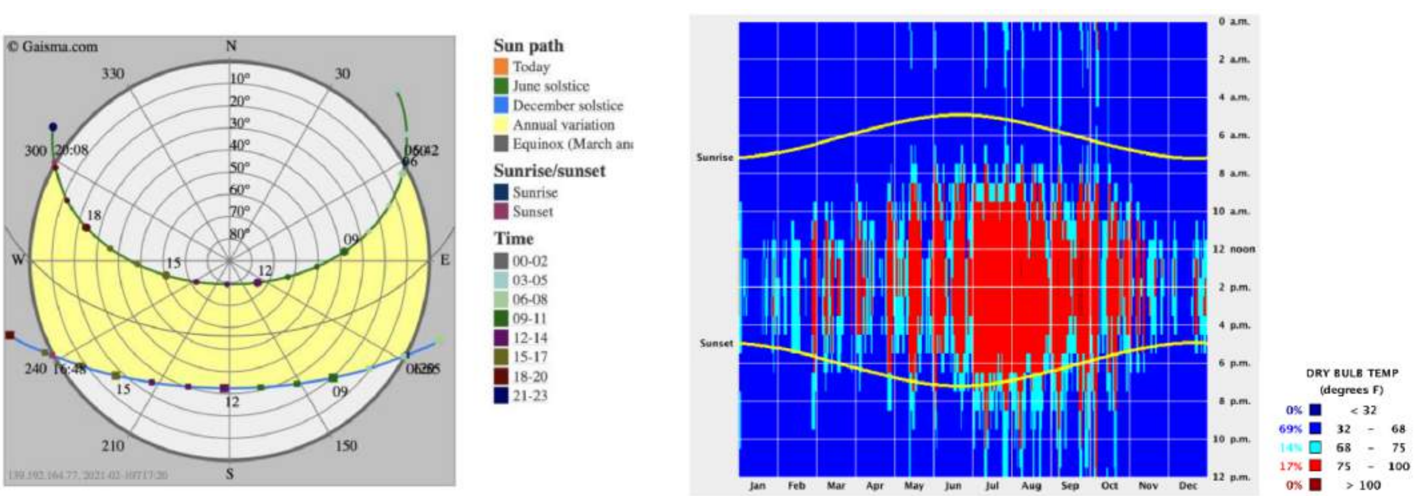


FIG 2 | (LEFT) Solar path in the sky over Los Angeles during the year. (RIGHT) Annual temperature envelope.

The Sylmar region receives about 12 hours of sunlight per day.[11] The monthly average Global Horizontal Irradiance (GHI) is about 5.3 kilowatt-hours per square meter per day (kWh/m^2/day). Solar installations in this area average about 6.06 kWh/m^2/day when tilted at the latitude of Sylmar. Sylmar has a moderately cool climate, with the temperatures mostly in the 32–68°F and almost never less than 32 °F or above 100 °F. The HVAC system was designed bearing the WHO standard for room comfort and minimal health risks, which is 64–75 °F for adults, and 68–75 °F for infants, children, and the elderly. The building will use low-powered, fan-based ventilation with natural airflow through double-paned windows. The system is off-grid and fully powered with PV and supported with enough battery to run a regular load for up to 36 hours and a critical load for up to 72 hours. Thus, building occupants will be unaffected by any temporary environmental disruptions until the primary power generation is restored.

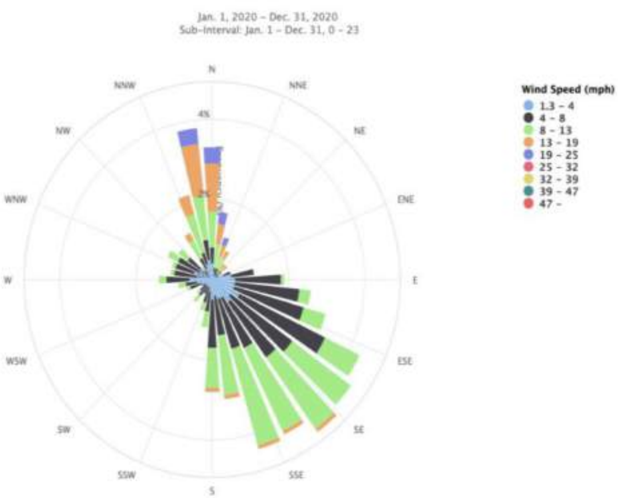


FIG 3 | Rose diagram of wind in Sylmar

There is a low to moderate amount of wind in Sylmar. The wind rose figure at the right shows that the particular location has a relatively low wind profile during the year. Each home will use heat-recovery stack ventilation with low power fans at one high and one low area. The fans operate in pairs: warm air will be blown out from the top and cool air will be blown in from the bottom fan and vice versa. The home will have both passive and forced ventilation, with openings for passive flow to aid the mechanical ventilation. This ventilation will aid in cooling the units without relying on the wind. The annual average rainfall is 15 inches, which is a low amount, but we still need to slant the roof to prevent water buildup. Due to the lack of rain, the garden will include local plants to reduce water usage, while maintaining the natural appearance and aesthetics of the building design.

2.4 Codes and Standards

LA Homelessness

The Los Angeles City Council has devised several potential solutions to addressing the housing crisis. The city spent $442 million last year developing homeless shelters and affordable apartments, with none fully realized. Thus far, the city's $77-million shelter expansion plan has produced two facilities, with room for 147.[12] Our building's design will take advantage of existing legislation and grant programs to fund the construction. Since the government has been trying to build homeless shelters in the Sylmar region, we believe our target location would offer faster and more successful permitting.

Building Code

The proposed building concept is specifically designed for affordable housing to address homelessness. Many existing codes and standards for traditional housing units may be waived. This is in accordance with the Transit Oriented Communities (TOC) Incentive Program — a voter-approved initiative (Measure JJJ) passed in November 2016 — that incentivizes the construction of affordable housing near transit routes.[13] The units will also comply with California Plumbing Codes, which include required sprinkler systems in all buildings post-2011 and determining the pipes needed for the qualifications.

Rebates

As the proposed location is in the Los Angeles region, the units potentially qualify for $35,2520 worth of rebates on a federal, state, and municipal level, including qualifying for the California Self-Generation Incentive Program, a 26% Federal Tax Rebate, and the Single-family Affordable Solar Homes (SASH) program. In addition, the housing unit also qualifies for efficiency rebates for using heat pumps and ENERGY STAR rated appliances from Southern California Edison, the utility company.

In addition to energy efficiency and energy generation incentives, California has a few grants that could be utilized by individuals who are at risk of homelessness or are currently unhoused. These incentives will be discussed further in section **4.3 Market Potential**

Other Certification

In order to keep track of meeting the competition and team design goals, we relied on established standards and their metrics. Other standards we use are ASHRAE Guidelines, the California Energy Code Comfort Model, LEED Certification and PHIUS+ 2018 Passive Building Standards.

3. Design Goals

3.1 Design Goal 1 – Affordability

Since our design is intended to house unhoused individuals, affordability is a key consideration for the team. We plan to keep costs down by tapping into California's rebate program, using recycled materials, and pursuing self-assembly where possible. Installing energy-efficient, gas-free appliances and implementing a passive house design complemented by on-site generation will also help to lower annual energy bills.

3.2 Design Goal 2 – Livability

Livability is a high priority of our team. All our decisions about insulation, common spaces, architectural design, and outdoor free space are geared towards making each unit as comfortable and dignified as possible for residents. We have learned not to repeat the mistakes of certain past efforts to alleviate homelessness - efforts which led to individuals being relocated into uncomfortable, cramped homes that severely harmed the mental health of residents, especially those with children. As such, we focused on prioritizing resident comfort. This includes utilizing smart home technologies such as a smart thermostat, smart blinds, smart MPPT controllers, and energy monitoring technologies. We also developed a dual passive/forced ventilation system with a robust air filtration system (MERV 8 filters) to minimize energy use while maintaining adequate air circulation. In addition, the design includes many large windows to capitalize on natural lighting and added plants, which improves the views of the outside garden and improves mental health (longer concentration, better sleep at night, etc.). The plants also help reduce noise pollution from the surroundings. The water heater heat pump provides cooling in the summer, aided by the ceiling fans, while the wall-mounted heat pump provides heating in the winter.

3.3 Design Goal 3 – Energy Efficiency

Our building utilizes the passive house design concept to achieve net-zero energy usage. The house is fully electric and does not have any gas hazards or risks (important for the Sylmar region where there is a risk of wildfires and earthquakes). Smart controllers control the HVAC's minimal energy usage. All appliances were selected based on their exceptional energy star ratings. Thick insulation and metal roofing help reduce heat loss/gain, which increases the energy efficiency of the HVAC system. Our system will generate more energy than it uses up annually. Instead of utilizing electric water heaters, which are energy-intensive, our team designed our own water heating system that simultaneously cools the roof and solar panels while supplying hot water for showering. Our goal is to work towards achieving LEED Platinum certification and qualify as a passive house based on the PHIUS 2018+ standards.

3.4 Design Goal 4 – Modularity

Each module is designed to be compact and easily added to or removed from a layout. The use of shipping containers as the primary building block of the home facilitates this mobility and also shortens the construction timeline. The layout itself can be adjusted as well, as the angle between the two containers can be made larger/smaller and the deck area added to any side of the house. The arrangement of the units as a cohesive compound can also take many shapes. For our intended square plot in Los Angeles, it is most efficient to place six units in a circular pattern to create a dodecagon, but for other more rectangular plots units can easily be arranged in an elongated zig-zag pattern.

4. Contest Narratives
4.1 Architecture

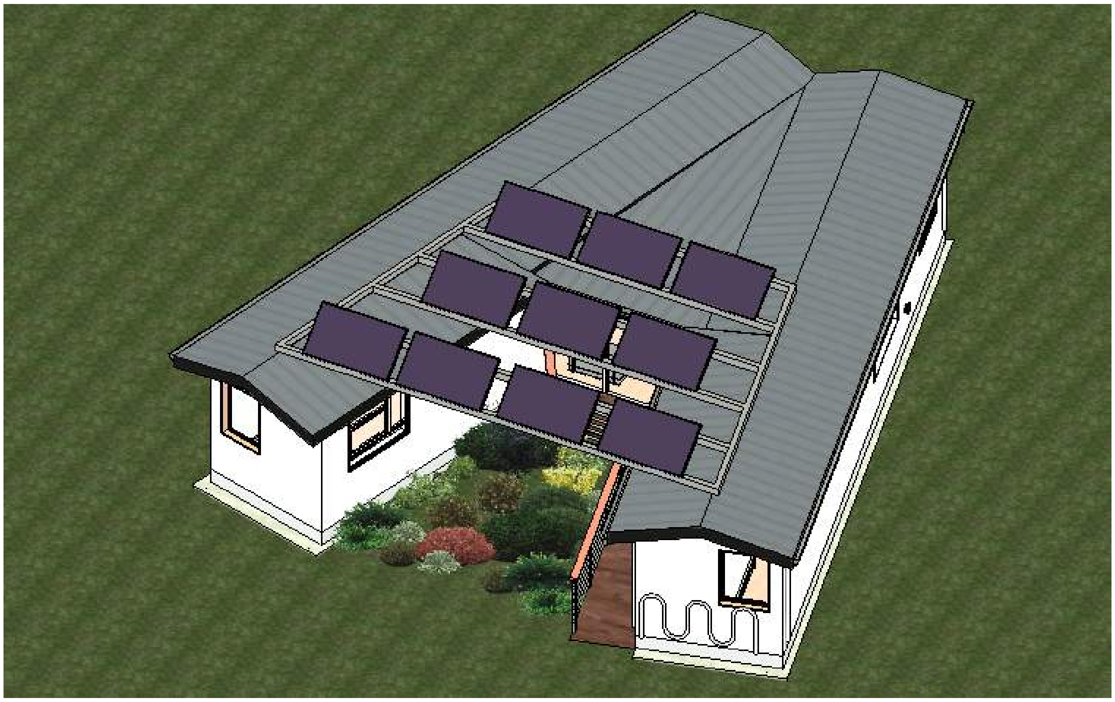


FIG 4 | Team ConSol design: Rendering of a single unit built from two renovated shipping containers.

Each living unit is composed of two renovated shipping containers, arranged in a V-shape. The design has enough roof space to connect solar panels in parallel, comfortable living quarters with separate areas for dining, cooking, recreation, and resting, as well as a front garden. The central living space also has abundant natural light and a view of the garden. The two-bedroom structure and dual space layout of the design is suitable for multi-generational families or mutually supportive pairs of living partners who may not fit the nominal 2-adult/2-children demographic. The house is also wheelchair-accessible, with a ramped deck for wheelchair/baby stroller access and ease of ascent for the elderly.

We decided to use shipping containers as opposed to the traditional building design strategy and materials because of many reasons, including build-readiness, modularity, pre-fabrication readiness and transportability, environmentally-friendliness, as well as the modification flexibility and DIY properties. The containers would have been engineered to support heavy loads and have stacked containers with even heavier loads, ensuring great structural durability and lateral load considerations due to the constant motion during the travel. The exterior would also be prepared for harsh conditions (higher humidity, increased risk of rust at sea, etc.), capable of withstanding weather extremities encountered in urban regions. In addition, container homes are easily modified and allows for DIY assembly and modifications, which allows for community engagement and a connection to the housing units as the residents work together to build houses that they will live in. This self-assembly principle will also help reduce labor costs and will allow more flexibility for on-site engineers to make modifications for the specific region based on weather conditions and surrounding factors. The containers will allow for prefabrication in another region— i.e., one closer to where materials are sourced—which could lower costs or make it easier for the builders and experts involved in the project. Not to mention, since containers are standardized, they allow for applications of the modularity concept, which may well work to the unit's advantage in the long term, while it can be easily transported to its final destination as the infrastructure to transport such containers through land, sea, and air are already commonplace and low-cost. The containers are also built for stacking and thus were already engineered to hold its own weight and more, allowing roof extensions and upward retrofits in the long-term should land become a scarcity. The containers can also be found at every port and every corner of the world, which would allow local sourcing and reduce transportation costs and emissions. The housing unit will make use of relatively-new shipping containers, in order to allow ease of tracking the container contents to make sure that the container did not transport any hazardous materials in a previous shipping run. Newer containers will also have more structural durability, which could allow the house to be used for an expected 20–25 years, with the materials (insulation, roofing, etc.) chosen to support the long-term goals of the housing unit.

The structure includes eight zones: two bedrooms, one bathroom, one mechanical room, and a large common room that gets divided into a living room, a dining area, as well as a kitchen-laundry area. The zones were determined based on the general types of activities the residents are expected to be engaged in in those specific areas. In addition, we implemented various lighting zones based on the activity zones to maximize user comfort and energy efficiency of the housing unit. The narrow structure also allows for increased natural cross ventilation, which can maintain a constant indoor temperature around 2-3 °F higher than the outdoor temperature. This can be especially effective in the April–June and October –November months, where the temperature is more temperate and naturally comfortable for occupants. This in turn can result in additional cooling/heating savings in those months. The following image includes the 8 zones for the occupants, with each zone color-coded:

FIG 5 | (LEFT) Overall layout. (RIGHT) Layout with living spaces color-coded. Floored space 801 ft^2.

The support (bar) structure added for the solar panels allows for the addition of panels that can be optimally oriented towards the sun regardless of the positioning of the housing unit. For example, a north-facing housing unit can have panels oriented towards the south of the unit, while a building unit facing the south-west can have panels oriented towards the north-east of the unit. The bars are spaced such that the panels can be installed at up to 45° angles relative to the bars, allowing the panels greater flexibility and thus increasing energy output even if the house is not south/north facing—as shown by the left panel of Figure 6, which depicts the arrangement of the panels in houses facing the south and southeast.

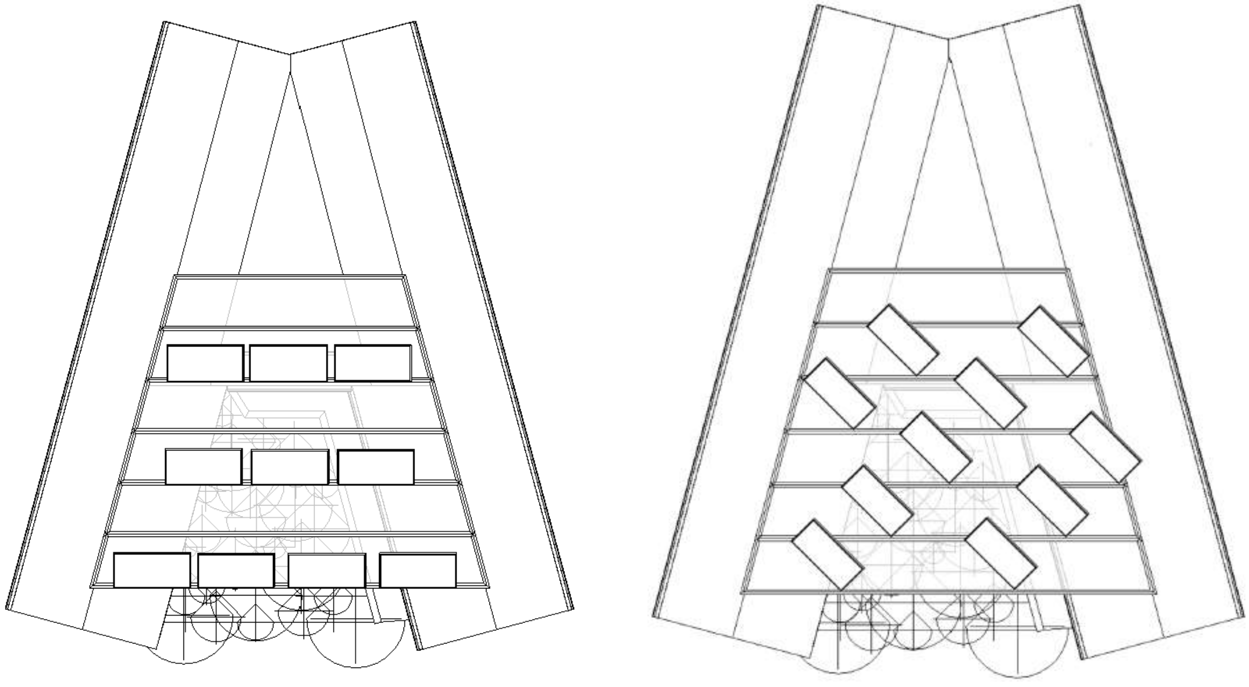
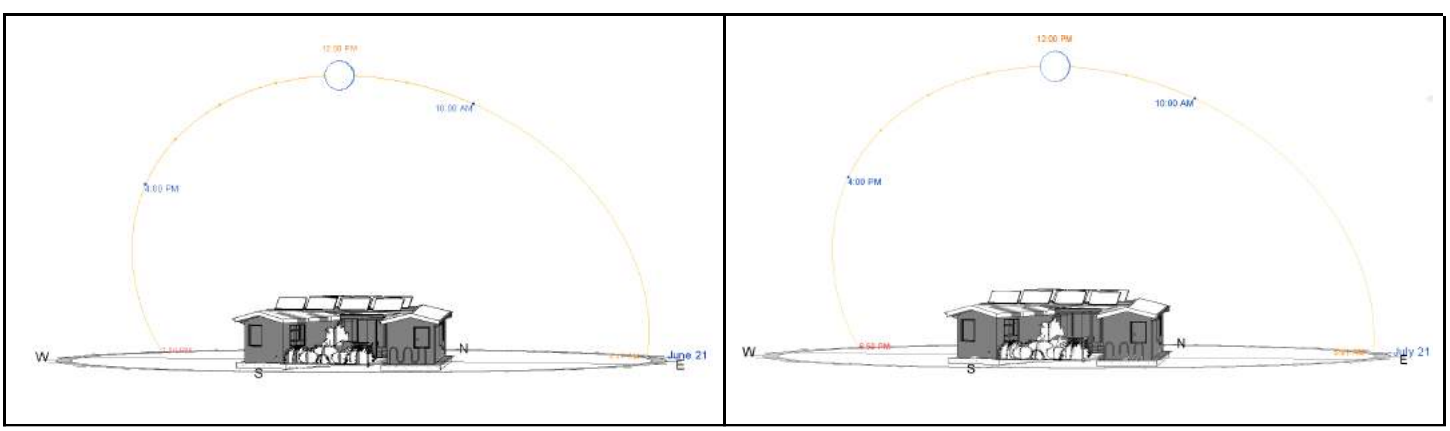


FIG 6 | Solar panel support structure allowing panels aligned for optimal exposure depending on a unit's geographic orientation.

We made sure that there are no elements of the house that are taller than the panels, which means that regardless of the orientation of the unit and its position with respect to the other housing units, the energy output will remain the same throughout the region.

The roofing of the unit has overhang in all directions to reduce sunlight in the hottest months (June–September) and improve water protection. This overhang helps block out the excessive sunlight of California's summer months. The overhang is balanced between maintaining safety and providing maximum shielding. The current design would provide 100% shading during noon in June, 95% shading in August, and 25% shading in September. We had to strike a balance between creating enough overhang to keep the building cool during the summer while maximizing the passive solar heating during the colder winter months. We also decided to keep the roof structure simple, maintaining continuity of the roofing material to increase stability and provide additional structural support, as well as to lower costs of installing the roof and purchasing the materials. Figure 7 shows the overhang analysis of the housing unit during the hottest summer months.



