SOLAR DECATHLON CHALLENGE 2022

# DESIGN NARRATIVE

RETROFIT HOUSING

## ENGLISH AVENUE YELLOW JACKETS

GEORGIA INSTITUTE OF TECHNOLOGY

U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON

ENGLISH AVENUE YELLOW JACKETS

Georgia Tech

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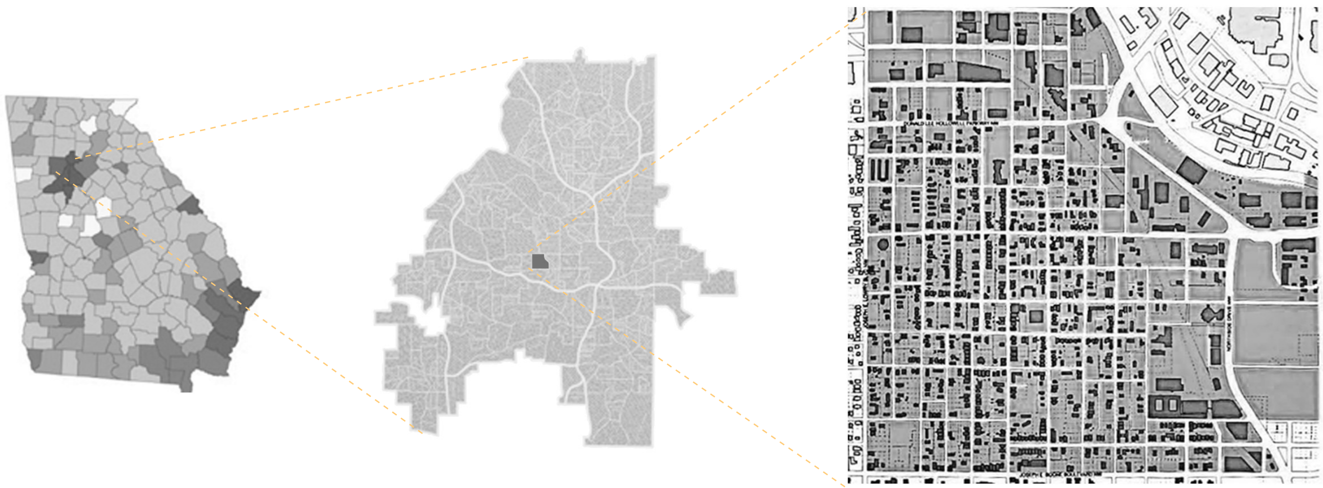
# CHAPTER 1 DESIGN PROCESS

English Avenue is a part of the Westside Neighborhood of Atlanta. This neighborhood is majorly comprised of 3 typical types of family structures which are considered focus user groups for the project. The residents experience similar living conditions and financial hardships and share the neighborhood's same cultures and architectural language. That is why the proposed design is developed to be an excellent fit for most community residents and scalable to other disadvantaged communities across the US.



Georgia Atlanta English Avenue

Figure 1: Location of the English Avenue

The English Avenue Yellow Jackets team from the Georgia Institute of Technology with design partner Westside Future Fund and industry partner Perkins&Will believe that retrofitting the existing built environment is of prime importance in today's global climate change context.

## 1.1 DESIGN CONSIDERATIONS

The proposal has been developed and structured to empower any house owner in the neighborhood to replicate any relevant design component to transform their house to be more energy-efficient in an affordable way. The current retrofit proposal is for a house with an east-west orientation, where the east embodies the house's front porch. Houses in the Westside Neighborhood with the same orientation can be a replica of this proposed design.

There are two major design considerations: First, a proposed angled roof of 29˚ that can generate the maximum amount of PV panel-based solar Energy from the roof and collect rainwater simultaneously. The same roof creates an opportunity to develop a vented attic space to provide the required thermal insulation for the house. This volume division between attic, living and crawl spaces reduces the HVAC system loads and immensely reduces electricity consumption. Second, a set of replicable envelope material assemblies. This proposed assembly is tested and resulted as superior performing in the current climatic conditions and at least until the year 2080. It offers essential protection to the residents for a longer period of performance as compared to typical best practices. The various insulation layers like thermal, vapor, moisture and air barrier provide sufficient protection from adverse climatic conditions.