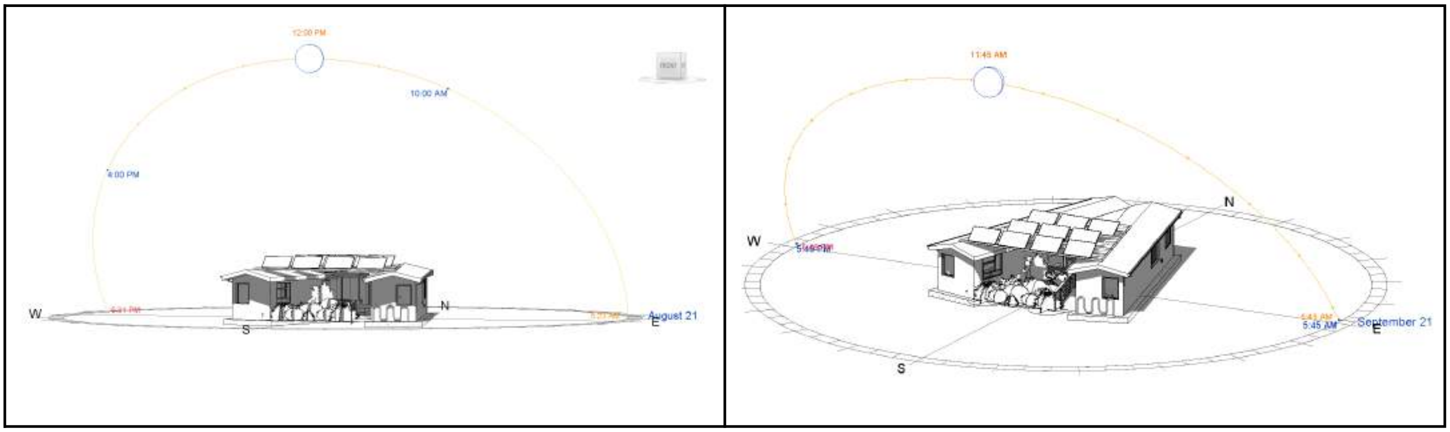
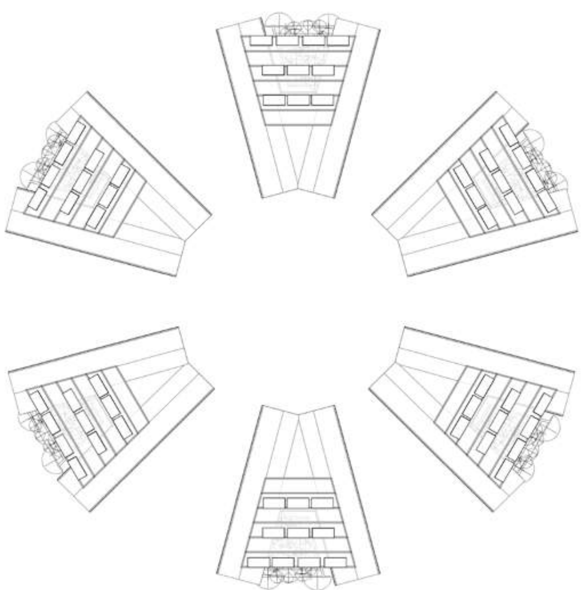


FIG 7 | 3D visualizations of the house for overhang analysis and panel orientation visualization with respect to the Sun.

Multiunit arrangements



Our compact modular design allows for flexibility and creativity in the arrangement of multiple units on a lot.

A radial design of six units creates a community ecosystem—a central "pod" where residents will encounter other residents, guaranteeing interaction between neighbors in a pod with the residents of the five neighboring units. This will enhance the community spirit and allow for a better all-round occupant experience. The unused space at the center of the design will allow for the installation and development of communal facilities (such as a fountain area with benches around or a communal barbeque deck) in the center space of each pod.

← FIG 8 | Radial multi-unit arrangement with 6 units surrounding a central communal "pod."

ConSol's residential unit design incorporates the concept of tactical urbanism, a term first popularized in 2010, which promotes low-cost improvements with maximum benefits for local communities. It incorporates five key characteristics, including:

1. A deliberate, phased approach to instigating change;
2. The offering of local solutions for local planning challenges;
3. Short-term commitment as a first step towards longer-term change;
4. Lower-risk, with potentially high rewards; and
5. The development of social capital between citizens and the building of organizational capacity between public and private institutions, non-profits, and their constituents.[14]

We achieve these five goals of tactical urbanism through our unique design that builds communities, upholds sustainability and accessibility values, and maintains modularity at low-costs (4 and 5). These short-term improvements to an urban environment are the first steps toward changing the narrative around affordable housing and can help disrupt the pipeline that channels families into a housing crisis and homelessness (2 and 3). Our financial model delivers a phased approach that will instigate change by providing a pathway to ownership and reduce housing insecurity (1).

4.2 Engineering

Insulation layers were designed with maximum functionality and minimal costs. We used thermal transfer principles to guide our design and allow for reduced energy requirements for cooling, while allowing us to develop our own system of passive solar heating and hybridized water heater heat pumps. Effective plumbing and wiring improve efficiency while reducing maintenance requirements and also simplifies any maintenance process. Our innovative removable maintenance panels will help simplify maintenance and allow faster repair times.

To maximize thermal comfort, increase resilience due to global warming and climate change, as well as reduce energy consumption for heating and cooling, we decided to prioritize creating a highly-insulating envelope. The building envelope includes the roofing (comprising the roof and the ceiling), the walls, and the floor.

The materials were also selected to maintain the acoustic comfort of the indoor areas. Since the location we selected is relatively close to the main street (less than 100 feet away from the San Fernando Road), we determined that we would need to ensure enough noise cancellation to allow the occupants to enjoy quiet day-to-day activities. The window and curtain system will have a Sound Transmission Class rating of about 30-35, while the wall is expected to have an STC rating of 43-48. This means that the housing unit blocks up to 50% more noise than the conventional housing structure (window STC of about 20-25 and wall STC around 35-40). Although using metal studs would provide added STC ratings (expected an STC rating gain of 3-5 depending on spacing and thickness), it can significantly reduce the R-values by up to 25%, and as such would not be worth the tradeoff. The polyurethane layer would have a Noise Reduction Coefficient value (NRC) of 0.75-0.83, which means that roughly 80% of the sound gets absorbed instead of reflected, helping maintain a quiet indoor environment[15]. This is especially beneficial to families with younger kids who often play loudly in their rooms, which can disturb a working parent, and especially useful for dealing with a pandemic, where everyone is confined to the limits of home and it may be hard for the parents and children to complete their respective responsibilities (work, school, etc) without disturbing others in the home.

The walls are all designed to have an R-value of 25.9 $ft^2·°F·h/BTU$, with the bulk of the insulative properties coming from the 4-in. polyisocyanurate closed-cell foam layer between the wooden stud frame. All electrical wiring and water system tubing will also be ingrained in the wall structure (insulated PEX and CPVC) for aesthetic reasons and ease of repair/replacement. The roofing is designed to have an R-value of 63.8 $ft^2·°F·h/BTU$, with the roof contributing an R value of 48.3 $ft^2·°F·h/BTU$ and the ceiling contributing with an R value of 15.5 $ft^2·°F·h/BTU$. The reason the ceiling has such a low R value is because we did not want to further "eat into" the limited space of the crates. As such, we shifted a large portion of the insulation to the roof instead. The air in between serves as additional insulation. The roofing's R-value is largely derived from the 5-in. thick primary insulation material, polyisocyanurate, and the 2-in. thick polyurethane foam included in the ceiling. The floor has an R value of 26.3 $ft^2·°F·h/BTU$, again largely contributed by the 4 ½-in. polyisocyanurate foam board with foil. Any holes or openings in the construction material or insulation will be sealed by polyurethane spray foam, which has an R-value of 6.7 per inch. The calculation takes into account the R-value reduction from the studs, and meets (even exceeds) the recommended values by the ENERGY STAR program for roofing (R: 30-60 $ft^2·°F·h/BTU$) and flooring (19-25 $ft^2·°F·h/BTU$) for the specific climate zone Slymar is in. Although the insulation leads to increased costs, the material cost increase is relatively insignificant compared to the increased energy savings for the long term (i.e. 10-15 years), as the bulk of the installation costs remain the same regardless of the addition of a few inches of insulation. In addition to increased energy savings, the house will also be more adequately prepared for climate change, increasing the resilience to hotter and more extreme weather conditions throughout the year.

For the curtain wall and the windows, double pane, soft coat low-E windows with argon gas filling were used. These windows have an R-value of 3.8 $ft^2·°F·h/BTU$. The windows have an SHGC factor of 0.36 (glass only) and a visibility transmittance of ~75%. Double glazed windows provide great thermal insulation and help with noise pollution reduction from the surroundings. In addition, the low-E coating will help reduce the IR and UV light that could enter the house, while preventing the heat from escaping the house during the colder winter months. We decided against triple pane windows because the moderate climate of the region means that the additional savings (2-3% of heating and cooling costs) are not worth the increased investment for the window purchase (10-17%). In addition to the double pane windows, the design includes a double curtain layer system, which includes a thinner curtain and a linen drape. Together, the two layers are expected to add on an R value of 3.5 - 4.0 ft^2·°F·h/BTU, while the blackout drapes are expected to block over 99% of incoming light and UV radiation. The light blocking can reduce summer heat gains by up to 33%, saving energy otherwise required for home cooling in the summer. In addition to the curtain layers, a pelmet is added to the design to prevent convection cycles that result in cool drafts and an increased thermal loss through the windows, reducing up to 25% heat loss in the winter months.

4.3 Market Potential: Financial Feasibility & Affordability

The unit is primarily for low-income families struggling to afford rent in the LA area. Los Angeles has one of the country's largest unhoused populations. Rising rent prices have compounded the effects of an already-growing homeless population.

The average employed unhoused individual makes only $9,970 in the year before losing residence, far below the nearly $80,000 median wage in California. A 2017 survey also suggests that most adults who are homeless are unemployed, with employment rates of only 8% (individual) or 27% (with a family). These numbers would qualify occupants for the Supplemental Nutrition Assistance Program; it is expected that most would rely on Medicaid/Medicare for healthcare. Our target family would likely also qualify for other low-income assistance programs, including CalWorks, which provides cash aid for families with children; many would qualify for unemployment benefits. The children would presumably be enrolled in a nearby public school. Families are not expected to have access to personal motor vehicles (some may). We expect substantial funding to support a target family's housing from federal, state, and local governments. As such, keeping the costs low would be essential for us to effectively help as many members of the community as possible and potentially pave a pathway for self-ownership of units.

The total costs for each housing unit is $68,183, which leads to a $85.1/$ft^2$ cost prior to rebates and land costs. Team members and occupants will self-assemble the prefabricated units to lessen labor costs. Professionals will carry out specialized jobs as needed to ensure high standards are maintained. Without taking into account the $35,520 energy-related rebates each housing unit qualifies for, we would be able to house an individual for a one-time cost of $17,045 (with additional monthly bill costs), far lower than LA's average cost of $32,079 per person and Sylmar's (2020 figures) of $43,529 per person. Taking into consideration the rebates qualified, it will cost $8,166 per individual, not including the cost of land. The land for the project would cost $68,725, and at a full land usage (the plot has a 24-unit capacity), will add $2,863 to each unit's cost.

Total Cost Estimate: $68,183.			
Appliances	3879.	Roofing	3452.
Furniture	2700.	HVAC	7180.
Insulation	3000.	Permits	2100.
Cladding (Interior)	1953.	Site Preparation	4667.
Containers/Structure	13,700.	Windows	3250.
Electrical (including Battery)	18,440.	Bathroom/Kitchen/Other	575.
Plumbing	2146.	Miscellaneous	1150.

TABLE 1 | Construction cost estimate.

What sets our project apart from others is our unique financial model where we are building a pathway to ownership for our target occupants. Empowering families through homeownership reduces financial burdens, especially in a COVID-19 environment, and establishes wealth and credit. The initial funding to build the residential units will come from a variety of sources.

We will work to secure federal grants from the US Department of Housing and Urban Development, and the US Department of Energy. Additionally, we will apply for grant programs from the California Department of Housing and Community Development, including the Affordable Housing and Sustainable Communities Program, CalHome, Community Development Block Grant (CDBG), Home Investment Partnerships Program (HOME), and Transit Oriented Development (TOD) Housing Program, among many others. We will most likely start with the CDBG program, which provides grants to provide decent housing to low-income households, because the program best aligns with our mission and is not in the form of loans. The team can also work to secure grants such as the Emergency Solutions Grants (ESG), which is a one-year or two-year grant that is awarded to groups conducting activities to reduce homelessness, including rapid re-housing assistance. Additionally, we will apply for the Low-Income Housing Tax Credit (LIHTC) for projects, which subsidizes the acquisition, construction, and rehabilitation of affordable rental housing for low- and moderate-income tenants. Credit amounts are determined by the size of the project. According to the Tax Policy Center, "The percentage is larger for new construction or substantial rehabilitation (roughly 9 percent but specified in the law as a 70 percent present value credit) than for properties acquired for rehabilitation or for projects funded using tax-exempt bonds (roughly 4 percent but specified as a 30 percent present value credit)."

The money received will be used to pay off the up-front costs of the housing unit, which will be $37,537 per unit. The residents will then pay rent that will go to pay off the total costs of construction. This model is not designed for profit: all payments from residents will ultimately lead to self-homeownership of the units. Our financial payment system involves a 12-year payment method with a $3,110 annual payment scheme (not including a $130/annum utilities cost for water and sewage), or $270 per month per family. This is only 11.4% of the average rent cost for a housing unit in Los Angeles. The rent payments will go to creating more housing units in the location. One key benefit of our design is that the building is expected to have zero electricity and gas expenses over its lifetime. As such, the utility costs will remain low and constant throughout the lifespan of the building, reducing the financial burden on the homeowners in the long term.

We will work with nonprofit organizations like our partner organization, Union Station Homeless Services, as well as other similar organizations such as Community Housing Partners, BRIDGE Housing, and Mercy Housing. The partner organizations will also help families transition between different living situations. Housing insecurity often creates physiological and mental health challenges, like stress and anxiety, so our partner organizations will provide resources to address these challenges. They will also work with new homeowners to learn how to properly care for appliances and provide financial literacy resources.

If a family is only seeking temporary housing because of unforeseen circumstances like eviction, our financial model will be adjusted to 50% of that for the home ownership financial model, with a $135 per month per housing unit, or about $4.5 a day. Our main mission is to adapt to both the needs of families and that of the surrounding environment. The revenue generated from this rent model will be primarily used to maintain the housing units, with any excess margins going towards the construction of more housing units.

4.4 Resilience

Container Resilience

Shipping containers are projected to have minimal rust issues. The metal roofing has a 30-year expected lifetime, with a layer of galvanizing paint applied. Using shipping containers allows us to tap into its construction and engineering, allowing the housing unit to withstand harsh weather and earthquakes, just like the various (extreme) weather conditions and constant moving experienced in a shipping voyage.

The container gains its strength through the continuous corrugated steel and cutting out sections of the container will result in reduced container strength. As such, every opening that we will cut on the container will need to be reinforced with a frame made from angle bars to ensure the safety of occupants. In addition, we will also be reinforcing the structure by the addition of a structural frame using 5½-in. × 3/4-in. reclaimed wooden studs.

Resilience in Case of Emergencies

Our building design factors in the natural hazards associated with the greater Los Angeles area (Figure 1). In the past century, two major earthquakes— the 1971 San Fernando Earthquake (magnitude 6.5) and the 1994 Northridge Earthquake (magnitude 6.7)—caused significant damages within the region. Sylmar is also a wildfire hotspot; the 2008 Sayre fire, 2017 Creek Fire, and 2018 Saddleridge fire all affected the area. As such, safety considerations were made to mitigate the risks, including going all electric (therefore no gas connections that pose additional risk), adding a sprinkler system, and a deeper-than-usual foundation. Furthermore, the use of steel shipping containers—highly robust structures—helps mitigate the risk of earthquakes and other harsh climate conditions. The structure is expected to be far stronger and stiffer than a traditional wood frame construction.

Our structure is designed to withstand earthquakes and fires, the two biggest threats encountered by Sylmar residents. In addition to the container's additional support structure to prevent collapse during an earthquake, we also specially designed a Y-shaped foundation pier to reduce earthquake risks. The foundation will help counteract the effects of any earthquakes and the piers will be joined together to increase the foundation's strength.

The house has an in-built wet fire protection system. Sprinklers are positioned less than 15 feet from one another and within 6 feet from the water heater and the electric stove, in compliance with the California Building Code. The pendant sprinkler system is connected to the Domestic Cold Water main system to ensure that the water will reach all parts of the house as and when needed. The plumbing system is done using CPVC for cold water and PEX for hot water, in compliance with the code and fire safety standards for such systems as recommended by the National Fire Protection Association (NFPA).

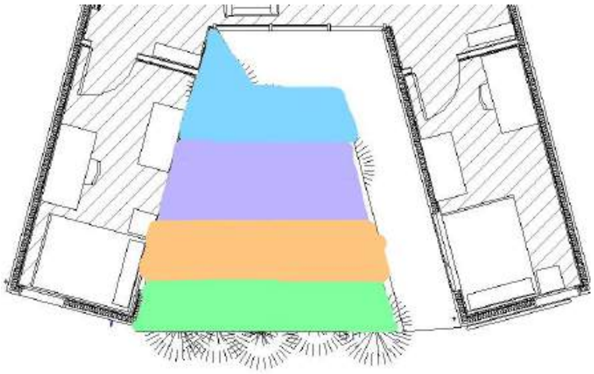
Climate Change Resilience

Due to climate change and the associated higher risk of wildfires in California, state residents are now 23% more likely to experience blackouts (controlled and uncontrolled). In the event of a power outage, the housing unit is fully self-sufficient in terms of energy use. With a 29.4 kWh battery storage capacity, the house can run the regular load for up to 36 hours and critical loads (with a 50% load factor) up to 72 hours. This is more than enough for non-emergency cases as well, because electricity from the Southern California Edison Company (which is a major provider for the LA region and our choice utility company due to its reach) is pretty reliable. In 2019, the company measured 91 outage minutes per customer per year using the System Average Interruption Duration Index (SAIDI) and 0.87 per customer per year on the System Average Interruption Frequency Index (SAIFI). SAIDI measures the amount of time the average customer experiences a power outage for more than five minutes (called a "sustained outage") in a given year, while SAIFI measures the number of times the average customer experiences a sustained outage in a given year. These numbers indicate a high level of reliability in regular operations, and with nearly all outages occurring for less than 24 hours in the region, our system is well equipped to mitigate near-100% of the risks associated with power outages.

In addition, there is still extra space on the roof for solar panels and in the mechanical room for added battery storage and inverters, which can help increase the production and storage capacity of the panels. This is important because of two factors: first, the cells and battery capacity deteriorate after repeated use and at some point, will be insufficient to meet the occupant's needs. This, coupled by the reduced efficiencies of the HVAC system down the line, would mean that energy demand will actually increase to maintain the current comfort levels of the occupants, which means that the occupants will need to have added capacity. Secondly, as climate change causes additional temperature rises, there is an expected increase of Cooling Degree Days, with a study published in Nature indicating up to 80% increased cooling needs and costs by 2100. As such, anticipating the increase of cooling needs would be very helpful for the occupants in the long-term and reduces the operational costs down the line.

Food Production Resilience

Each unit includes over 150 ft^2 of land to grow produce for self-sustenance. Although occupants may use the plot to grow larger plants or non-edible plants for noise cancellation and aesthetic purposes, occupants are encouraged to use some of the land for produce growth. This can also be vital in the event of unexpected economic volatility that reduces food production or people's ability to purchase food. The small garden farm can be maintained using a hose attached to the outdoor tap. In order to encourage a healthy lifestyle and also lower costs, we designed a manual watering system for the plants. Rainwater collected can also be used for watering purposes.



The garden will be sectioned for three purposes. The blue section will be dedicated to bush or branch heavy greenery. This is where the fruit trees will be planted year round for harvest annually. The purple section will be sectioned for the crop rotation system and will vary according to the crop calendar. The crop planting calendar can be referred to in **Appendix H**. In the front of the garden, decorative plants will be put in place for decor purposes.

← FIG 9 | Plantation Zones in the Garden

The order of planting will be leaf, fruit, root, and legume. In the 220 -240 ft^2 garden, the legumes will be planted first because of their nitrogen fixing ability[16]. Leaf plants have a high need for nitrogen, and will be planted next to take advantage of the excess nitrogen in the soil. They also replenish the organic matter in the soil and enhance worm and microbial activity in the soil. Fruits will follow leafy plants because there will be lower levels of nitrogen in the soil following leafy plant crops. Excess nitrogen causes fruit plants not to grow fruits, and phosphorus benefits fruit plants. Root plants will follow the fruits because they need potassium and need less nitrogen than the fruits. Finally, the legumes follow the roots to put nitrogen back into the soil. This process allows optimal self-sustaining agricultural use of the gardening space. The cycle restores essential nutrients back into the soil, erasing the need for constant replacing of soil of nutrients.

4.5 Energy Performance

Efficiency

Energy efficiency is prioritized, utilizing Energy Star certified appliances and lighting. The housing unit's energy use is entirely in the form of electricity. A natural gas interconnection was not included in the design because of three reasons: first, it is not environmentally friendly. Second, it requires more piping installations, which increases the disruption to the surrounding environment. Lastly, due to the high earthquake risk, it would be safer to simply disconnect the housing units from the natural gas system than connecting it with added earthquake protection measures (which has a risk of failing and still risks gas buildup).

Appliances (Examples)

The appliances were selected on the basis of their energy performance, simplicity of use, environmental impact, and affordability. We also take into account the general user perception of these devices through the ratings and comments made in forums, web marketplaces, and recommendations from trusted websites and blogs. The following table describes some energy-intensive appliances included in the house design.

TABLE 2 | Appliances

Dishwasher
Danby 18 in. Control Smart Dishwasher 120-volt with Stainless Steel Tub

Chosen for energy efficiency (ENERGY STAR compliant), durability (stainless steel tub), low water consumption, and quiet sound rating.

Price: $440

Clothes Washer
Samsung 4.5 cu. ft. High Efficiency Stackable Front Load Washer with Steam

Chosen for energy efficiency (ENERGY STAR compliant), suitability for families (ADA compliant), and convenient Smart Care features.

Price: $700

Clothes Dryer
Samsung 4.0 Cu. Ft. Heat Pump Dryer With Smart Care

Chosen for energy efficiency (ENERGY STAR compliant, uses heat pump technology) and convenient Sensor Dry features.

Price: $800

Refrigerator
LG 20 cu. ft. Top Freezer Refrigerator

Chosen for energy efficiency (ENERGY STAR compliant), affordability, and spaciousness (20 cu. ft.).

Price: $700

Range
GE 30-in 4 Elements 5-cu ft. Freestanding Electric Range

Chosen for energy efficiency (ENERGY STAR compliant, uses Sensi-temp technology), positive ratings online, and affordability.

Price: $45

Renewable energy

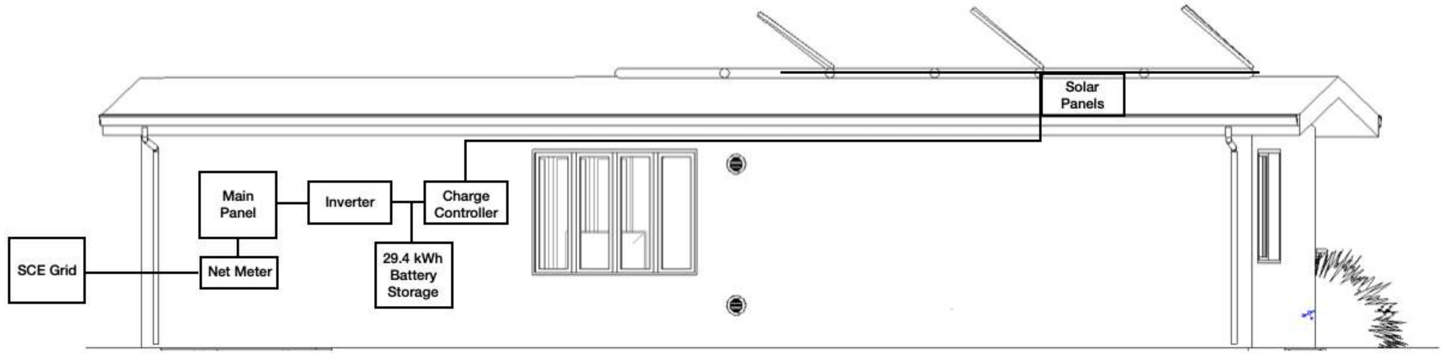


FIG 10 | Solar panels and electrical system

The house was designed to generate 100% of the energy it consumes. Based on the load analysis, we determined that we would use 7,090 kWh of electricity and sized a 4.0 kWh (DC) solar panel system that is expected to generate 7,471 kWh according to the NREL Detailed PV Model Analysis. By utilizing net metering, which is a service provided by the utility company Southern California Edison, we would be able to sell off the excess electricity produced in the summer months and purchase electricity during the winter months. This would help mitigate the harmful effects of the supply and demand mismatch. We also decided against expanding the storage to overcome the limitations because we did not see the need to store that much energy for such a prolonged period of time. Increasing storage would also significantly increase the cost, which goes against our first design goal of creating affordable housing to help reduce homelessness.

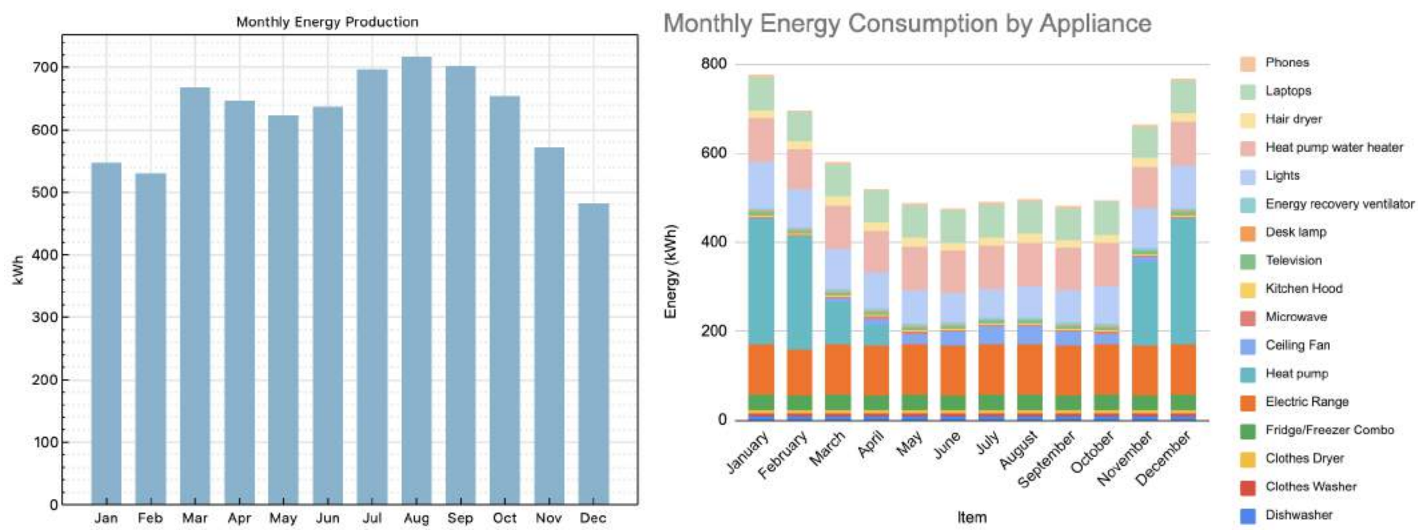


FIG 11 | Monthly energy production and consumption

We will use 10 SunPower panels, each with an STC rating of 400 W and operating at 21.4% efficiency. For the inverter, we will use an SMA America inverter, with a maximum DC input power of 4172 W and a conversion efficiency of 95.6%. The inverter has anti-islanding protection and has ground fault detection and interruption features, both of which improve the safety for the users and grid operators performing maintenance on offline grids. The panels will be placed in three strings: one string of four panels and two strings of three panels. They will have a 34° tilt angle for optimal sunlight collection. In all, the panels will cover 175.4 ft^2.

	POA front-side irradiance beam after shading and soiling (kWh/mo)	AC energy (kWh/mo)
Jan	2305.64	546.947
Feb	2193.53	530.034
Mar	2705.57	667.637
Apr	2535.89	645.976
May	2411.62	622.875
Jun	2678.72	636.9
Jul	3149.69	696.382
Aug	3318.07	716.541
Sep	3242.34	701.301
Oct	2956.48	653.508
Nov	2500.69	571.218
Dec	1951.65	481.329

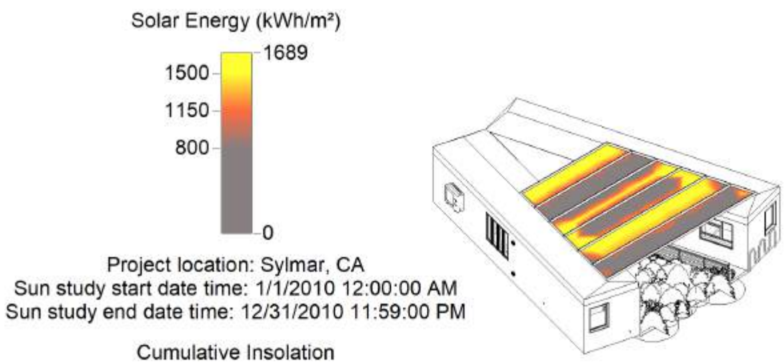
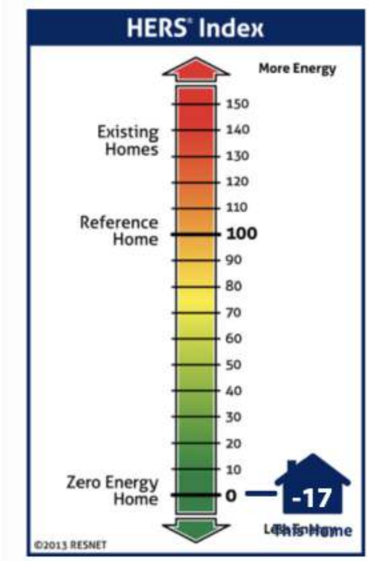


FIG 12 | Irradiance (TOP) and energy produced (BOTTOM)

To store the energy generated, we will utilize three LG Chem RESU batteries, each sized at 9.8 kWh at 48V, bringing the total capacity to 29.4 kWh, enough to power devices in the household for 36 hours (100% to 0%) or 72 hours at 50% critical load (i.e., reduced room and water heating, no television and heater use, etc.). We chose the LG batteries due to its unmatched price-to-performance standards, with a 90-95% Depth of Discharge recommendation and warrantied to retain at least 60 percent of its capacity by the time you hit a lifetime of 10 years or an energy throughput of 22.4 MWh.

The system design does not include tracking systems because such systems, despite adding up to 20% production during the summer, ends up adding more costs and makes it very difficult to create the panel cooling system that helps reduce water heating costs. As such, we decided to size a bigger system. This way, we would also be able to qualify for additional rebates as most rebates in the California region are provided on a per kWh basis. In addition, the increased panels mean that there will be a more even distribution of energy production (as opposed to having a much higher production in the summer; the final annual energy output will remain constant in both cases), which could work better in the case of California. A lot of homeowners in the state have PV systems that over-produce electricity in the summer, lowering energy prices and resulting in a net-loss for the occupants due to the changing net-metering prices between the peak summer months and every other time of the year. Having less energy to sell during the summer but having more energy to use during the winter will help reduce the effects of the pricing differences.

The housing unit was able to achieve a –17 HERS rating when taking into account PV generation capabilities, and has a 58% reduction of energy consumption from a typical new home (and 43% less energy consumption than a typical ENERGY STAR rated home).



Home Feature Summary:

Home Type:	Single family detached
Model:	N/A
Community:	N/A
Conditioned Floor Area:	673 ft^2
Number of Bedrooms:	2
Primary Heating System:	Air Source Heat Pump • Electric • 3.78 COP
Primary Cooling System:	Air Source Heat Pump • Electric • 23.5 SEER
Primary Water Heating:	Water Heater • Electric • 2.85 Energy Factor
House Tightness:	0.5 ACH50
Ventilation:	72 CFM • 11.2 Watts
Duct Leakage to Outside:	Forced Air Ductless
Above Grade Walls:	R-29
Ceiling:	Vaulted Roof, R-61
Window Type:	U-Value: 0.33, SHGC: 0.361
Foundation Walls:	N/A

FIG 13 | HERS Index

The HERS value takes into account the DoE Energy Star Size Adjustment Factor of 1.0 since the house has a smaller conditioned floor area (673 ft^2) as compared with the benchmark 2-bedroom home (1600 ft^2). The HERS value calculated by Ekotrope also takes into account the Index Adjustment Factor, an amendment from 2019 that helps level the playing field for small-sized home units and allow for further HERS rating reductions by up to 10 or up to 20% lower HERS ratings in comparison to larger homes. A detailed calculation for the Size Adjustment Factor (and how we ended up with the value of 1.0) can be found in **Appendix L**.

4.6 Operations

Mechanical Systems (HVAC)

The housing unit has 673.35 ft^2 of conditioned area. The ERV system and heat pump combination make up for a very energy-efficient HVAC system, which allows overall annual energy savings by up to 18.4%. The housing unit also generates more energy (7,471 kWh) than it uses in a year (7,090 kWh), making it a zero-energy building by the DOE's definition. The use of argon-filled double pane windows and insulation for all the walls, the roof, and the floor reduces heat inflow and saves energy on the cooling systems by up to 25%.

Heating/Cooling

For heating and cooling, each housing unit comes with a heat pump water heater, an air-source heat pump, and four ceiling fans. The heating and cooling will be controlled by the smart thermostat technology, which would allow for increased energy savings and better indoor temperature adjustments without the need for additional monitoring from the occupants.

We installed a heat pump to heat and cool the housing unit, saving up to 40% of the energy used in a conventional AC/heating system. The bi-directional, wall-mounted, and air-source heat pump will serve as the primary heating unit in the winter. The Cooper & Hunter CH-D09MSPHWM-230VI heat pump unit has a SEER rating of 23.5 for cooling, and a 3.78 COP value for heating based on Sylmar's temperature range, which are both superior to conventional air conditioners and electric resistance heaters (with a SEER rating of 17-19 and a 1.0 COP value, respectively). In the event of an extreme weather event or that climate change causes temperatures to increase in the long term, the air-source heat pump can then be utilized to help cool the room and maintain comfortable indoor temperatures.

The heat pump water heater will be based on a SanCO2 heat pump water heater, a new and innovative outdoor-source heat pump that we will retrofit to accommodate indoor and outdoor heat sources. The reasoning for the retrofit is to allow the water heater to operate through its heat pump principles at all times, which would also allow it to lower cooling costs during the summer as it uses up the unwanted heat, which would allow for reduced energy use: normally, the heat pump will use energy to pump out excess heat and an electric heater would use energy to heat the water; the ConSol housing unit mechanism could allow for energy savings by eliminating any redundant energy use. The heat pump water heater will use less than 50% of the energy of a conventional heater.

Since Sylmar has a moderate climate, we expect cooling to be primarily done by the ceiling fans. The ceiling fans can lower the room temperature by 5 - 10 °F, which is usually enough for a majority of the year. In addition, the SanCO2 heat pump will also help reduce the room temperature. Combined, the two should be able to minimize cooling for the summer, where temperatures remain in the 60 -85 °F range ~ 94% of the time. We chose low-hanging ceiling fans because the ceiling stands at 7' 10", and as such we decided on a hugger ceiling fan with a 9 inch height so that we remain clear of the 7' ceiling fan minimum height requirement as per the California building code standard.

FIG 14 | Interior rendering focusing on ventilation

Ventilation

The house remains well-ventilated to ensure a comfortable experience for the occupants. There will be both mechanical and passive ventilation. The mechanical ventilation involves four Lunos e2 Energy Recovery Ventilation (ERV) units with an adjustable ventilation rate of 10/15/20 CFM or 9/18/22CFM per unit. The units operate as a pair to prevent major air pressure changes within the building, which can have negative impacts on a person including dizziness, ringing ears, and in worse cases, cause breathlessness and impaired decision-making. In addition, the ventilation rate can vary per person depending on setting, but generally complies with ASHRAE Standard 62.2, "Ventilation for Acceptable Indoor Air Quality," which would require 15-17 CFM ventilation per person. The ERV system also helped maintain 5.1 ACH, which is also in line with the ASHRAE recommendations for COVID prevention.

The passive ventilation will involve shuttable trickle vents fitted with MERV-8 filters, which helps reduce mold spores, hair spray, and dust. MERV 8 filters have 90% efficiency on particles that are 3 to 10 micrometers in size and are generally recommended for residential building use. MERV 8 filters are commonplace, so they are readily available and can last up to one year of usage before a recommended clean up or replacement. In addition to the continuously open trickle vents, windows are placed at strategic locations for optimal ventilation. There are enough windows and trickle vents to fully ventilate the housing unit in the event of a power outage or a failure of the mechanical ventilation system.

We selected ERV units as opposed to traditional ventilation systems because they help maintain internal temperatures and humidity. The Lunos model we selected allows up to 90% energy recovery and 30% humidity recovery. This helps reduce energy consumption for heating by up to 18% and cooling by up to 15%.

Water Systems

The design strategy for the housing unit was to place all the plumbing fixtures at the rear end of the housing unit, which would allow for a more efficient plumbing system and needing less piping, which reduces the insulation space, increases end-of-use environmental impacts, and increases installation costs. This would also reduce the potential of any unwanted smells to reach the general activity areas and bedrooms, improving the occupant experience. Each unit has five primary water systems: a domestic hot water system, a cold water system, an isolated extension the cold water system to cool the panels, a hydronic supply system (two separate subsystems for each heat pump), and a fire sprinkler system.

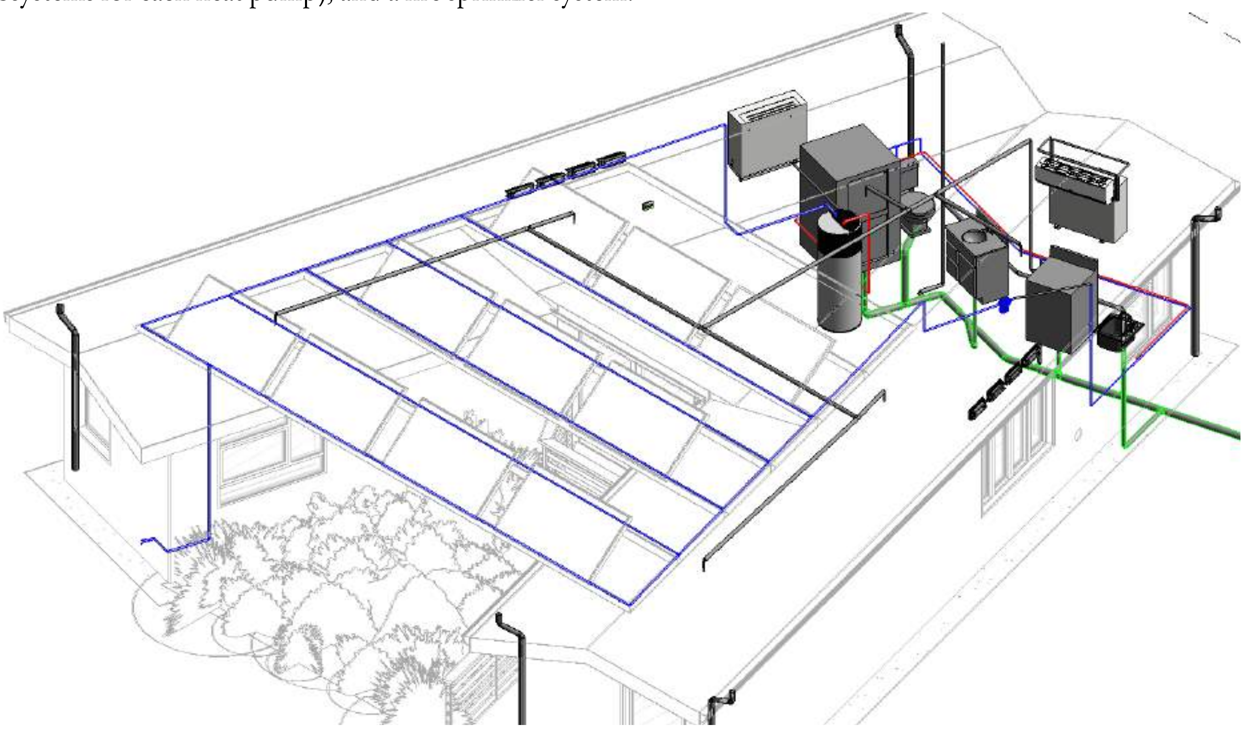


FIG 15 | Every Water System of the Housing Unit

The domestic cold water system, in blue, is connected to LADWP's primary water supply. Water usage will be metered by LADWP, and regular rates will apply. The fixtures in the bathroom and kitchen area are all connected to the domestic water system. The heater is also connected to the domestic cold water system, but water would be pumped through the solar panel area to help cool the panels while also using the excess heat to heat the water and save energy required to heat the water. An additional pump is utilized to pump the cold water through the solar panel system and to the heater, because the pressure from the main line varies between 53 - 120 psi, sufficient for the other appliances but insufficient for the additional distance and elevation for the solar cooling system. There is an outdoor tap connected to the domestic cold water system, which will provide warm water throughout the year (due to the heating effect by the panels). Since the water supply from LADWP will generally be 45-60 °F, the water will be heated to around 65-75 °F before it reaches the tap, closer to the optimal 68 °F temperature for plants to maximize nutrient uptake. The domestic cold water piping will utilize ½-in. thick, 1-in. diameter CPVC piping, in compliance with California Plumbing Codes.

The domestic hot water system, colour coded in red, primarily relies on the 83-gallon SanCO2 heat pump water heater, with additional heating provided by the solar panel racks. The domestic hot water system utilizes ½-in. thickness, 1-in. diameter PEX pipes, which are an affordable option that meets the requirements of the California Plumbing Codes. Since PEX pipes are somewhat good conductors of heat, we will add a foam insulation layer onto the pipes to reduce energy loss (to no more than 1.5 °F per 100 feet) loss from the heated water.

Other pipes included are the sanitation and fire protection system pipes. The 3-in. sanitation pipes are colour coded in green; they are connected to the vent by pipes colour coded in black. The sanitation pipes have a 1/72 slope, and will be connected to LADWP's sewage system. A single vent exists at the back of the housing unit to maintain pressure differential between the pipe and the surroundings. There is a wet fire protection system (sizing based on the California Plumbing Code) using ¾-in. Piping that is also colour coded in black, which is connected to 6 sprinkler heads, each spaced no more than 14' from another sprinkler and with at least one sprinkler within a 6' distance from the water heater and the kitchen area, in compliance with the NFPA guidelines and the California Building Code requirements.

Since LA receives very little rainfall (15 inches/year), we did not focus on creating a complex rainwater management system. Instead, we utilized gutters and 3-in. downpipes to move the little water that does fall into the garden soil or collected in barrels. The water can then be used by the occupants to water the plants themselves to reduce water usage. The barrels will be covered relatively tightly to prevent unwanted breeding of insects, such as mosquitoes, which may be harmful to the crops or occupants.

Electric Systems

The following diagrams show the wiring pathway from the main panel and the electric schematic of the PV system, including all the disconnects and grounding positions. Each component can be disconnected from the system for individual maintenance, and an outdoor disconnect will be placed at an 8' 3" elevation between the panels and the controller. The outdoor disconnect will make it easier for firefighters or other emergency responders to turn off the power production system, while it is placed at an elevation that would make it difficult for accidental disconnects or malicious disconnection intent by other people (neighbours, passerbys, etc). For added safety, each connection is grounded and the MPPT and inverter are selected to have the ground fault protection as well as the anti-islanding protection respectively for added safety. The combiner boxes also function as circuit breakers with a 300V rating to prevent excessively high voltage from entering the house and causing harm (shocks or overheating wires and causing a fire). For indoor wiring, we will use THWN wires that are housed in PVC pipes for ease of maintenance and replacement in the future.