Such design considerations were observed with the goal of significantly impacting Energy Use Intensity (EUI). The selection of lighting fixtures and appliances can be replicated from the proposal to reduce any house's lighting and plug loads. Apart from these, strategies like rainwater harvesting and stormwater management lower water usage bills and impact the users' cost of living. The financial model developed for this project can be used by the entire neighborhood to reduce their financial burdens. It enables them to live an affordable life in an energy-efficient house.

### 1.1.1 TIMELINE

We envision the project to be completed in 12 months, with the Pre-construction phase spanned across the first 6 months, and the construction phase, which includes the retrofitting work, will be spanned across the remaining 6 months. A detailed Gantt chart describes each stage in detail.

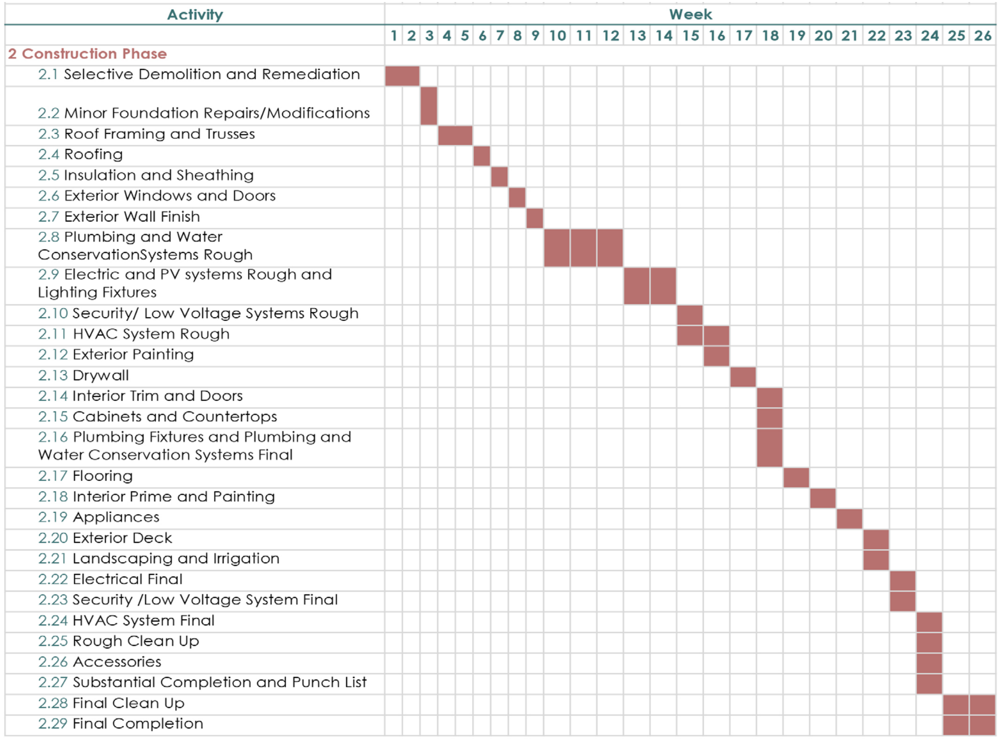



Figure 2: Construction schedule for the proposal

### 1.1.2 BUDGET

An analysis of the English Avenue market reveals a disproportionally working-class, working-age neighborhood where 60.53% of residents are housing burdened, expending more than 30% of their incomes toward rent or mortgages. Building upon the affordability programs championed by local non-profits Westside Future Fund and Atlanta Land Trust and repositioning their existing subsidy streams, our team has developed a strategy to offer this home at 60% of Area Median Income (AMI) while still providing an ample budget of over $243/sf to meet its performance goals. These include reducing utility burdens in a Southeast region where 17.9% of low-income households are Energy burdened in Atlanta1 When combined with the equity sharing, property tax reduction, and maintenance cost-reducing benefits of a community land trust model, we estimate the homeowner will be able to accrue benefits of almost $71,096 in present value throughout an average six-year period of ownership making the house not just a place to live, but a platform for upward mobility to create wealth and prosperity.