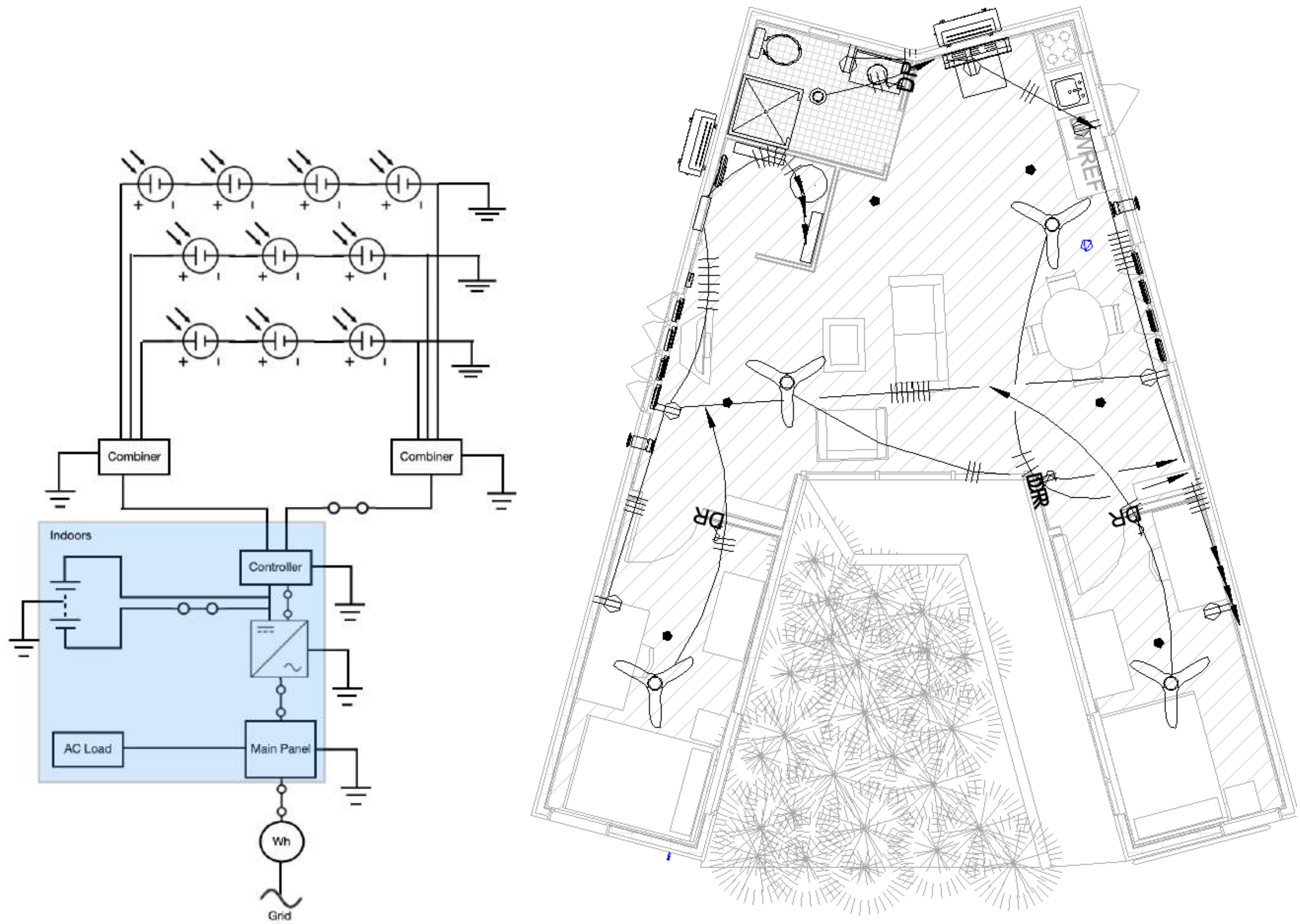


FIG 16 | (LEFT) Electrical system showing disconnects and grounding positions. (RIGHT) Overall layout showing wiring of the components

Smart Home Technologies

Our house design utilizes modern technology reliant on real-time sensors to ensure the efficient use of lighting and cooling systems. Smart blinds control the entry of natural light. Heat recovery ventilation maintains the internal temperature while the heat pumps keep it at a comfortable level throughout the year.

A smart thermostat is used to help maintain optimal room temperature and help save energy by avoiding excessive heating and cooling. A smart thermostat saves up to 12% of heating costs and 15% of cooling costs, which is quite a significant energy saving for a house in which HVAC operations make up nearly 35% of the total energy consumption of the housing unit.

Smart blinds technology is also implemented to further push down the heating and cooling costs. In the hottest summer months, the lighting analysis showed that our building had a 92% risk of overlighting on a day-to-day basis. This, in turn, could lead to overheating and increased cooling costs. By simply adding blinds, we could add an R value of ~2 ft^2·°F·h/BTU. Making them smart would also allow for optimized indoor lighting conditions and increased energy savings.

A solar charge controller optimizes the solar panel's energy production. The charge controller helps prevent battery overcharge or battery-panel voltage mismatch, which can result in losses of over 40% of usable output electricity.

4.7 Occupant Experience and Comfort

Living Space

Few, if any, affordable housing or homeless complexes are designed for comfort. Our goal was explicitly to create a unit with a comfortable living environment. Building materials and appliances were chosen with cost constraints in mind, as well as energy efficiency and environmental impact. Our design uses two shipping containers for the exterior structure, providing enough living space for a family of four—nominally two parents and two children. With an average space (conditioned and unconditioned) of 200 ft^2 per person, the units are not overcrowded by HUD's standard, which is 165 ft^2/person. The modular design aims at maximizing outdoor (garden) space within the overall envelope of the house.

Thermal Comfort and Ventilation

In order to maximise the occupant comfort, the house is designed to have natural and mechanical ventilation in addition to heating and cooling systems. As discussed in the previous section, a robust HVAC system is set in place to ensure user comfort and maintain 5.1 ACH, which can be increased depending on the occupant's preference by opening and closing the windows. Ceiling fans help improve indoor circulation, moving air around to cool the occupants, while the heat pump and water heater heat pump ensure that the room stays at a comfortable temperature. The smart thermostat helps maintain internal temperature by adjusting the heat pump and water heater heat pump operations to remain stable at the optimum temperature range defined by the WHO, which a user can override manually in the event of a sensor malfunction or an unconventional preference for the cold or the heat.

We also take into consideration the humidity factor in our design: The ERV system is capable of recovering 30% of the humidity that would otherwise be lost to the surrounding environment during the winter, and prevent excessive humidity from building up and entering the housing unit during the summer.

During the design process, external and internal heat gains from equipment operations and occupant activities (e.g., respiration) have been taken into account to prevent overheating during the winter months, which results in energy loss and potential discomfort, while also preventing under-cooling during the summer months and causing occupant discomfort.

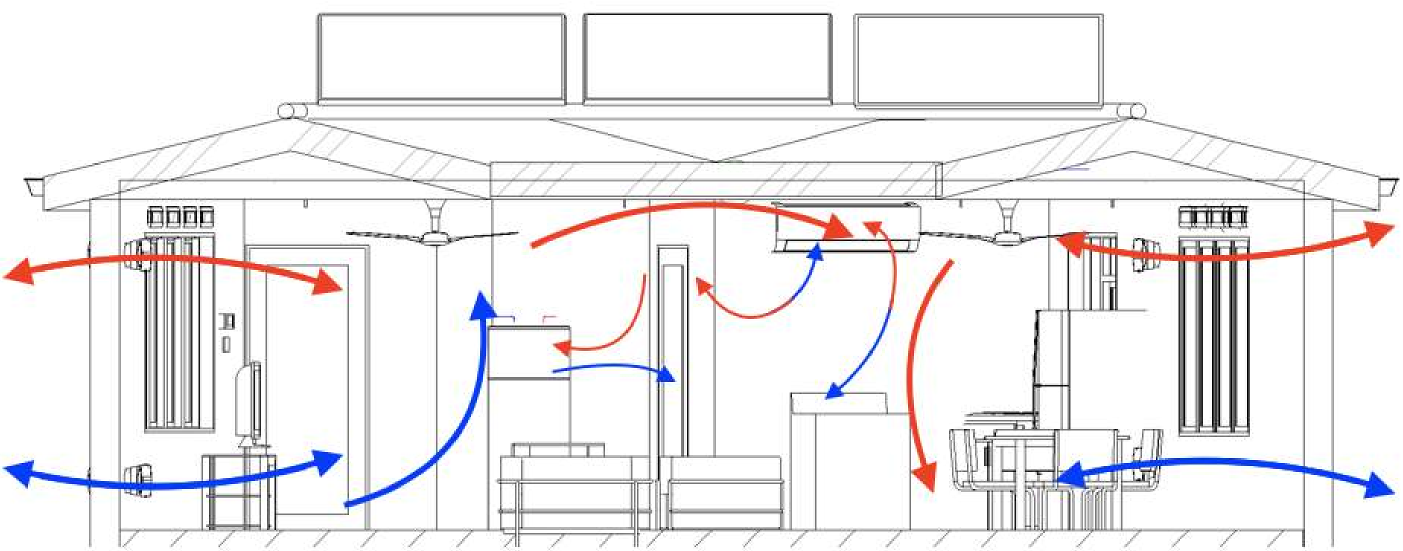


FIG 17 | Section view showing ventilation pathways

Lighting

To maximize occupant comfort, the lighting needs to be adjusted so that it does not become too bright or too dark at any given period of time. In order for us to also reduce the lighting loads, we aimed to maximize natural lighting while also preventing excess heat from entering the home. Based on the recommended lighting by the National Optical Astronomy Observatory (See **Appendix I**), we can classify the general lighting requirements of each room is as follows:

TABLE 3 | Lighting Requirements			
Room Type	Minimum Requirements (lux)	Minimum Requirements (lumens)	Power Density Based on the IECC 2021 (W/ ft^2)
Kitchen	300	1,250	1.09
Bedroom	300 - 500	3,180 - 5,300	0.50 - 0.96
Bedroom (Children)	500 - 800	5,300 - 8,480	0.50 - 0.96
Living Room	300 - 500	4800 - 8038	0.71
Laundry Area (joint with kitchen)	200	200	0.52
Dining Area	200	3220	0.4
Office/Work Area	500 - 800	n/a	0.74
Bathroom	100 - 300	830	0.63
Mechanical Room	200 - 500	1,370	0.43

Based on the graph, values, we decided to add enough lighting for each room to meet the requirements of the room for nighttime use, utilizing 14W LED light bulbs with a luminescence of ~1500 lumens. As such, we ended up using 18 Greenlite light bulbs (LED; Power Factor: 1.0; CRI: 84; Light Appearance: 3000K), with different amounts of lighting per "zone": 4x in each bedroom, 1x in the bathroom, 1x in the laundry-kitchen area, 3x in the dining area, 4x in the living area, and 1x in the mechanical room. The lighting units have separate switches that allows the occupants to tailor the lighting to their needs. We will be using smart switches that could be activated and deactivated remotely using a smartphone. The different zoning system for lighting allows the users to switch off unused lighting in irrelevant zones to their current activity, saving energy in the process. Additionally, motion sensors will be put in place for every zone, which will automatically turn off the lights after a period of inactivity. The following is the mapped lighting zones and daytime analysis of the sunlight for the house while in general operation with full lighting:

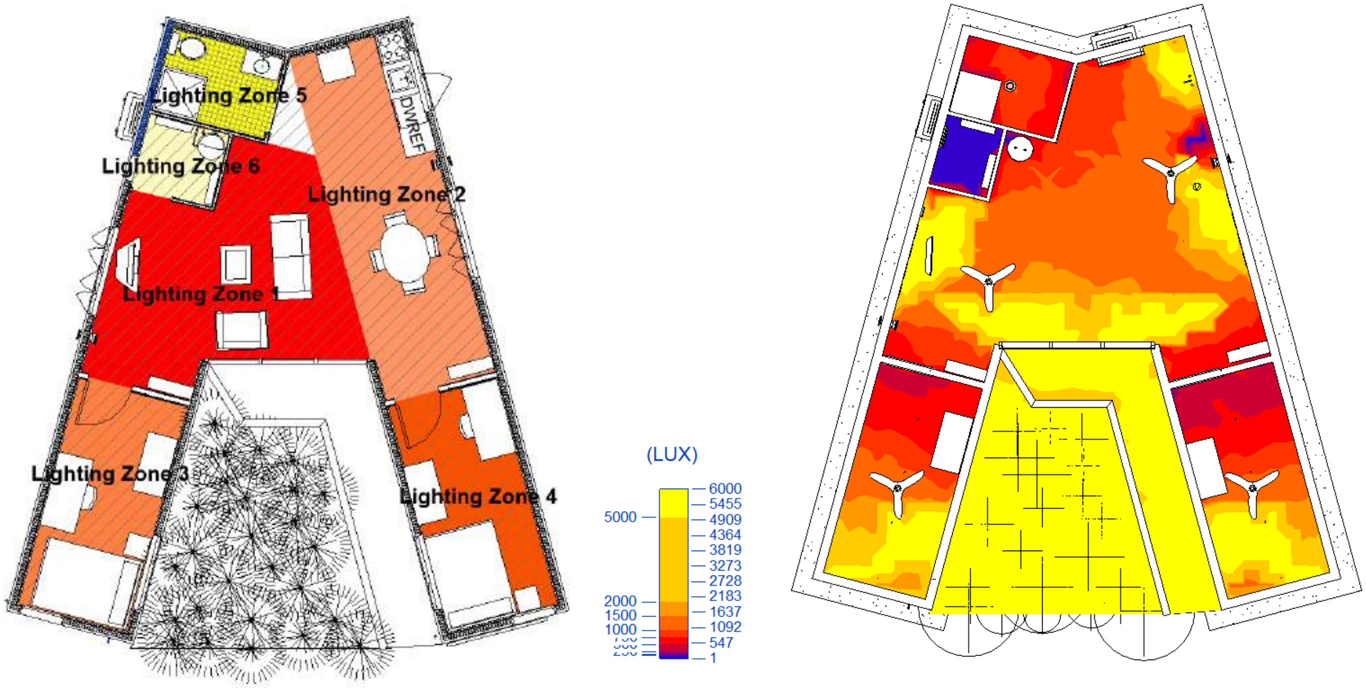


FIG 18 | Lighting zones (LEFT) and illuminations (RIGHT)

It is worth mentioning that under general operation conditions, the mechanical lighting is not on. In addition, the lights have minimal effect for the most part during the day because the lighting from the outdoor sources overwhelm the lights. A quick look at the windowless bathroom shows that the lights do provide over 500 lux of lighting, but virtually has no effect on the other areas with windows, which have much higher lighting throughout the day.

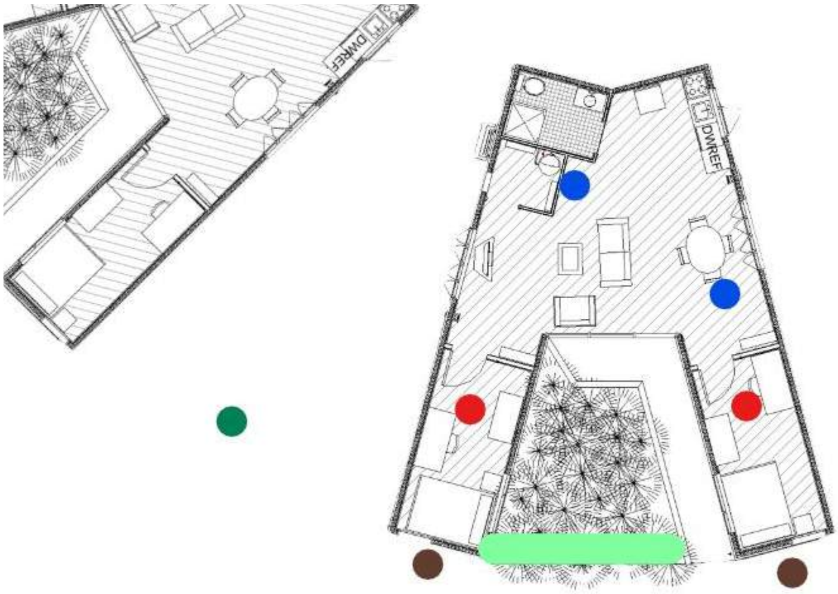
Because the light is very bright and can cause discomforting glare due to excess UDI (any value above 2500 lux), we put in place hand-operated curtains for the windows and a smart blind system for the curtain wall. Each curtain has two layers: a thin curtain layer and a thick linen drape. This provides the occupants additional comfort by increasing their control over the incoming light, either by partially blocking it or completely blocking it out. The smart blind system utilizes a single, 60% blackout polyester blend curtain. We decided on utilizing the smart blind technology for only the curtain wall because the curtain wall is the largest glass surface in the entire house; as such an optimal system to reduce excess light and heat inflow could significantly improve the comfort levels inside the housing unit and save energy costs for heating and cooling. The other windows use hand-drawn curtains as a balance to minimize costs and ensure that the building remains affordable.

Air Quality

Simple indoor sensors are included in the building unit to monitor smoke, carbon monoxide, and other toxic gases that could build up in the house unnoticed. The sensors will trigger an alarm if a certain known harmful gas exceeds a predetermined concentration in the indoor air. In addition the stoves utilized in the housing unit are fully electric, reducing the harmful emissions (such as PM 2.5, carbon monoxide or nitrogen oxides) from incomplete combustion of fossil fuels, gases which may be toxic, flammable, or corrosive in nature. The air quality sensor will also be linked to the ERV controller unit, which would allow the ERV system to adapt (increase airflow, decrease airflow, shut off) to the indoor air quality.

For indoor comfort quality of living, potted snake plants and peace lily plants will be placed. According to the NASA clean air study, the peace lily can remove benzene, formaldehyde, trichloroethylene, xylene, toluene, and ammonia pollutants from the indoor air. The snake plant can remove the same pollutants, except for ammonia[17]. Two snake plants will be placed in the living area, and one peace lily will be placed in each bedroom. The optimal number of plants is one per 100 square feet of space. Each container home module will be about 400 square feet. The four plants will promote optimal air purification of the pollutants listed above. In addition, both plants are low maintenance and do not require excessive amounts of water. They also do not undergo respiration and therefore will not use the oxygen in the container.

Plants and Vegetation



Vegetation was included in the design strategy for four main reasons: aesthetics, noise reduction, air quality control, and self-sustenance. When it comes to aesthetics, trees and plants have been shown by studies to have a positive effect on a person with regards to stress reduction and restoring the ability to concentrate and think clearly. A study published by researchers from the Denmark University of Aarhus indicates that the lack of "green" exposure can lead to 55% increased risk of developing psychiatric disorders such as depression, anxiety, and substance abuse in later years[18]. As such, each unit having a small garden space works well for both aesthetic and mental health purposes.

← FIG 19 | Design strategy with plants

Larger plants function as a noise reduction layer to keep out unwanted noise from the surroundings. The walls are thick and covered with insulation material, which doubles as a noise-dampening layer that reduces unwanted outside noise and provides privacy. As such, only the front-end with the glass curtain requires additional noise reduction principles, providing 0.2-0.3 dB of noise cancellation per foot of bushes (the value is proportional to thickness)[19].

This can be achieved by adding larger, leafy shrubs or short trees that have thick branches to the front of the house, which is designated for the fruit trees and scrub oaks in the light blue zone shown under **the Food Production Resilience** section. The scrub oak grows to about 10 feet, so it will not grow to a height that could hinder the solar panels' operations.

The dark green spot is where scrub oak or Jacaranda trees will be planted. Jacaranda trees can be planted for aesthetic purposes, and also absorbs up to 5 tons of carbon dioxide a year while having a long life. It stores a significant amount of carbon dioxide for its relatively small size and also thrives in warmer weather, such as the warm weather of the San Fernando Valley. The scrub oak is a native tree of this area so it is also drought tolerant. Hummingbird sage in the brown spots are an option for this area for its drought tolerance and benefits for passing hummingbirds in the area. In addition to the aesthetic value created by having green spaces, the users also benefit from the added natural noise reduction barrier. The variety of drought tolerant trees provide aesthetic appeal without drastically increasing the overall water consumption.

The front light green garden zone is designated for california lilacs for decorative purposes in front of the crops. The dark blue is for the snake plants, and the red is for the snake lilies. These are the indoor plants described in section **Air Quality** and will be additional air purifiers in the home.

4.8 Innovation

Solar Panel Cooling System

We have our own solar panel cooling system, which connects the water heater to the cold water system from the city's main water lines. By using an additional pump to help push the water along, the cold water will be passed through piping systems around the solar panels, which would then serve two purposes: First, the water cools the solar panels off. Second, the water would gain heat due to thermal transfer processes before going to the water heater. As such, less work needs to be done by the heater, allowing for reductions in energy consumption. Overall, the process works in a similar way with a solar-powered water heater, but has the added benefit of cooling the electricity-producing solar panels and allowing for less energy needed by the water heater heat pump. The pipes used will be ½-in. copper piping without insulation to allow for maximum heat conductance into the piping. The system will be isolated (through the use of one-directional valves) from the rest of the house to prevent any "backflow" of water or having water "stuck" at the roof, where the conditions may be optimal for bacteria growth if the water remains stagnant for long periods of time. The users can set a schedule for the pump to turn on at a certain time, i.e. 30 minutes before the usual shower time, with an option to manually turn on and off the system whenever needed in the event of a sudden change of scheduling or a scheduling system failure.

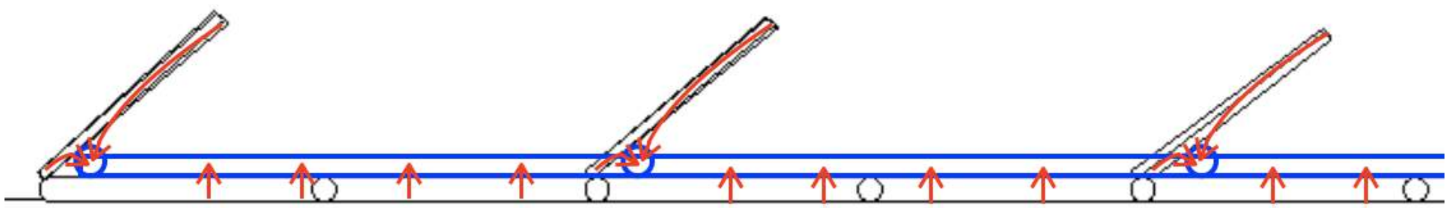


FIG 20 | Solar panel cooling system

Retrofitted Heat Pump Water Heater

We will also be retrofitting a SanCO2 heat pump water heater to accommodate for both indoor and outdoor heat exchange. An indoor water heater heat pump is beneficial because it takes in the heat from the room to heat the water, effectively acting as an air conditioner while heating the water. This can lead to increased savings over the summer as less energy would be required than traditional methods of cooling the room and heating the water separately. However, this can be problematic over the winter months, because the room requires heating instead of cooling. As such, we will be utilizing the SanCO2 heat pump's original mechanism of using an outdoor unit to heat the water, allowing the internal temperatures to be maintained and ensuring environmental comfort.

Foundational Structure

Rather than going with regular pile foundations, we went with a specially-designed pile foundation (Y-shaped) that would counteract the destabilizing effects of lateral ground movements during an earthquake. The design is inspired by tree roots since trees tend to survive earthquakes better than buildings in large part due to the branching effect of their roots, which help brace against lateral destabilization in any direction. We also drew inspiration from the Liray House in Chile - another shipping container home in an earthquake prone region. Like the Liray house, we raised the containers above grade to minimize contact with the ground and installed additional piers for extra stability. To further strengthen the foundation we joined the piers together with a concrete grade beam. This arrangement allowed us to comply with the continuous foundation requirement for buildings in Los Angeles, in addition to making the entire structure resilient.

By joining the structure and utilizing the Y-shape, we were able to increase the foundational stability to address the instability of the region, which lies in a high-risk region for earthquakes due to its proximity to the San Fernando-Symlar fault line.

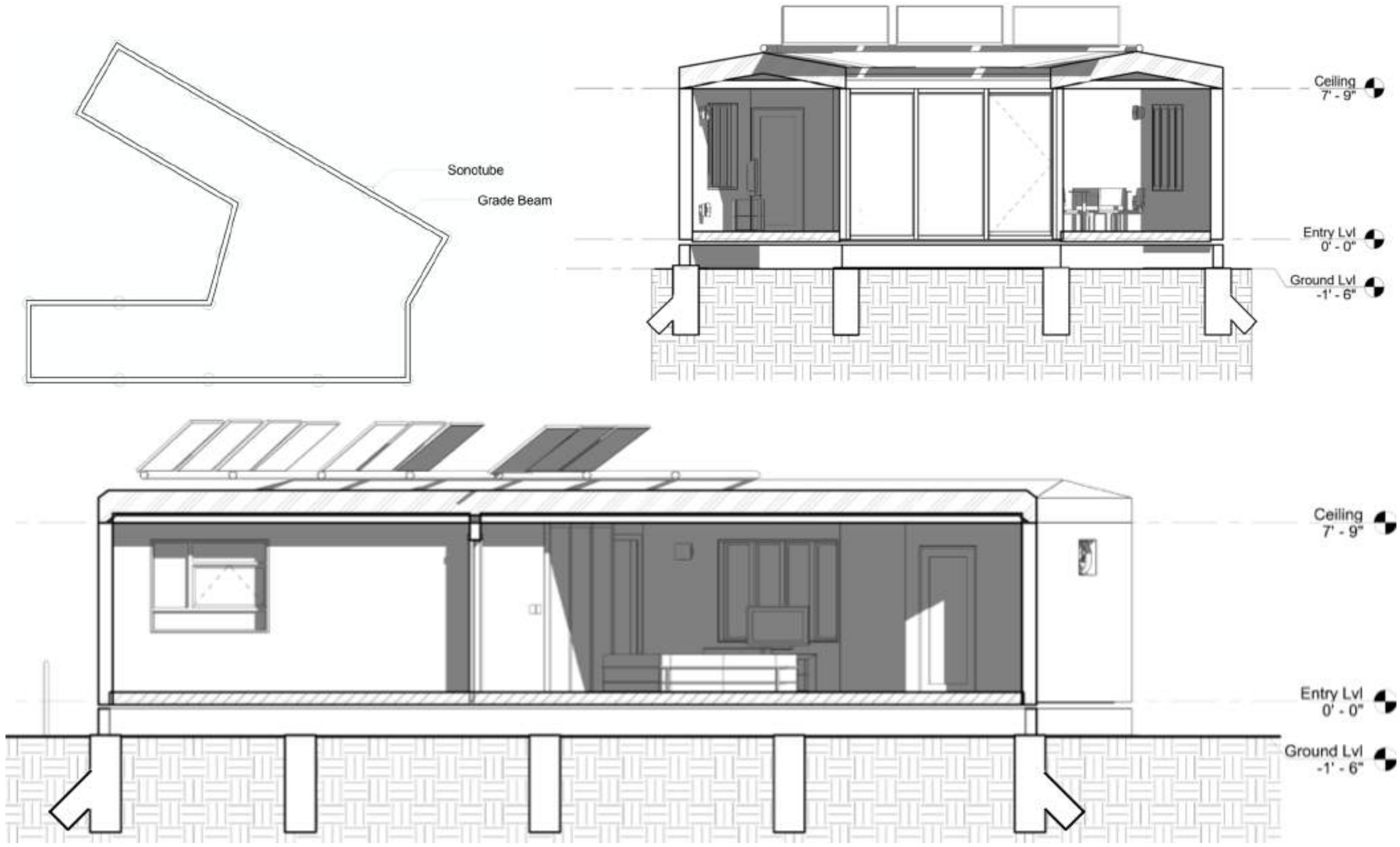


FIG 21 | Detail on the foundation supports. (TOP LEFT) Overhead view of structure. (TOP RIGHT) Elevation view along narrow axis of structure. (BOTTOM) Elevation view along long axis.

Removable Panels

The team designed removable insulation panels embedded within the walls, from which maintenance teams can access piping from. Thus, instead of removing large chunks of the wall or the need to forcefully remove the cabling, the removable panel patches, spaced around the container unit, technicians and repairers simply need to remove the panel closest to the area needing repairs. To maintain the insulation layers, each panel will be spray foamed back into the wall to seal off any openings; technicians will need to cut open these foam layers to remove the panel, which they can then re-seal when replacing the panels into their original positions.

4.9 Environmental Impact

Embodied Environmental Impact

The house is designed and built based on green engineering principles, PHIUS+ 2018, and LEED Certification to reduce the environmental impact of construction. The unit primarily utilizes recycled materials that are locally sourced. The design fully integrates PV technology, which reduces operational GHG emissions to 346.8 kg of CO_2 per year - 83% less emissions than the 2,076 kg of CO_2 emitted for the same building and energy consumption by using SCE's electricity supply.

Materials used are locally sourced and hace as low embodied-carbon as possible. During building construction, embodied carbon is one of the largest environmental impacts. To reduce the impact of carbon during construction, materials are locally sourced from Los Angeles suppliers. The team chose to use either recycled materials or materials that can be recycled at the end of the building life cycle. For example, EPDM, Tar and Gravel, Modified Bitumen will be avoided because it cannot be recycled at the end of building life, while other types can be recycled. This includes using reclaimed wood, which is relatively abundant and sourced from the nearby California-Mexico border, for the studs and construction. The wood will be surveyed beforehand by a structural engineer and graded to ensure that we are not compromising the safety of the occupants to lower the costs and environmental impact of the project. By reusing shipping containers, we are saving roughly 8,000 kWh of electricity per container (which is the amount of energy needed to melt down the container and recycle the steel); in contrast, fully retrofitting the container is expected to use up only 400 kWh of electricity, or reducing 95% of energy consumption and creating additional value from a used product.

OneClick LCA was used to perform a Life Cycle Analysis (LCA) to assess the Embodied Carbon impacts of the full life cycle of the shipping container home. This includes the four life cycle stages in a cradle to grave LCA model: Product Stage, Construction Stage, Use Stage, and End of Life Stage.

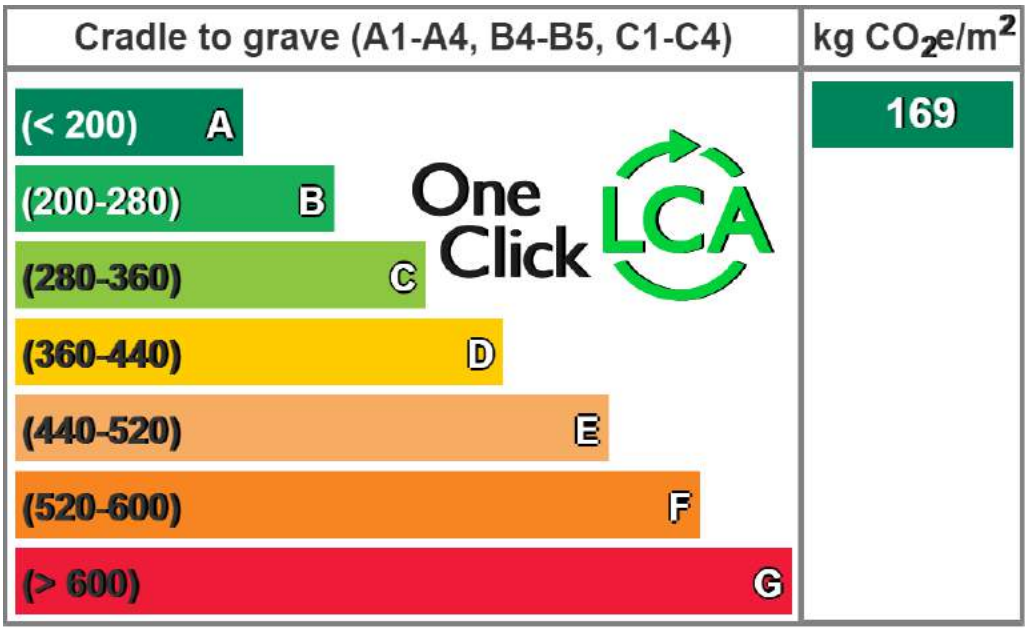


FIG 22 | Environmental impact life-cycle analysis (LCA)

Based on the Life Cycle Analysis, the estimated contribution to global warming, specifically in kilograms of carbon dioxide is 169 kg of carbon dioxide per square meter. The main contributor to the building's contribution to global warming is the materials. This does not take into account the positive impact of all solar energy use, the reuse of the shipping containers, and on-site plants and crops. The LCA also cannot account for the primary reused material, the shipping container, but accounts for the transportation of the container to the site. The included materials include every modification to the shipping containers to build it to sufficient comfort level for occupants.

The materials included in the LCA includes exterior walls, interior walls, roof, foundation, floors, exterior deck, windows, glass wall, and doors. Interior decor such as furniture and kitchenware were not included since they are flexible over the course of the lifetime of the house. The house was designed to last for a lifetime of at least 25 years, as specified in OneClick LCA. The materials were also chosen through careful considerations on their embodied environmental impact. Due to the use of a reused metal shipping container, we could not incorporate the container's reuse into the LCA. Assumptions were made to estimate as close as possible to the actual total use of materials.

The main insulation materials were chosen to function efficiently at low and high temperatures to maintain a comfortable indoor environment. A main focus of insulation materials was to maximize energy efficiency of the building. For example, the rigid foam polyisocyanurate prevents thermal bridges from forming; thermal bridges reduce the energy efficiency of the building. It also does not contain CFCs and HCFs. The heat pump water heater uses R744 refrigerant (CO_2), which is one of the least harmful refrigerants available, with a 100-year GWP of only 1 (compared to the 100-year GWP in the 1,000s for refrigerants such as R-22 and R-414).

The chosen insulation materials also reduce the infiltration of air pollutants and soil gases from outside the building. The closed-cell spray foam polyurethane, in particular, has a durability of at least 50 years and reduces heating and cooling usage dramatically to reduce construction cost while increasing energy efficiency of the building. It also contains no ozone depleting substances or formaldehyde, helping in conservation of energy to reduce carbon dioxide emissions.

For the end of life cycle for the building, the goal is to recycle a majority of the materials used. Our goal is to maximize the recovery of materials and to preserve resources through reuse. The easy to remove items, such as doors and appliances, can be salvaged for reuse. The wood cutoffs can be chipped and used as mulch in this location or any other locations. The concrete can be recycled either on site as fill or driveway bedding. The de-papered and crushed gypsum can be used as a soil amendment. The more intensive recycling, such as for the wood, concrete, metals, and more, will be with the aid of a local recycling agency called Direct Disposal in Los Angeles, California. It is a construction and demolition recycling association. In total, the amount of recycled materials includes up to 20 tons of the initial construction materials. Only a small fraction (~5%) of the total construction materials is projected to be sent to landfill.

WaterSense

In order to minimize water loss, we utilized fixtures that are WaterSense certified, selecting a low-flow shower head, a low-flow flushing mechanism, and utilizing low-flow faucet aerators for the bathroom and kitchen faucets. The Watersense products are expected to reduce water flow per minute by 20-30%, leading to up to 25% water and energy savings annually without compromising the everyday quality and lifestyle.

TABLE 4 | WaterSense Appliances

Shower Glacier Bay Chrome 3-Spray Hand shower *Chosen because of its great value for money and low water use; rated 1.8 GPM, or 28% less water use compared to the conventional showerheads* Price: $19.98	
Kitchen Faucet Dominion 2-Handle Standard Kitchen Faucet *Chosen because of its minimalistic design, low cost, and low water use; rated 1.75 GPM, or 20% less water usage compared to a standard- requirement US kitchen faucet.* Price: $35.25	

Toilet
Niagara Single Flush 12 in Original Stealth Round Toilet Bowl+Tank

Chosen for high functionality but extremely low water use; rated 0.8 GPF, only 40-50% compared to standard bathrooms in the US while maintaining functionality

Price: $129

Bathroom Faucet
Aragon 4 in. Centerset 2-Handle Low-Arc Bathroom Faucet

Chosen for its affordability and low water use; rated 1.2 GPM, which is only 30% of the standard modern bathroom faucet (only 17% water flow rate of older models)

Price: $21.97

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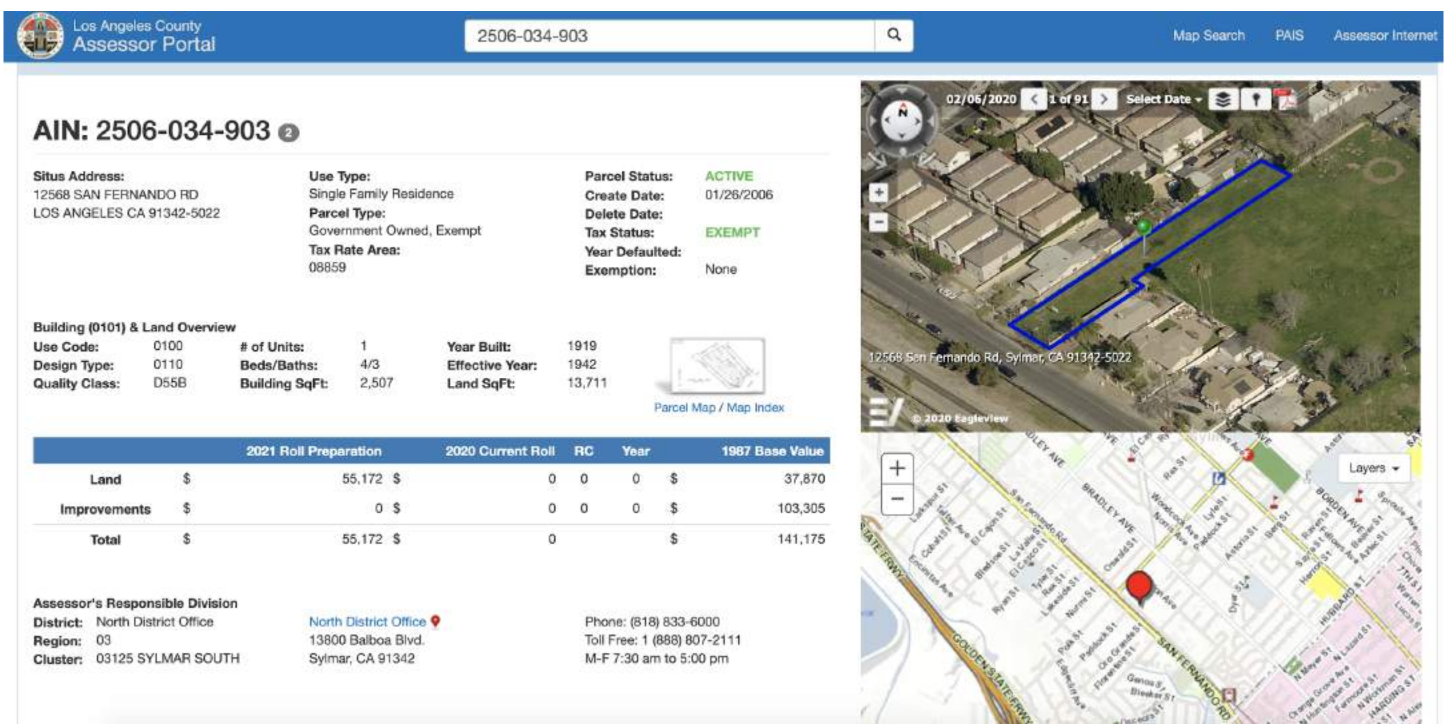
Appendix

Appendix A: Rendering + Images of the Housing Unit

Alternative Arrangements

Appendix B: Location Details



Los Angeles County
Assessor Portal

2506-034-902

Map Search PAIS Assessor Internet

Summary

AIN: 2506-034-902

Situs Address:

Use Type: Single Family Residence
Parcel Type: Government Owned, Exempt
Tax Rate Area: 00016

Parcel Status: ACTIVE
Create Date:
Delete Date:
Tax Status: EXEMPT
Year Defaulted:
Exemption: None

Building & Land Overview
Use Code: 0100
Design Type:
Quality Class:
# of Units:
Beds/Baths: /
Building SqFt: 0
Year Built:
Effective Year:
Land SqFt: 6,897

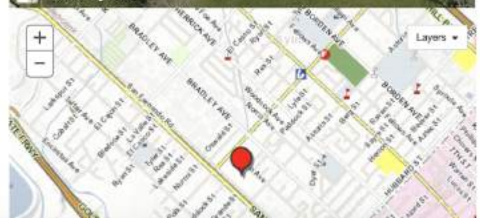
Parcel Map / Map Index

		2021 Roll Preparation	2020 Current Roll	RC	Year		1975 Base Value
Land	$	1,276 $	0	0	0	$	1,000
Improvements	$	0 $	0	0	0	$	0
Total	$	1,276 $	0			$	1,000

Assessor's Responsible Division
District: North District Office
Region: 03
Cluster: 03125 SYLMAR SOUTH

North District Office
13800 Balboa Blvd.
Sylmar, CA 91342

Phone: (818) 833-6000
Toll Free: 1 (888) 807-2111
M-F 7:30 am to 5:00 pm



Los Angeles County
Assessor Portal

2506-034-900

Map Search PAIS Assessor Internet

Summary

AIN: 2506-034-900

Situs Address:

Use Type: Other Property Type
Parcel Type: Government Owned, Exempt
Tax Rate Area: 00016

Parcel Status: ACTIVE
Create Date:
Delete Date:
Tax Status: EXEMPT
Year Defaulted:
Exemption: None

Building & Land Overview
Use Code: 8800
Design Type:
Quality Class:
# of Units:
Beds/Baths: /
Building SqFt: 0
Year Built:
Effective Year:
Land SqFt: 20,676

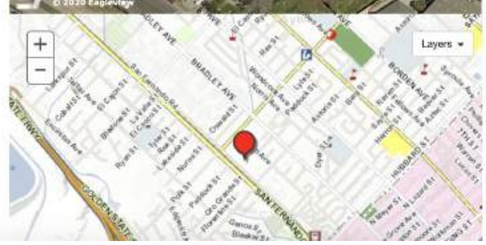
Parcel Map / Map Index

		2021 Roll Preparation	2020 Current Roll	RC	Year		1975 Base Value
Land	$	1,914 $	0	0	0	$	1,500
Improvements	$	0 $	0	0	0	$	0
Total	$	1,914 $	0			$	1,500

Assessor's Responsible Division
District: North District Office
Region: 03
Cluster: 03900

North District Office
13800 Balboa Blvd.
Sylmar, CA 91342

Phone: (818) 833-6000
Toll Free: 1 (888) 807-2111
M-F 7:30 am to 5:00 pm



Los Angeles County
Assessor Portal

2506-035-900

Map Search PAIS Assessor Internet

Summary

AIN: 2506-035-900

Situs Address:

Use Type: Other Property Type
Parcel Type: Government Owned, Exempt
Tax Rate Area: 00016

Parcel Status: ACTIVE
Create Date:
Delete Date:
Tax Status: EXEMPT
Year Defaulted:
Exemption: None

Building & Land Overview
Use Code: 8800
Design Type:
Quality Class:
# of Units:
Beds/Baths: /
Building SqFt: 0
Year Built:
Effective Year:
Land SqFt: 48,265

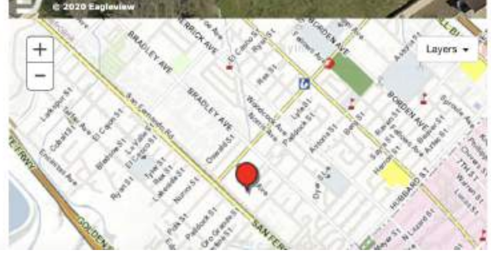
Parcel Map / Map Index

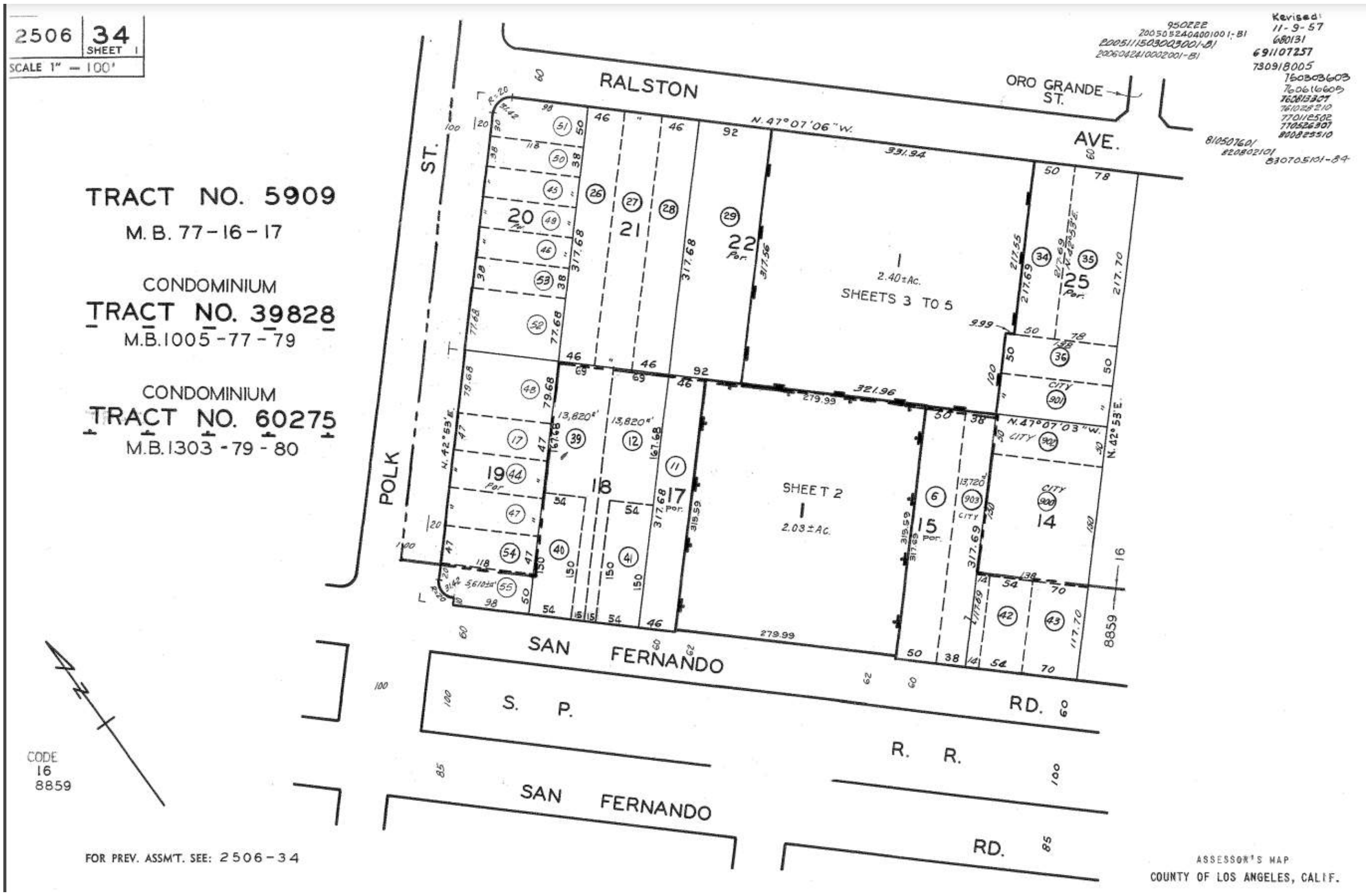
		2021 Roll Preparation	2020 Current Roll	RC	Year		1975 Base Value
Land	$	9,087 $	0	0	0	$	7,100
Improvements	$	0 $	0	0	0	$	0
Total	$	9,087 $	0			$	7,100