### 1.1.3 COMMUNITY SETTING

The historic neighborhood of English Avenue was purchased in the 1890s and contained over 100 years old houses. It faced a series of unfortunate events beginning with neglect in the 1930s due to redlining, followed by the recession and disinvestment in the 1980s. The steady decline continued in the neighborhood; currently, 44% of homes are vacant, and a significant number of these majority single-family houses are in poor condition. English Avenue first developed as an all-white community, and in the 1950s, the community's demographics had shifted primarily to African Americans. Currently, the neighborhood has a population of 3,558 residents comprising multiple ethnicities, with 89.4% of the total residents African Americans. Some notable patrons of the neighborhood included Gladys Knight, Mable Thomas, and Herman Cain.

Three major transit hubs that encourage interconnectivity are located in the area, namely the Bankhead, Ashby, and Vine City MARTA stations. The area is also now home to seven academic institutions. A small portion of the neighborhood is also known as 'The Bluff,' infamous for its crime rates, but as of 2011, many improvement plans have aided in remediating the impacts of this on the neighborhood.

Our specific home of focus at 588 James P Brawley Dr, Atlanta, GA was built in 1920, changing several hands. The home was built with two bedrooms and a bathroom to one side and a living/dining space to the other. It is currently not in a livable state, so there is much-needed work to make the home habitable again and take advantage of its lot size, location, and proximity to major city points of interest.

Most buildings in English Ave. were constructed before the 1950s, and many states chose to adopt energy efficiency codes in the 1970s. Because of that, most house

1 Atlanta has the highest sewer bills and third-highest combined water and sewer bills of any in the United States.

holds in English Ave. will not meet any of the current standards for energy efficiency. According to West Side Future Fund, the chosen house was approximately constructed in the 1920s. Prior to the ban of lead-based paint, lead water pipes, and asbestos, such hazardous materials had an immense effect on the health of occupants, as has been proven, thus resulting in its ban.

Furthermore, the soil in English Ave is highly contaminated with lead, which is a byproduct of industrial activity that dates back to the turn of the 19th century. Sanborn Insurance maps from 1892 reveal that at least ten foundries were in Atlanta. From an analysis that a consultant hired by West Side Future Fund carried out, it was found that lead concentrations of 483ppm appear in the front of the property and 368ppm in the rear. They then replaced the soil with more than 400ppm (Above the safety cutoff that the EPA identified). Even though it has been replaced, the high concentration of lead and measures for lowering it must be considered.

### 1.1.4 CLIMATE

According to the IECC climate classification, Atlanta falls within the 3A climate zone (Warm-Humid). It is the largest city in Georgia, and it receives a large amount of rainfall (58 inches per year). The city has an average yearly temperature of 18.8 °C | 65.8 °F, average relative humidity of 68%, and is always above the 40-60% comfort range; this shows the need for considering dehumidification strategies in our design. The wind directions are towards the southwest in summer and the northwest in winter. The sun moves during the summer solstice with a solar angle of 79.8° and in the winter solstice with a solar angle of 32.8° as per the sun path diagram (Figure 2)