Assessor's Responsible Division
District: North District Office
Region: 03
Cluster: 03900

North District Office
13800 Balboa Blvd.
Sylmar, CA 91342

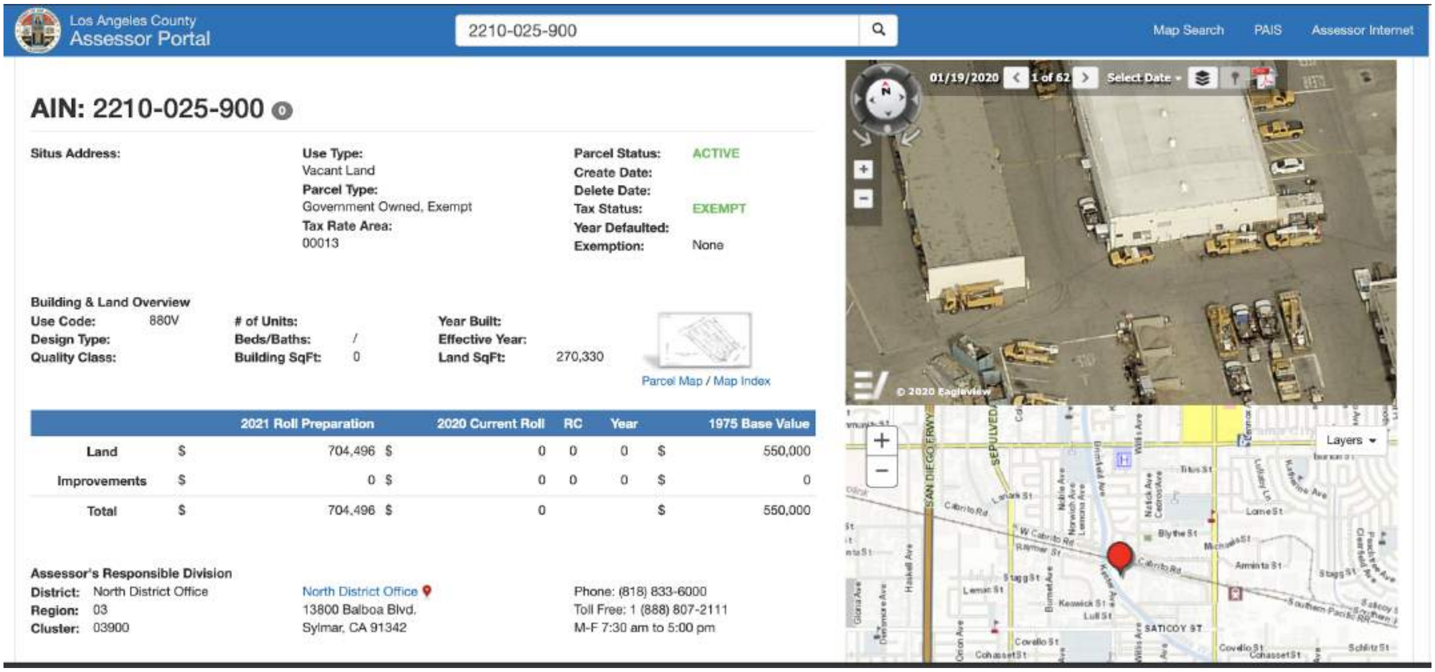
Phone: (818) 833-6000
Toll Free: 1 (888) 807-2111
M-F 7:30 am to 5:00 pm





Parcel No.	AIN No.	Price ($)
1	2506034903	55,172
2	2506034900	1,914
3	2506034902	1,276
4	2506034901	1,276
5	2506035900	9,087
Total		$68,725

Additional Proposed Locations:
Van Nuys:


Los Angeles County Assessor Portal

2210-025-900

Map Search | PAIS | Assessor Internet

AIN: 2210-025-900

Situs Address:	Use Type: Vacant Land	Parcel Status:	ACTIVE
	Parcel Type: Government Owned, Exempt	Create Date:	
	Tax Rate Area: 00013	Delete Date:	
		Tax Status:	EXEMPT
		Year Defaulted:	
		Exemption:	None

Building & Land Overview

Use Code:	880V	# of Units:		Year Built:	
Design Type:		Beds/Baths:	/	Effective Year:	
Quality Class:		Building SqFt:	0	Land SqFt:	270,330

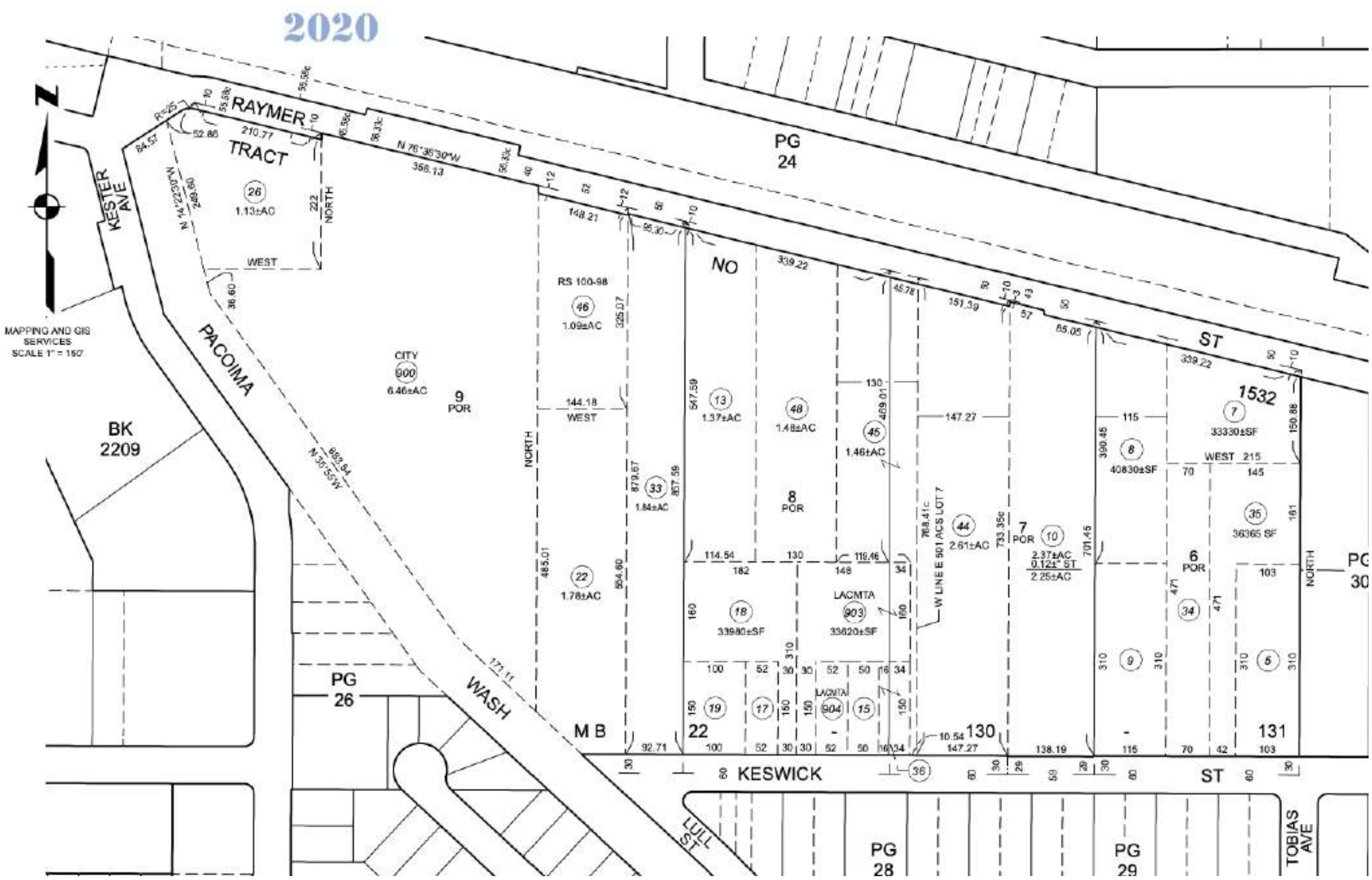
Parcel Map / Map Index

		2021 Roll Preparation	2020 Current Roll	RC	Year		1975 Base Value
Land	$	704,496 $	0	0	0	$	550,000
Improvements	$	0 $	0	0	0	$	0
Total	$	704,496 $	0			$	550,000

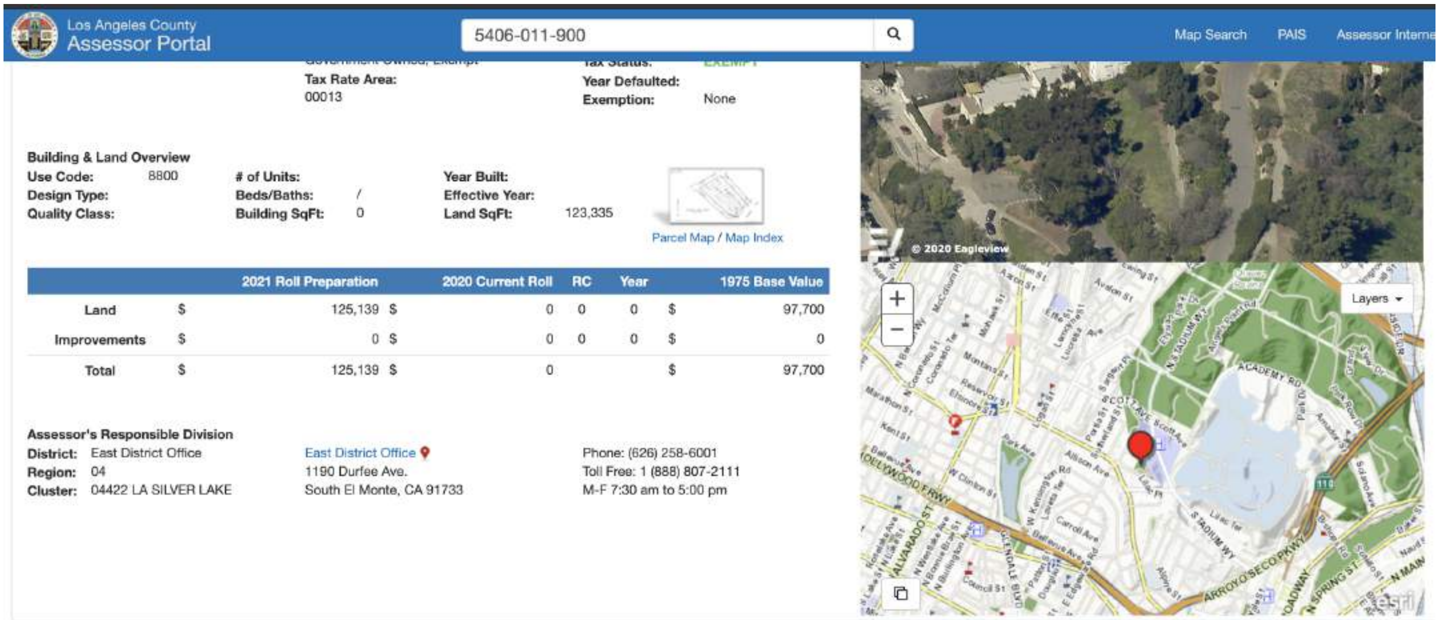
Assessor's Responsible Division
District: North District Office
Region: 03
Cluster: 03900

North District Office
13800 Balboa Blvd.
Sylmar, CA 91342

Phone: (818) 833-6000
Toll Free: 1 (888) 807-2111
M-F 7:30 am to 5:00 pm



1353 Elysian Park Drive



Los Angeles County Assessor Portal

5406-011-900

Map Search | PAIS | Assessor Interne

Tax Rate Area: 00013

Year Defaulted:

Exemption: None

Building & Land Overview

Use Code:	8800	# of Units:		Year Built:	
Design Type:		Beds/Baths:	/	Effective Year:	
Quality Class:		Building SqFt:	0	Land SqFt:	123,335

Parcel Map / Map Index

		2021 Roll Preparation		2020 Current Roll	RC	Year		1975 Base Value
Land	$	125,139	$	0	0	0	$	97,700
Improvements	$	0	$	0	0	0	$	0
Total	$	125,139	$	0			$	97,700

Assessor's Responsible Division

District: East District Office

Region: 04

Cluster: 04422 LA SILVER LAKE

East District Office

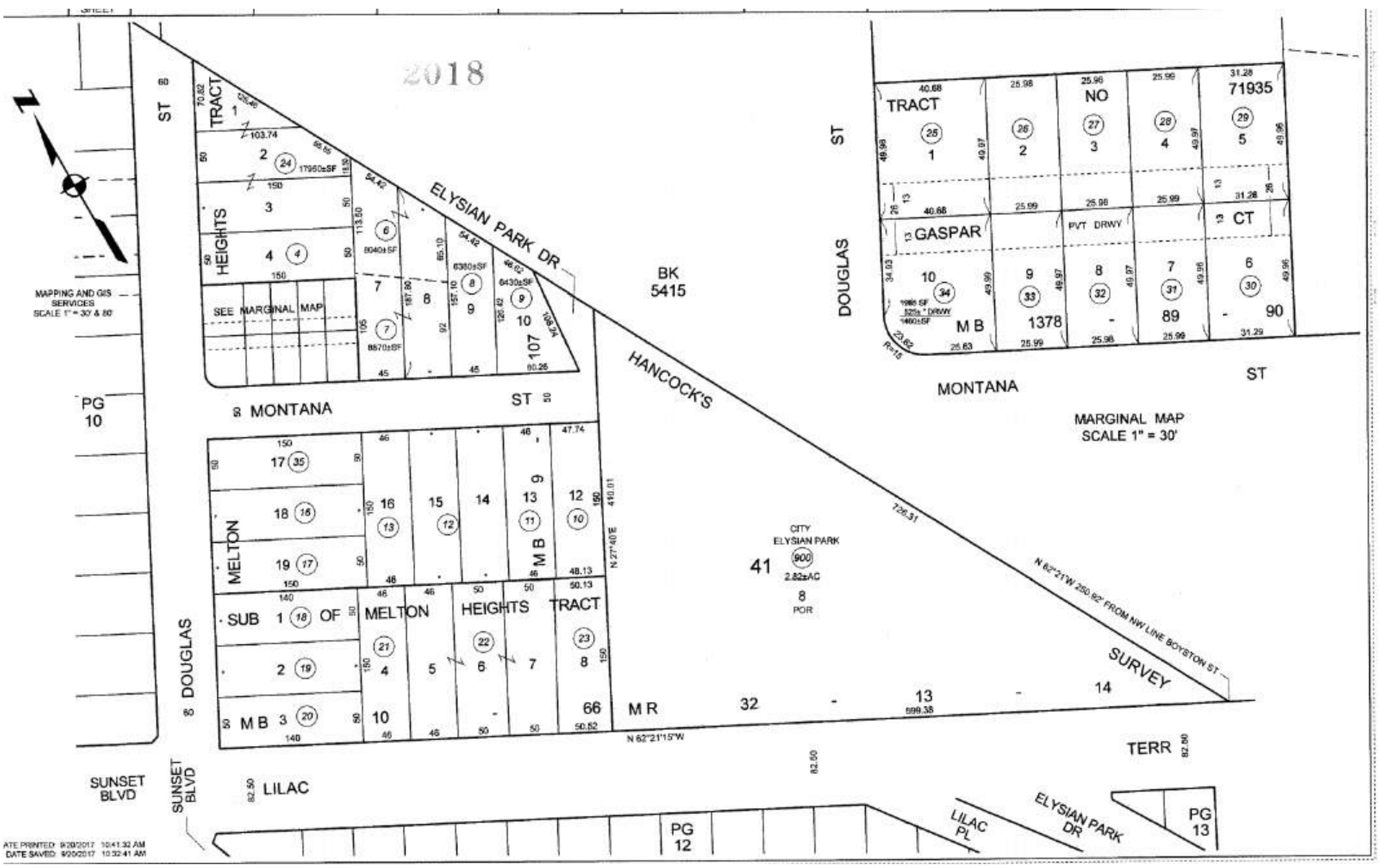
1190 Durfee Ave.