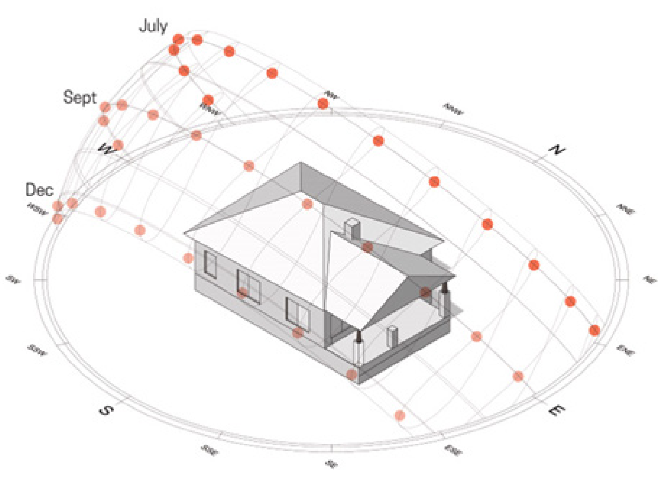



Figure 3: Sunpath diagram study of 588 James P Brawley Dr, Atlanta, GA

### 1.1.5 BUILDING SCIENCE CONSIDERATIONS

The spaces and layouts are designed to make the best use of the living room in the north with lower incident radiation to provide comfort during the day and the bedroom in the south and west to capture heat and reduce energy loads for heating. We placed all the windows to allow cross ventilation. The size of the windows is reduced, and adding ribbon windows improves thermal comfort and allows daylight into the house's deeper spaces. East and west facades have larger windows as the porches shade them to allow better daylight and visibility to the outdoors. The roof is enclosed with a flat ceiling to act as a thermal barrier.

### 1.1.6 CODES

The applicable building codes for our project are as follows:

•International Building Code, 2018 Edition, with Georgia Amendments (2020) - (Effective Jan 1, 2020)
•International Residential Code, 2018 Edition, with Georgia Amendments (2020) - (Effective Jan 1, 2020)
•International Fire Code, 2018 Edition, with Georgia Amendments (2020) - (Effective Jan 1, 2020)
•International Plumbing Code, 2018 Edition, with Georgia Amendments (2020) - (Effective Jan 1, 2020)
•International Mechanical Code, 2018 Edition, with Georgia Amendments (2020) - (Effective Jan 1, 2020)
•International Fuel Gas Code, 2018 Edition, with Georgia Amendments (2020) - (Effective Jan 1, 2020)
•National Electrical Code, 2020 Edition, with no Georgia Amendments (Effective Feb 1, 2021).
•International Energy Conservation Code, 2015 Edition, with Georgia Supplements and Amendments (2020) - (Effective Jan 1, 2020)
•NFPA 101, Life Safety Code 2018 Edition with State Amendments (2020) - (Effective Jan 1, 2020) CODE INTERPRETATIONS

### 1.1.7 OCCUPANT CHARACTERISTICS

Based on our market analysis of the neighborhood, a family in English Avenue can comprise one of the three types (Percentages are out of the total residents of 3558):

1. Family of up to 4 people (21%)
2. Single parent with one/two children (33%)
3. Single person household (45%)

Our proposal is flexible for all family types, creating a dwelling unit that fosters homeowners' upward mobility and personal capital. The AMI distribution of the families in English Ave is between 50-80% who currently spend more than 30% of their monthly income on rent and close to 7% on utility. Estimating a monthly cash flow of their income helped us determine the possible monthly investments that the family can make towards home-ownership. Further reductions in utility would mean more savings for the family to invest in future improvements and foster a better quality of life. The flexibility of the layout caters to the different family structures and their modern needs.



Figure 4: Typical family structures

### 1.1.8 DESIGN GOALS

To achieve our goals of affordability, replicability, and high performance, the following systems were integrated:

•Passive design solutions (such as envelope design, volume division, etc.)
•Continuous thermal envelope with high insulation.
•Material reuse.
•Efficient equipment and appliances.
•Photovoltaic Energy.
•Indoor and outdoor flexibility (alternate use of bedroom 02 as a study room, multiple uses of backyard lawn)

### 1.1.9 RATING SYSTEM

We developed the retrofit to comply with the following benchmarks:

•Living Building Challenge 4.0 Petal Certification
•LEED 4.1 Platinum
•HERS Index = 44 (w/o PV), -1(with PV)
•Life Cycle Assessment = Grade A

### 1.1.10 ENERGY AND WATER TARGETS

To achieve efficiency targets, we used a step-by-step methodology to reduce the energy footprint of the building as much as possible before the introduction of photovoltaics. We introduced rainwater harvesting and greywater recycling to offset potable water consumption for irrigation to flush fixtures.