South El Monte, CA 91733

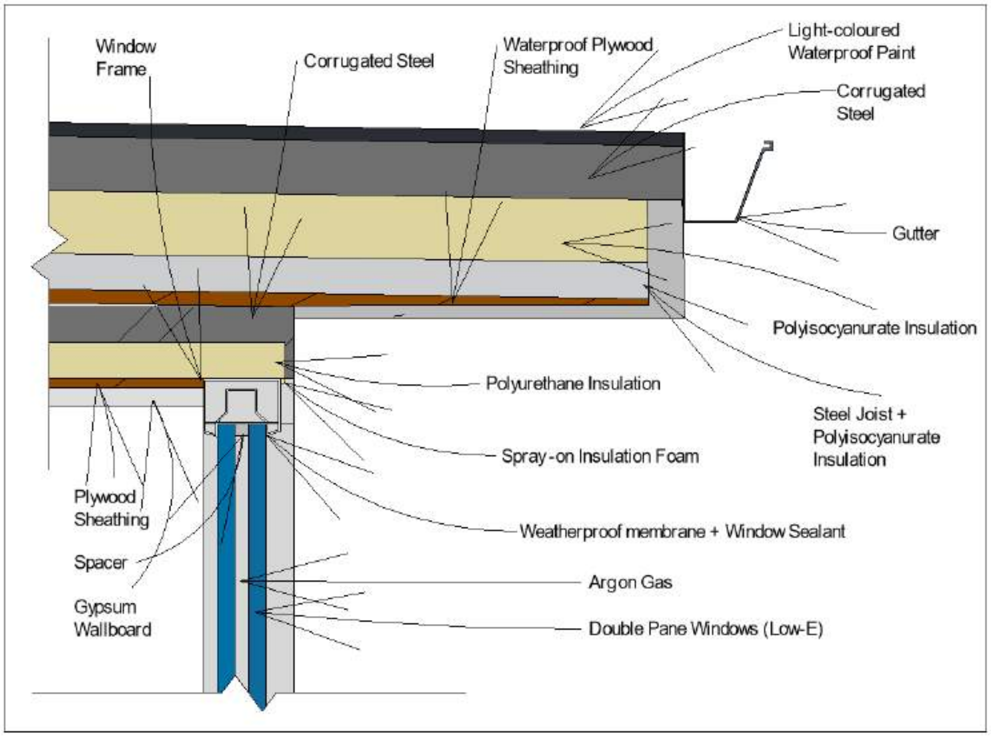
Phone: (626) 258-6001

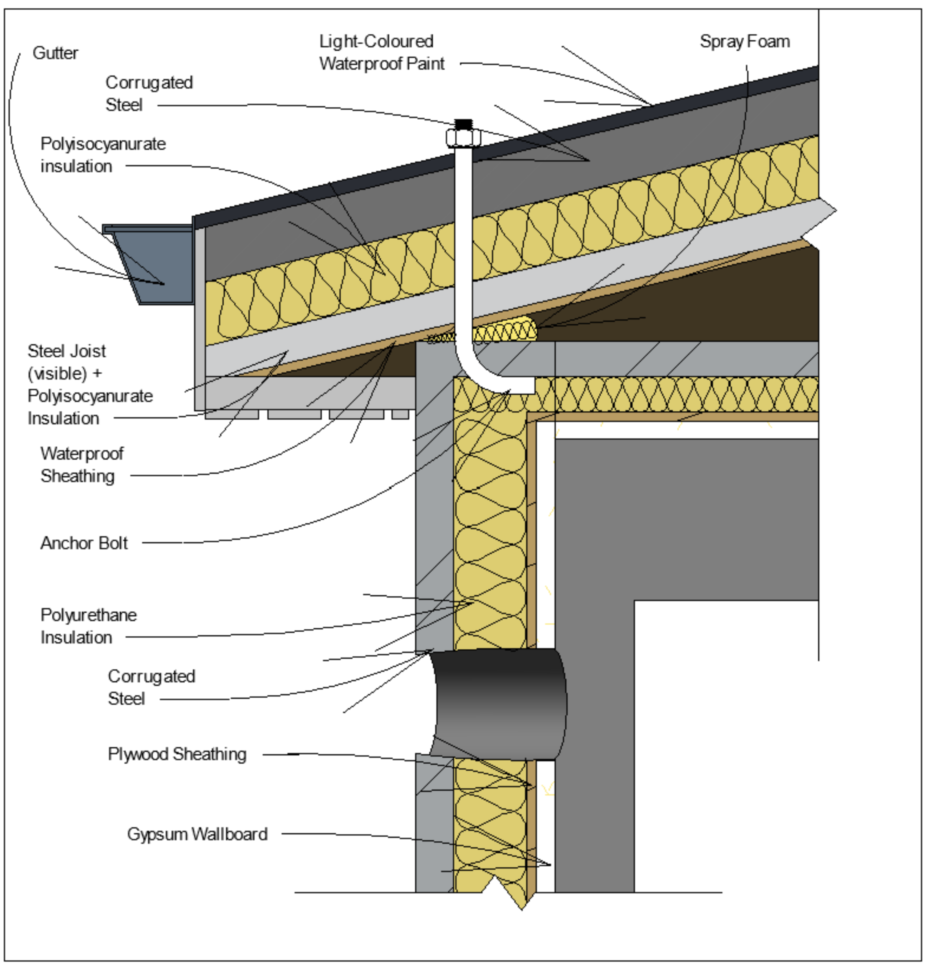
Toll Free: 1 (888) 807-2111

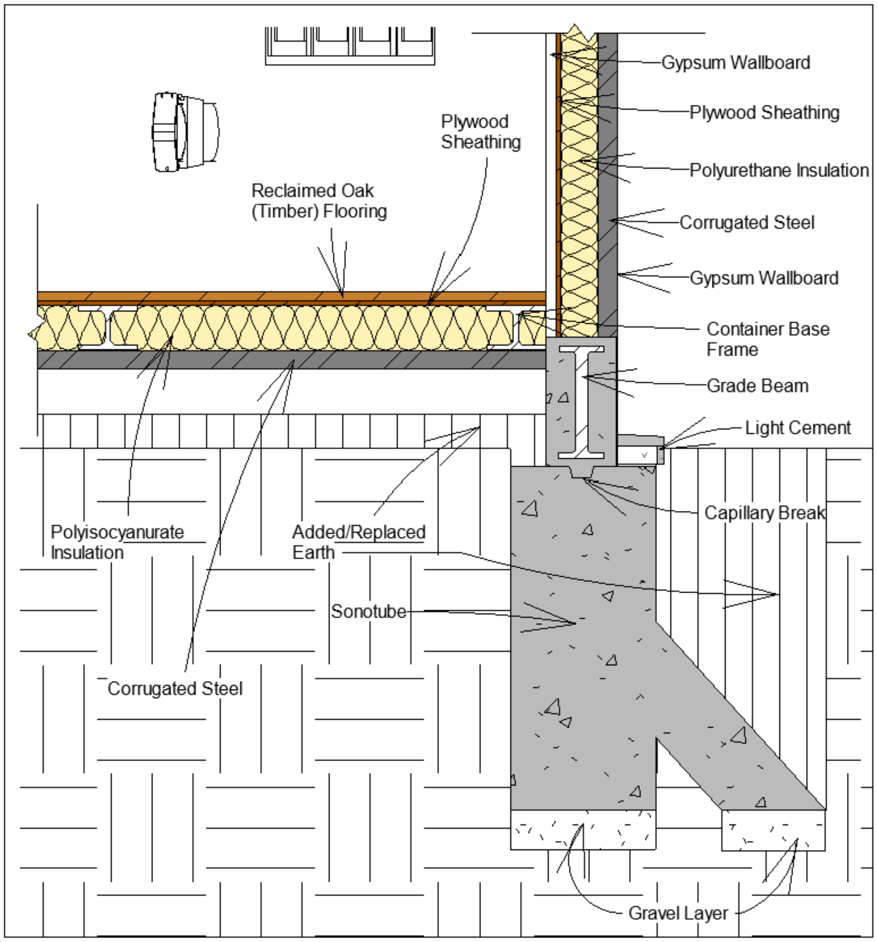
M-F 7:30 am to 5:00 pm



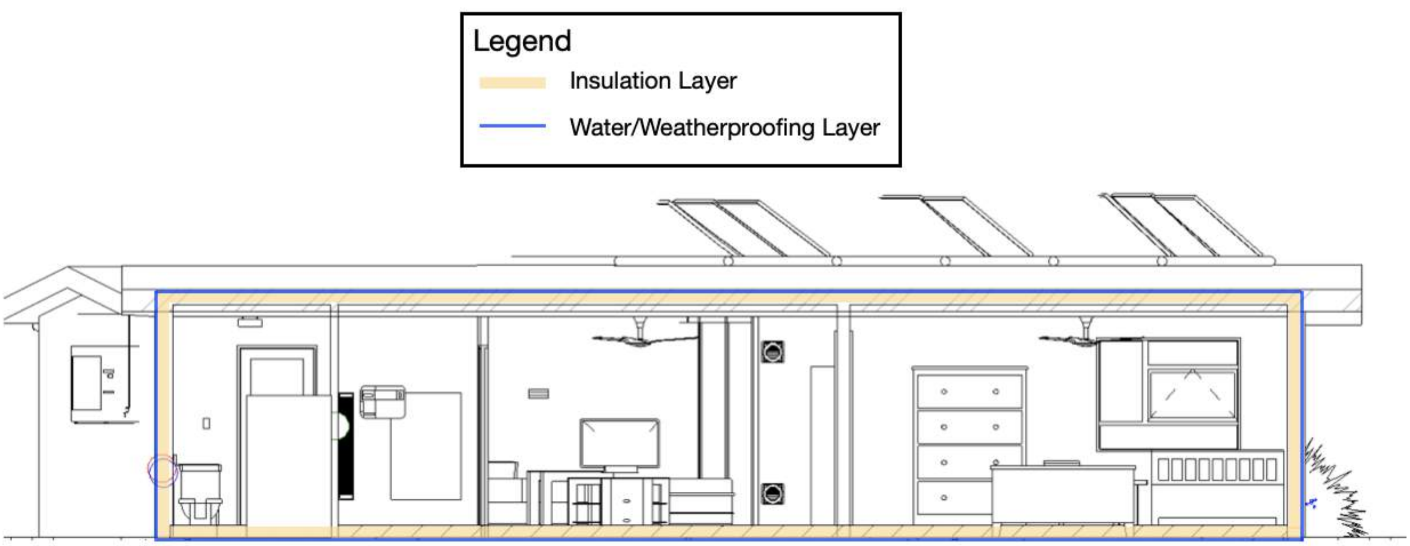
Appendix C: Detailed Callouts of Floor, Roof, andGlass Curtain Walls







Appendix D: Thermal Envelope of Building

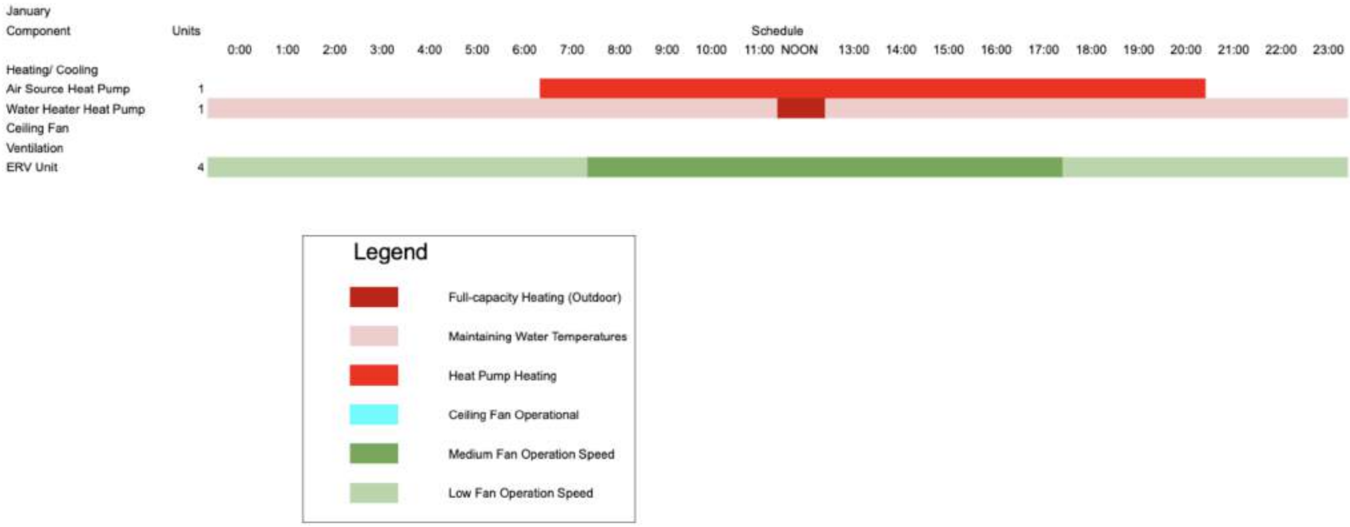


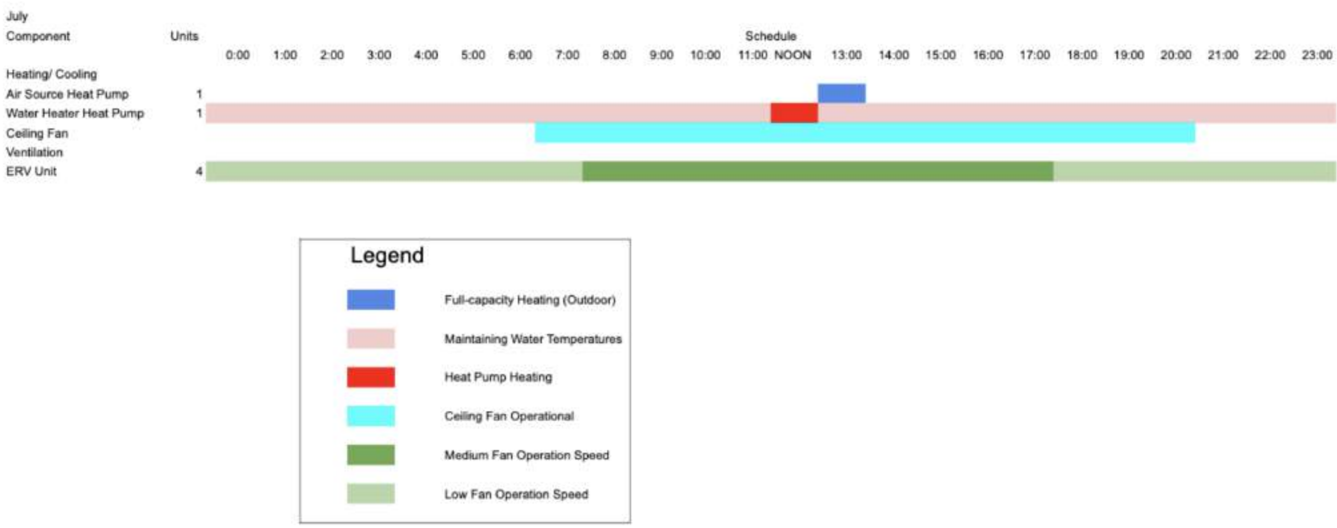
Appendix E: Insulation Materials and Reason for Selection

Material	R-value	R-value/inch	Why Chosen
Air	0.16 (outside) 0.68 (inside)	___	N/A
STUD → Wooden structure lumber (¾" *5'½")	4.935	___	Wood is more energy efficient. It is a better insulator than steel as it has an average r-value per inch of 0.91, whilst steel has one of 0.0031
Closed-cell spray foam Polyurethane 4¾"	31⅔	6.7	Has higher R-value (6.0) per inch than open-cell (3.5) Effective at low and high temperatures Aids in maintaining a comfortable, constant, temperature throughout the building, from room to room and floor to floor. Assists in improving indoor air quality. Reduces the infiltration of air pollutants and soil gases from outside the building. The high-quality insulation efficiency reduces heating and cooling usage dramatically. HVAC equipment can be down-sized. This reduces construction costs, and increases energy efficiency of the building. It contains no ozone depleting substances or formaldehyde, and helps conservation of energy which reduces CO_2 emissions. Durability of at least 50 years
Rigid Foam Polyisocyanurate (Reflective foil face inclusion encouraged) 3"	19.8	6.6 (6.5-6.8)	Meets the criteria of ASTM E84 Standard, proving its superior fire

			resistance properties. Used to insulate both walls and ceilings High thermal efficiency Has excellent dimensional stability as it retains original dimensions after installation. It prevents thermal bridges from forming. These thermal bridges reduce the energy efficiency of the building. Does not contain CFCs and HCFCs The only foam plastic insulation product to have both FM 4450 and CAN/ULC-S126 approvals when installed directly.
Rigid Foam Polyisocyanurate (Reflective foil face inclusion encouraged) 5”	33	6.6	Reflective foil facing is an excellent insulation material which adds to its effectiveness as an insulator
Drywall (Gypsum board ¼”)	0.2	0.8	Ease of installation. Versatility; can be used almost anywhere in the building. Fire resistant. Effectively help in reducing sound transmission. Readily available
Wall and (Plywood) floor (¾”) Sheathing	1.3 and 0.31	__	Increased wall rigidity and structure strength. Also provides a structure to mount the floor panels and the gypsum drywall to.
Double Pane Glazed windows One Low-E coating with Argon gas.	3.8	__	Improves energy efficiency of building compared to the 2.0 R value of clear dual pane windows with no coating.
Soft wood for floor 1”	1.41	1.41	More environmentally friendly than hardwood; also a more Affordable option

Appendix F: Components + Expected Schedules for HVAC





HVAC Controller Settings	
Expected Operating Days	7 days / week
H/AC Expected Operation Time	07:00 - 20:00
Ventilation Expected Operation Time	00:00 - 23:59
Humidity Range	30 - 60%
Ramp Up/Down Time	1 Hour
Diversity Factor	5%
Setpoint	
Time Range	06:00 - 22:00
Temperature Range	68-74°F
Setback	
Time Range	22:00 - 06:00
Temperature Range	62-84°F

Energy Recovery Ventilator	
Location	Dining Area / Living Room
Manufacturer	Lunos
Model	e2
Type	ERV
Power Supply	110V/ 60Hz, 1Ph
Dimension	6.8 in x 6.4 in ø
Dimension (Outside/Inside)	7.1 in x 7.1 in (square) / 7.1 in ø
OPERATIONS	
Thermal Recovery	90.60%
Humidity Recovery	20-30%
Operational Noise	16.5db/19.5 dB /26.0 dB
Fan Efficiency	0.11-0.14 W/cfm
Filter	MERV 8-10
Air Flow	9/18/22 CFM
Number of Fans	4
Total air flow	72 CFM

Air-Sourced Heat Pump	
Location	Laundry-Kitchen Area
Manufacturer	Cooper & Hunter
Model	CH-D09MSPHWM-230VI
Power Supply	208-230V/ 60Hz, 1Ph
MCA	10 A
MFA	15 A
Dimension (Indoor)	32.87x7.80x11.02 in
Dimension (Outdoor)	30.31x11.81x21.85 in
Fluid source/load	410A
Air Flow (Indoor)	370/268/196 CFM
Air Flow (Outdoor)	1177 CFM
Operational Noise (Indoor)	41.7/33.4/26.5 dB(A)
Operational Noise (Outdoor)	55 dB(A)
HEATING	
Max Heating Capacity	1.3 kW
Heating COP	3.78
HSPF Region IV	10.8
Operational Range (Indoor)	32~86°F
Operational Range (Outdoor)	-13~86°F
COOLING	
Max Cooling Capacity	0.89 kW
Cooling COP	4.4
SEER Rating	23.5
EER Rating	14.9
Operational Range (Indoor)	62~90°F
Operational Range (Outdoor)	-13~122°F
PIPING	
Refrigerant Piping	1/3 - 3/8 in
Max. Refrigerant Piping Length	82 ft

Heat Pump Water Heater	
Location	Mechanical Room
Manufacturer	Sanden
Model	SAN-83SSAQA
Uniform Energy Factor	3.75
Power Supply	208-230V/ 60Hz, 1Ph
MCA	7.2 A
MFA	15 A
Dimension (Tank)	68.9 in x 24.5 in ø
Dimension (Outdoor)	15.0x35.1x26.4 in
Refrigerant	R744
Air Flow (Indoor)	370/268/196 CFM
Air Flow (Outdoor)	1177 CFM
Operational Noise	37 dB(A)
HEATING	
Max Heating Capacity	4.5 kW
Heating COP	5.5 (@80°F) / 4.2 (@47°F)
Annual Energy Usage	1485 kWh
First Hour Capacity	115 Gallons
Operational Range (Indoor)	-25~104°F
PIPING	
Pipe Size	1/2 in
Max Piping Length	66 ft
Max Vertical Separation	23 ft
Max Incoming Pressure	96 Psi

Appendix G: The Components of the Electric System and Smart Home Technology with Their Basic Specifications

Electric System

Component	Product Name	Base Specifications
Solar Panel	SunPower SPR-A400	Nominal Efficiency: 21.4% Maximum → P_{mp}: 400.0 W; V_{mp}: 39.6 V; I_{mp}: 10.1 A V_{oc}: 47.6 V_{dc}; I_{sc}: 10.9 A_{dc} Temperature Coefficient: -0.31%/°C (-1.24 W/°C)
Charge Controller	MIDNITE SOLAR Classic-200 MPPT Charge Controller	Max V_{oc}: 200 V Max current out: 55 amps @ 48V Type 1 ISO 14024:2018 Environmental Labelling
Battery Storage	LG Chem RESU Lithium Battery	Rated Capacity (100% DOD): 9.8 kWh

		Recommended Capacity (90% DOD): 8.8 kWh Voltage Range: 42.0 - 58.8 V (Rated 48 V) Capacity (C): 189 Ah Certifications: IP55 Enclosure Protection Rating; UL1642, UL1973
Disconnects	MS Power Solar PV DC Quick Disconnect Switch DC1600V32A2IO (DC) GE Energy Industrial Solutions TF60RCP Pullout Disconnect (AC)	DC - Maximum Rating: 2 x 32 amps each (Up to 1000 V) Outdoor rated, waterproof, UV resistance UL 746C AC - 60A Pullout Disconnect at 120/240V Rainproof
Inverter	SMA America SB4000TL-US-22	Weighted Efficiency: 97.1% Maximum Power: 4000 (AC); 4172 (DC) Acceptable DC Voltage: 100 - 480 V Maximum DC Current: 10.4 A_{dc}
Wiring	Solar Photovoltaic (PV) Wire 600V UL 4703	Size: 10 AWG (105 @ 30 AWG strands) Ratings: 90°C wet or dry @ 600V Compliances: UL Type PV (overall) UL 4703, UL 44, UL RHW-2 600V Direct Burial, Passes UL VW-1 Flame Test, RoHS Compliant
Combiner Box	MidNite Solar MNPV3 Solar Array Combiner	Compliance: Aluminum rainproof type 3R enclosure, UL1741 Added: 300 VDC Breaker included; Adaptable for two separate inverters or charge controllers

Smart Home Control Technology

Component	Product Name	Base Specifications
Smart Blind	Graywind Motorized Shades	Compatibility: Graywind App, Google Home App, Alexa Dimensions: Customized Colour: E-jacquard White Material: Polyester & Polyester Blend Curtain Blackout: 60%
Smart Thermostat	Google Nest Thermostat	Compatibility: Google Home App, Alexa Dimensions: 3.31 x 3.31 x 1.07 in Colour: Charcoal; Weight: 0.31 pounds Remote monitoring: Yes
Air Quality Sensor	Temtop M10 Air Quality Monitor	Compatibility: Offline Dimensions: 3.23 x 1.22 x 3.23 in Sensors: HCHO/PM2.5/AQI/TVOC
ERV Controller	Lunos Universal Controller	Type: Universal Coding Dial Extension: Rocker switches for ease of use

Smart Switches (Occupancy Sensor)	C by GE 3-Wire Smart Motion Sensor Light Switch	Compatibility: C by GE Mobile App, Google Home App, Alexa Dimensions: 4.21 x 7.24 x 5.71 in Colour: White Sensors: Light sensor (smart dimmer) and motion sensor (occupancy sensor)

Electricity Load Scheduling on Coldest Month (January):

Item	Product Name	Quantity	Power (kW)	Hours per day	Days per month	Cycles per wee	Energy per cycle	Hours per month	Energy over month (kWh)
Dishwasher	Danby 18" Built-In Dishwasher	1			31	2	1.125		9.964285714
Clothes Washer	Samsung WF45R6100AC	1			31	4	0.3044871795		5.393772894
Clothes Dryer	Samsung DV22N6800HW	1			31	4	0.5123674912		9.076224129
Fridge/Freezer Combo	LG LTCS20020	1			31	Continuous			32.25
Electric Range	GE 30-in 4 Elements 5-cu ft. Freestanding Ele	1	2.9975	1.233333333	31			38.23333333	114.6044167
Air Source Heat pump	Cooper & Hunter CH-12SPH-115VI/O-WK	1	0.76	14	31			434	329.84
Ceiling Fan	Hampton Bay AM588-BN	4	0.0314	0	31			0	0
Microwave	Black+Decker EM720CB7	1	0.7	0.1666666667	31			5.166666667	3.616666667
Kitchen Hood	Broan Glacier BCSEK1	1	0.078		31			38.23333333	2.9822
Television	SCEPTRE - H43	1	0.0342	7	31			217	7.4214
Desk lamp	JOSTIC B08D8FCXVW	2	0.006	4	31			124	1.488
Energy Recovery Ventilator	LUNOS e²	1	0.0084	24	31			744	6.2496
Lights	EcoSmart–1002459555 bulbs	18	0.007	15	31			465	58.59
Heat Pump Water Heater	ECO_2 Systems SanCO2	1	4.5	1	31			31	139.5
Hair dryer		1	1.2	0.5	31			15.5	18.6
Laptops		4	0.05	12	31			372	74.4
Phones		4	0.005	8	31			248	4.96
Total									818.9365661

Electricity Load Scheduling on Hottest Month (July)

Item	Product Name	Quantity	Power (kW)	Hours per day	Days per month	Cycles per week	Energy per cycle (kWh)	Hours per month	Energy over month (kWh)
Dishwasher	Danby 18" Built-In Dishwasher	1			31	2	1.125		9.964285714
Clothes Washer	Samsung WF45R6100AC	1			31	4	0.3044871795		5.393772894
Clothes Dryer	Samsung DV22N6800HW	1			31	4	0.5123674912		9.076224129
Fridge/Freezer Combo	LG LTCS20020	1			31	Continuous			32.25
Electric Range	GE 30-in 4 Elements 5-cu ft. Free	1	2.9975	1.233333333	31			38.23333333	114.6044167
Heat pump	Cooper & Hunter CH-12SPH-115	1	0.89	1	31			31	27.59
Ceiling Fan	Hampton Bay AM588-BN	4	0.0314	14	31			434	54.5104
Microwave	Black+Decker EM720CB7	1	0.7	0.1666666667	31			5.166666667	3.616666667
Kitchen Hood	Broan Glacier BCSEK1	1	0.078	1.233333333	31			38.23333333	2.9822
Television	SCEPTRE - H43	1	0.0342	7	31			217	7.4214
Desk lamp	JOSTIC B08D8FCXVW	2	0.006	4	31			124	1.488
Heat recovery ventilator	LUNOS e²	1	0.0084	24	31			744	6.2496
Lights	EcoSmart–1002459555 bulbs	18	0.007	9	31			279	35.154
Heat pump water heater	ECO_2 Systems SanCO2	1	4.5	1	31			31	139.5
Hair dryer		1	1.2	0.5	31			15.5	18.6
Laptops		4	0.05	12	31			372	74.4
Phones		4	0.005	8	31			248	4.96
Total									547.7609661

Total Annual Energy Consumption (month by month breakdown + appliance)

	Energy Consumption												
Item	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Dishwasher	9.964285714	9	9.964285714	9.642857143	9.964285714	9.642857143	9.964285714	9.964285714	9.642857143	9.964285714	9.642857143	9.964285714	117.3214286
Clothes Washer	5.393772894	4.871794872	5.393772894	5.21978022	5.393772894	5.21978022	5.393772894	5.393772894	5.21978022	5.393772894	5.21978022	5.393772894	63.50732601
Clothes Dryer	9.076224129	8.197879859	9.076224129	8.783442706	9.076224129	8.783442706	9.076224129	9.076224129	8.783442706	9.076224129	8.783442706	9.076224129	106.8652196
Fridge/Freezer Combo	32.25	32.25	32.25	32.25	32.25	32.25	32.25	32.25	32.25	32.25	32.25	32.25	387
Electric Range	114.6044167	103.5136667	114.6044167	110.9075	114.6044167	110.9075	114.6044167	114.6044167	110.9075	114.6044167	110.9075	114.6044167	1349.374583
Heat pump	329.84	255.36	94.24	47.12	0	0	27.59	0	0	0	188.48	282.72	1225.35
Ceiling Fan	0	0	7.7872	15.5744	23.3616	31.1488	54.5104	38.936	31.1488	23.3616	11.6808	0	237.5096
Microwave	3.616666667	3.266666667	3.616666667	3.5	3.616666667	3.5	3.616666667	3.616666667	3.5	3.616666667	3.5	3.616666667	42.58333333
Kitchen Hood	2.9822	2.6936	2.9822	2.886	2.9822	2.886	2.9822	2.9822	2.886	2.9822	2.886	2.9822	35.113
Television	7.4214	6.7032	7.4214	7.182	7.4214	7.182	7.4214	7.4214	7.182	7.4214	7.182	7.4214	87.381
Desk lamp	1.488	1.344	1.488	1.44	1.488	1.44	1.488	1.488	1.44	1.488	1.44	1.488	17.52
Energy recovery ventilato	6.2496	5.6448	6.2496	6.048	6.2496	6.048	6.2496	6.2496	6.048	6.2496	6.048	6.2496	73.584
Lights	58.59	49.392	50.778	45.36	42.966	37.8	35.154	39.06	41.58	46.872	49.14	54.684	551.376
Heat pump water heater	139.5	126	139.5	135	139.5	135	139.5	139.5	135	139.5	135	139.5	1642.5
Hair dryer	18.6	16.8	18.6	18	18.6	18	18.6	18.6	18	18.6	18	18.6	219
Laptops	74.4	67.2	74.4	72	74.4	72	74.4	74.4	72	74.4	72	74.4	876
Phones	4.96	4.48	4.96	4.8	4.96	4.8	4.96	4.96	4.8	4.96	4.8	4.96	58.4
Total	818.9365661	696.7176081	583.3117661	525.7139801	496.8341661	486.6083801	547.7609661	508.5025661	490.3883801	500.7401661	666.9603801	767.9105661	**7090.385491**

Appendix H: Plumbing Systems and Schedules

Cold Water System	
Pipe Type	CPVC
Main Pipe Sizing	1 in.
Branch Pipe Sizing	3/4 in.
Total Pipe Length of System	23.4 ft
Additional Insulation?	No
Pipe Pressure	52 - 120 psi
Temperature Range	45 - 60 °F

Sanitation Piping System	
Pipe Type	PVC
Main Pipe Sizing	3 in.
Branch Pipe Sizing	1 1/4 - 2 in.
Total Pipe Length of System	14.75
Additional Insulation?	No
Pipe Pressure	45 - 80 psi
Temperature Range	50 - 90 °F

Wet Fire Protection System	
Pipe Type	PEX
Main Pipe Sizing	3/4 in.
Branch Pipe Sizing	3/4 in.
Total Pipe Length of System	72.2 ft
Additional Insulation?	No
Pipe Pressure	52 - 100 psi
Pressure Loss	11.7 psi
C-factor of Piping	150
Temperature Range	120 - 140 °F

Domestic Hot Water System	
Pipe Type	PEX
Main Pipe Sizing	3/4 in.
Branch Pipe Sizing	3/4 in.
Total Pipe Length of System	29.6 ft
Additional Insulation?	Yes
Pipe Pressure	35 - 60 psi
Temperature Drop	1.5 °F / 100 ft
Temperature Range	120 - 140 °F

Isolated Solar Cooling System	
Pipe Type	Copper
Main Pipe Sizing	1/2 in.
Branch Pipe Sizing	1/2 in.
Total Pipe Length of System	120 ft
Additional Insulation?	No
Pipe Pressure	45 - 80 psi
Temperature Range	55 - 75 °F

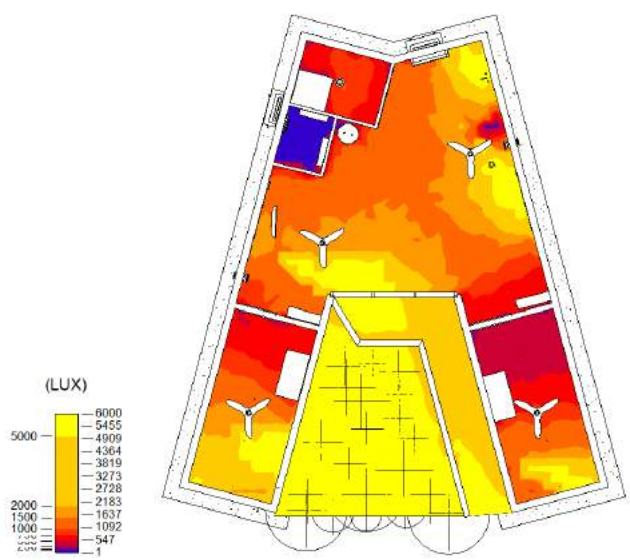
Hydronic Supply System	
Pipe Type	CPVC
Main Pipe Sizing	3/4 in.
Branch Pipe Sizing	3/4 in.
Total Pipe Length of System	19.8 ft
Additional Insulation?	Yes
Pipe Pressure	15 - 30 psi
Temperature Range (Supply)	55 - 75 °F
Temperature Range (Return)	120 - 140 °F

Appendix I: Recommended Lighting Levels

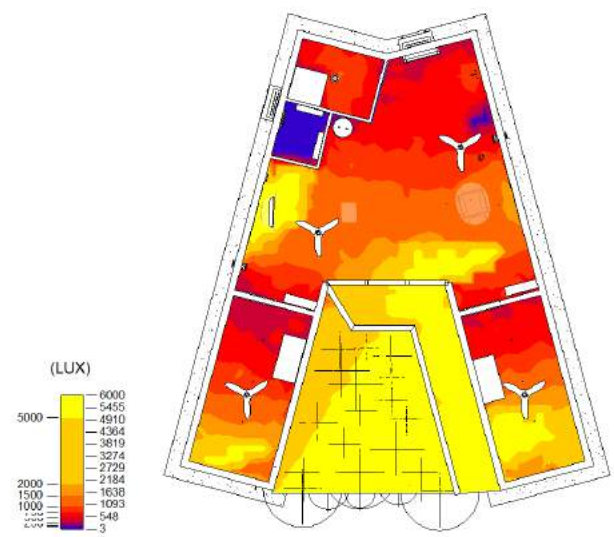
The recommended lighting levels for performing certain activities by the National Optical Astronomy Observatory

Activity	Illumination ($lux, lumen/m^2$)
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 - 150
Warehouses, Homes, Theaters, Archives	150
Easy Office Work, Classes	250
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 - 2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 - 5000
Performance of very prolonged and exacting visual tasks	5000 - 10000
Performance of very special visual tasks of extremely low contrast and small size	10000 - 20000

Lighting Analysis (Morning and Afternoon)



Lighting lx: 9/21 9am



Lighting lx: 9/21 3pm

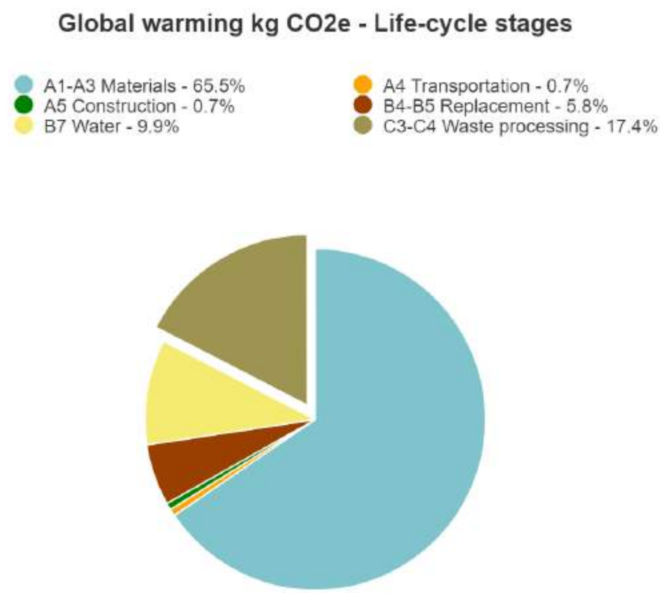
Appendix J: Suggested crop schedule use for the garden

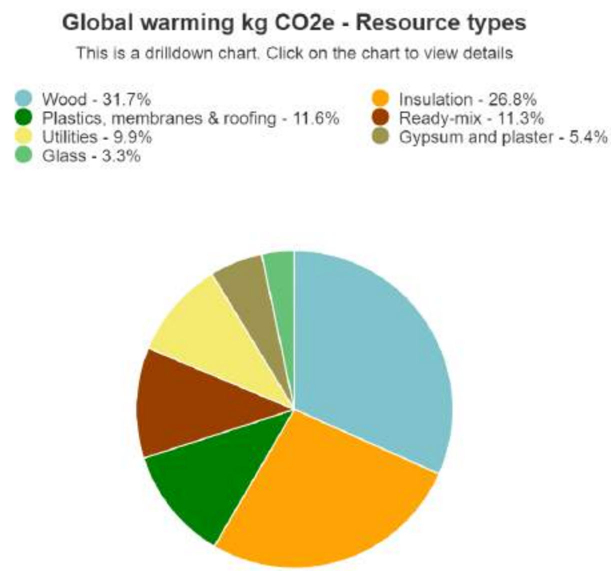
Suggested crop schedule use for the garden. Colors coordinate with zoning as described in section above.

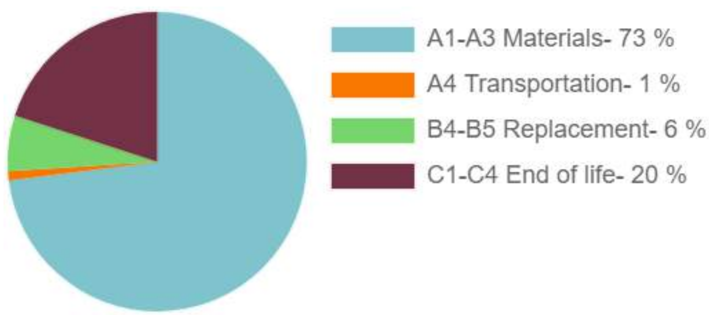
	Plant	Purpose	Harvest
January	Pomegranate Peaches Cherries * These trees will be grown year round	Needs the last nitrogen	Spinach
February	Peas	Restores nitrogen to soil	Cabbage
March	Green beans	Fixes nitrogen	
April	Potatoes	Requires less nitrogen	Peas
May	Carrots		Green beans
June	Cucumbers		Green beans
July			Peaches Carrots
August	Celery		Potatoes Cucumbers
September	Lettuce	Uses excess nitrogen	Pomegranates
October	Mustard	Uses excess nitrogen	
November	Spinach	Uses excess nitrogen	Lettuce
December	Cabbage	Uses excess nitrogen	Mustard, Celery

Appendix K: Life Cycle Assessment Diagrams

LCA Diagrams: The Breakdown of Contributions to Global Warming as Percentages.







Appendix L: Size Adjustment Factor Calculation

Size Adjustment Factor Calculation (No Basement Area)

$$\text{SAF} = [\text{CFA Benchmark Home / CFA Home To Be Built}]^{0.25}$$

(not to exceed 1.0)

$$\text{SAF of the housing unit} = [1600 \text{ (2-bedroom benchmark)} / 673]^{0.25} = 1.24$$

(since it cannot exceed 1.0)

SAF = 1.0

Appendix N: Ratings (HERS from Ekotrope)

Annual Carbon Dioxide (CO_2) [tons/yr]	HERS Ref.	Rated Home	Savings	% Saved
Heating	0.2	0.0	0.2	88.5%
Cooling	0.3	0.1	0.2	56.4%
Water Heating	0.7	0.2	0.5	76%
Lights & Appliances	1.5	1.1	0.5	30.7%
Photovoltaics	-0.0	-1.9	1.9	
TOTAL	2.7	-0.5	3.2	119.7%

Annual Sulfur Dioxide (SO_2) [lbs/yr]	HERS Ref.	Rated Home	Savings	% Saved
Heating	0.9	0.1	0.8	88.5%
Cooling	1.6	0.7	0.9	56.4%
Water Heating	3.7	0.9	2.8	76%
Lights & Appliances	8.0	5.6	2.5	30.7%
Photovoltaics	-0.0	-10.1	10.1	
TOTAL	14.2	-2.8	17.0	119.7%

Annual Nitrogen Oxide (NO_x) [lbs/yr]	HERS Ref.	Rated Home	Savings	% Saved
Heating	0.5	0.1	0.5	88.5%
Cooling	0.9	0.4	0.5	56.4%
Water Heating	2.1	0.5	1.6	76%
Lights & Appliances	4.5	3.1	1.4	30.7%
Photovoltaics	-0.0	-5.7	5.7	
TOTAL	8.0	-1.6	9.6	119.7%

ENERGY STAR® CERTIFIED NEW HOME

ENERGY STAR

Builder Name:
Permit Date/Number:
Home Address: 12568 San Fernando Rd, Sylmar, CA 91342

Rating Company: Yale University Solar Decathlon
Rater ID (RTIN):
Rating Date:
Version: 3.0

Standard Features of an ENERGY STAR Certified New Home

Your ENERGY STAR certified new home has been designed, constructed, and independently verified to meet rigorous requirements for energy efficiency set by the U.S. Environmental Protection Agency (EPA), including:

Thermal Enclosure System

A complete thermal enclosure system that includes comprehensive air sealing, quality-installed insulation and high-performing windows to deliver improved comfort and lower utility bills.

Air Infiltration Test: **0.5 ACH50**

Primary Insulation Levels:
Ceiling: R-61 **Floor: R-29**
Wall: R-29 **Slab: N/A**

Primary Window Efficiency:
U-Value: 0.33 **SHGC: 0.361**

Water Management System

A comprehensive water management system to protect roofs, walls, and foundations.

Flashing, a drainage plane, and site grading to move water from the roof to the ground and then away from the home.

Water-resistant materials on below-grade walls and underneath slabs to reduce the potential for water entering into the home.

Management of moisture levels in building materials during construction.

Heating, Cooling, and Ventilation System

A high-efficiency heating, cooling system, and ventilation system that is designed and installed for optimal performance.

Total Duct Leakage: **Untested**
Duct Leakage to Outdoors: **Forced Air Ductless**

Primary Heating (System Type • Fuel Type • Efficiency):
Air Source Heat Pump • Electric • 3.78 COP

Primary Cooling (System Type - Fuel Type - Efficiency):
Air Source Heat Pump • Electric • 23.5 SEER

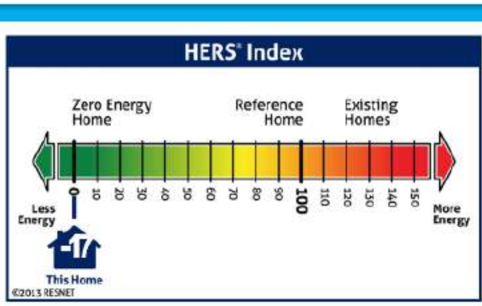
Energy Efficient Lighting and Appliances

Energy efficient products to help reduce utility bills, while providing high-|quality performance.

ENERGY STAR Qualified Lighting: **100%**

ENERGY STAR Qualified Appliances and Fans:
Refrigerators: 1 **Dishwashers: 1**
Ceiling Fans: 4 **Exhaust Fans: 4**

Primary Water Heater (System Type • Fuel Type • Efficiency):
Water Heater • Electric • 2.85 Energy Factor



This certificate provides a summary of the major energy efficiency and other construction features that contribute to this home earning the ENERGY STAR, including its Home Energy Rating System (HERS) score, as determined through independent inspection and verification performed by a trained professional. The Home Energy Rating System is a nationally-recognized uniform measurement of the energy efficiency of homes.

Note that when a home contains multiple performance levels for a particular feature (e.g., window efficiency or insulation levels), the predominant value is shown. Also, homes may be certified to earn the ENERGY STAR using a sampling protocol, whereby one home is randomly selected from a set of homes for representative inspections and testing. In such cases, the features found in each home within the set are intended to meet or exceed the values presented on this certificate. The actual values for your home may differ, but offer equivalent or better performance. This certificate was printed using Ekotrope™ (Version 3.2.4.2642).

Learn more at www.energystar.gov/homefeatures

2018 IECC R-406 Projected Energy Rating Index Report

Property	Organization	Energy Rating Index Information
Builder: Address: 12568 San Fernando Rd, Sylmar, CA 91342	Company:Yale University Solar Decathlon Phone: Rater:Theo Haaks	Projected Rating Rating No: Rater ID (RTIN): Date Rated:

Estimated Annual Energy Consumption*

	Rated Home Calculated Energy Use (MBtu)	Rated Home Cost ($/yr)
Heating	0.2	$9
Cooling	1.5	$57
Water Heating	1.9	$72
Lights & Appliances	11.8	$451
Photovoltaics	-21.4	$0
Total	**15.5**	**$0**

*Based on standard operating conditions

ERI with PV:-17

ERI without PV:51

Annual Estimates

Electric (kWh):4,532.3	CO2 Emissions (Tons):-0.5
Natural Gas (Therms):0.0	

Maximum Energy Rating Index:57	This Home's Energy Rating Index:-17	PASS

This home MEETS the Energy Rating Index Score requirement of 2018 IECC R-406 for Climate Zone 3. It MEETS all of the requirements verified by Ekotrope. Mandatory requirements are summarized on the 2nd page of this report, some of which are not verified by Ekotrope.

Name: Theo Haaks

Signature:

Organization: Yale University Solar Decathlon

Date: 3/29/21 at 4:30 PM

Rating Provider Data and Seal

Company:No Provider ID
Address:N/A
Phone #:N/A
Fax #:N/A

To determine if a provider is properly accredited go to: **www.resnet.us/professional/programs/search_directory**

Climate Zone 3	Mandatory Requirements	
Provision Number	**Topic**	**Compliance Decision**
2009 IECC Table 402.1.1 or 402.1.3	Building thermal envelope minimum insulation levels and maximum fenestration U-factor and SHGC	PASS
R401.3	Post a permanent certificate listing the level of efficiencies installed in the house	Certificate required for CO
R402.4.1.2	Envelope air leakage maximum leakage rate	PASS
R402.4.1 / Table R402.4.1.1	Comply with air sealing and insulation requirements in Table R402.4.1.1	Checklist required for CO
R402.4.4	Rooms containing fuel-burning appliances	PASS*
R402.5	Maximum fenestration U-factor and SHGC	(U-Factor) PASS
		(SHGC) PASS
R403.1.2	Heat pump controls	PASS*
R406.2	Ducts outside of conditioned space to be insulated to a minimum of R-6.	PASS*
R403.3.2	Duct sealing on all ducts	PASS*
R403.3.3	Duct testing for ducts in unconditioned space	PASS*
R403.3.5	Building cavities not used as ducts.	PASS*
R403.5.1	Heated water circulation and temperature maintenance systems comply	PASS*
R403.5.3	Hot water pipe insulated to R-3	PASS
R403.6	Mechanical ventilation meeting the requirements of the IRC or IMC. Outdoor air and exhaust dampers installed	PASS*
R403.7	ACCA Manual J and S conducted for all heating and cooling systems.	ACCA forms required for permit
R403.8	Systems serving multiple dwelling units to meet the mechanical requirements of IECC commercial code	PASS*
R403.9	Snow melt and ice system controls installed where applicable	PASS*
R403.10	Pools and permanent spa energy consumption meet requirements for heaters, time clocks and covers	PASS*
R403.11	Portable spas meet the requirements of APSP-14.	PASS*
R404.1	High efficacy lights installed in 75% of permanently installed fixtures.	PASS

* This is a projected rating. These items must eventually be field-verified by the Rater, Field Inspector, Code Inspector, or Builder.