- R-25.8 (Wall), R-6.2 (Crawl Space Wall), R-60 (Roof)
- Improved the air tightness of the existing, leaky façade to 1.0 ACH
- Windows: U-value = 0.27 Btu/h.ft2.F, SHGC = 0.21, VT = 0.49
- Annual Heating Demand = 4.952 KBTU/ft2.yr, and Cooling Demand = 1.379 KBTU/ft2.yr
- Selection of efficient HVAC and lighting systems
- 6kW PV system with 15 400W panels
- Net-zero Energy target was exceeded by achieving a net-positive energy house
- Rainwater harvesting potential = 26,205 Gallons/yr, underground cistern size = 6,000 Gallons

### 1.1.11 OCCUPANT EXPERIENCE

Our goal is to directly translate concerns that occupants in English Avenue face through a multifaceted planning approach that forms a synergy between their various objectives. Affordability is an important aspect that is interlinked to the occupant experience goals of our project as a way of easing a users' mind. This includes decreasing the risk of moisture or air infiltration through flashing, where occupants are ensured low maintenance costs, comfort, and returned value on investments. To address privacy and security concerns, windows are situated at a designed height to draw the blinds at the eye level while receiving daylight from the panes located at a higher level. This serves as a mode of natural lighting to improve mood and experience and regulate circadian rhythms for better sleep/wake cycles. In addition, covered exterior spaces offer privacy and, at the same time, allow the users to spend time outdoors while feeling secure. Efficient appliances that serve multiple purposes and are self-sufficient decrease maintenance and thus improve user experiences.

### 1.1.12 OPERATIONAL COSTS

By combining strategies including high-performance weatherization and the installation of photovoltaics, the project achieves net-positive Energy and reduces the annual expected electricity bill from $883 to $0. In addition, although this is an energy-focused competition, we felt that reducing the water and sewer utility burden was critical to achieving our project goals for an underserved community. Toward that end, implemented rainwater harvesting and greywater recycling from shower and bathroom lavatory water streams for flush fixtures use and irrigation use. Using the USGBC's LEEDv4 calculators for indoor and outdoor water use, we ascertained a 41.73% reduction in potable water consumption that, in the case of both water and sewer fees, pushed the project into a much more affordable category within the rate structure. Anticipated annual water bills were reduced from $321.94 to $174.74 (45.72% savings), and anticipated annual sewer bills were reduced from $699.99 to $362.23 (48.25% savings). To summarize, annual anticipated utility bills have been reduced by $1,367.45 representing a total utility cost reduction of 71.8%.

# CHAPTER 2 CONTEST NARRATIVES

## 2.1 ARCHITECTURE

### 2.1.1 SITE CONTEXT

The house is located in the English Avenue neighborhood in Atlanta, Georgia, on James P. Brawley Drive. The area is surrounded by major roads and railroad lines, putting it in close proximity to downtown Atlanta while separating the two at the same time. There is currently a house sitting on the lot adjacent to it on the south with a vacant lot on the north. It is anticipated that the lot on the right will be developed into a single-family home. This historic neighborhood was purchased in the 1890s and contains over 100 years old houses. It faced a series of unfortunate events beginning with neglect in the 1930s due to redlining, followed by the recession and disinvestment in the 1980s. The steady decline continued in the neighborhood; currently, 44% of homes are vacant, and a significant number of these majority single-family houses are in poor condition. Our proposed house is surrounded by several vacant homes and is close to the old English Avenue Elementary School, closed since 1995. While buses run through the neighborhood, many amenities are not accessible by walking. Since the early 2010s, English Avenue has attracted the attention of several investors and community members who grew up there and are making efforts to rebuild it, paving the way for future revitalization efforts to bring back its dynamic community.

### 2.1.2 ARCHITECTURE CONTEXT

Our proposal uses design to optimize energy performance while still considering the vernacular architecture of the neighborhood. The main focus of this 946 square foot house is the roof. It has been transformed into a single roof with a lean to hip roof in the front and back porches which is one of the main aspects defining the architectural language of the neighborhood. The simplified geometry of the roof allows for solar panels to be placed in an optimum position on the south side and allows for proper collection and drainage of rainwater. For decades, English Avenue has been a porch community, focusing on community engagement and interaction. Our design recaptures and redirects the attention to the front porch as a place for socializing and gathering. By installing a ramp, redecking, and adding vegetation, the porch is reactivated and accessible to people of different ages and abilities. The house is wrapped in pale yellow wood siding with metal frame windows, matching it with the colorful English Avenue homes. The interior is split in half along the east-west direction, with the bedrooms and bathroom on the south side and the dining, living, and kitchen on the north side.

The more communal activities in the house have an open plan with no disruption with partitioning only in the more private side. There is a main bedroom accompanied by another room that can be used as a secondary bedroom or home office, allowing for flexibility of use for resident types. A back porch has been added as another space for socializing and gathering, with room for a grill and a backyard to host a range of recreational activities.

> Optimize energy performance while considering vernacular architecture and contemporary needs

Our philosophy in the design of this home was to follow Raymond Loewy's MAYA Principle. Loewy is referred to as the father of modern industrial design and the streamlined modern aesthetic. He believed that the American public generally believed in the value of technology and its ability to enhance their lives but noted that products that looked too high-tech and unfamiliar often frightened consumers. Thus, the MAYA Principle: "Most Advanced Yet Acceptable." In the case of our home, to make it acceptable to the market, we've taken a high-technology, high-performance building and cloaked it in the vestiges of a very comfortable and traditional 102-year-old house form. This is the MAYA Principle in action. It is even more important given the high likelihood that most of the homeowners in our target demographics will have had less extensive exposure to technologies like photovoltaics or even smart thermostats. Therefore, we feel our design philosophy is critical for accepting and absorbing these technologies central to net-positive energy homes in the English Avenue community.

## 2.2 ENGINEERING

### 2.2.1 STRUCTURAL SYSTEM

We are motivated to archive the aftereffects of a visual investigation directed at 588 James P Brawley NW. This was a visual examination, and the inferences in this report are based on the findings onsite corroborate educated estimations. We inspected the home's structural components to assess if these elements are performing at the expected capacity or if they need a prompt retrofit. The essential load-bearing components considered are the foundation, wall, second floor, and roof framing. Level readings were taken on the ground and different floors and were considered significant to assist with the evaluation. We did not investigate inside the establishment's unfinished plumbing for security reasons. The state of the subfloor outlining on this house needs addressing for the most part, and we noted plant outgrowth from within the walls.

**Preliminary report**

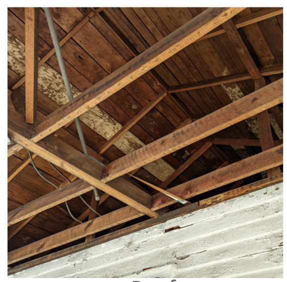
**Foundation**

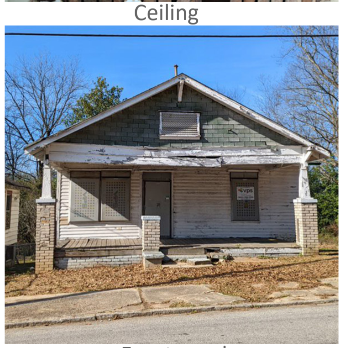
**Inspection 1:** There was a clear foundation settlement in the west part of the building. Measuring from the corner post, @ 10' is where the settlement starts. Although it is just 1.56" at its settlement point, it is essential to check the foundation's condition. At the south/back part of the building's highest settlement point is 3.23". This settlement was created because of faulty plumbing that led to moisture exposure to the foundation, leading to the formation of cracks and subsequent settlement. The eastern part of the building is perceived as in pristine condition, but there is a settlement at the junction post where it meets the northern part of the building. There was clear moisture infiltration by the soil around the foundation, and it had started to affect the subsoil structures. This can lead to further repairs and costs. The stairs coming out of the kitchen to the backyard were unstable and would need to be demolished.

**Inspection 2:** The second inspection was inside the foundation, thanks to our industry partner Westside Future Fund. There is an entrance to the foundation from the southern part of the building. Currently, it is home to the HVAC system installed in the house. The pipes and remnants of the system are currently present in the foundation. The foundation is a pier and beam where the house has retained its original brick piers and wooden beams. The inspection revealed what was previously suspected about the foundation settlement. It also revealed masonry errors in fixing up the foundation. The foundation had some obvious settlement problems. The major settlement was in the western and southern parts of the building. The foundation consisted of masonry piers (74" c/c) with stem walls made of concrete blocks connecting them. Going towards the north side of the building, the crawl space decreases in height. The floor resting on the block piers was a wood joist construction. Although there was no visible moisture infiltration or damage to the floor, there might be a possibility of dry rot because of the old construction. Apart from the masonry piers in the perimeter, wood piers supported the floor at critical junctions, i.e., corners and entrances/exits to rooms.

**Conclusions:** The foundation needs to be lifted by anchors in a total of 11 places in the western (4), southern (4), and eastern (3) parts of the building. There is also a need to clear all old systems out of the crawl space. The crawl space needs moisture treatment as there are increased levels of water seepage throughout the perimeter. The wood joist floor will need further inspection and lab testing to accurately evaluate moisture damage. Any additional piers added to the foundation would require steel shims and dampers to counter any future foundation settlement. There is water standing or running alongside the foundation as the neighborhood seems to be flood-prone, and there are not enough slopes provided around the foundation for it to be a natural waterway. A sloped area around the foundation will help minimize water infiltration into the foundation, hence increasing the life of the structure. Extreme care needs to be taken by the contractor when taking out the existing settled foundation walls.


Ceiling


Roof


Front porch


Crawl space

Figure 5: Existing condition of the house

**Walls and Roof**

**Inspection 1:** The initial inspection clearly showed signs of disintegration in the southern parts of the exterior façade. One of the key elements is that most of the external siding was found to be bowing. This, accompanied by the paint coming off most of the siding, added to the concerns regarding salvageable materials. On the western part of the façade, there was significant weed growth going all the way to the roof and foundation outside the bath. There were clear holes around the areas of the win dows on the eastern side of the building, which created an energy liability. Ceiling joists and roof joists seem to be in excellent condition except for the northern part of the building. There are some joists with visible water damage.

**Inspection 2:** The second inspection was to check the inside conditions of the walls. The construction of the interior walls was plaster and lath. Although there were some visible holes, plaster and lath are easily replaceable materials. The holes gave an opportunity to check the quality of the wood studs. Wall studs were in pristine condition, which was a relief considering other retrofit challenges. The only concerning part of the inspection was the broken electrical plugs and switches in the living and dining rooms. The plaster and lath on the ceiling have gaping holes in the dining room and bedrooms. Although this can be replaced, there is an urgent need to check for the condition of the rest of the plaster lath roof.

**Conclusion:** The exterior siding needs to be replaced. It can be reused to make furniture for the house. Certain sections of the interior need to repair by changing the lath section. It is highly recommended to have a fresh layer of plaster. A change of 60% plaster lath from the damaged corner for any room with a damaged area of more than 20% of the total area. Electrical wires need to be safely boxed, and the location of boxes (outlets) needs to be marked for future reference. Salvageable wood siding can be used to make furniture and outdoor chairs for the front and back porch.

## 2.2.2 BUILDING ENVELOPE AND MATERIAL SELECTION

The building envelope in its current condition needed a lot of additions and modifications. Starting from the foundation, there were clear indications of the settlement. Using anchors, building new concrete piers, and reconstructing the foundation wall at the culmination of the southern and western façade will immensely improve its service life. Retaining the wood studs and the framing of the house and building on it created an avenue of a classic retrofit condition. The plan of retaining a larger portion of plaster and lath led to an exterior expansion of the wall. The introduction of rigid insulation and thick dense pack will lead to a tighter distinction between the outside temperatures and inside temperatures while vapor barriers keep the moisture away from the oddly frequent Atlanta rain. Keeping the roof joists, plaster, and lath in the ceiling that is in good condition, it is advisable to have a layer of zip sheathing and vapor barrier before applying the loose-fill insulation. Essentially, what is happening is the creation of a conditioned box with insulation on all sides. The reason for using cellulose insulation is the number of recycled materials it contains and since this model needs to be replicable it is extremely important to keep things inexpensive. In this case, it does quite well. One of the other advantages of using cellulose insulation is that it has a Class 1 fire rating. Since it is a retrofit, most of the structure is retained, addition to it in form of insulation or structural members helps in improving the energy consumption of the house. Another way to improve energy consumption is using energy star cool roof shingles to limit the amount of induction in the house. The use of PV on the eastern roof enhances the energy balance of the house.

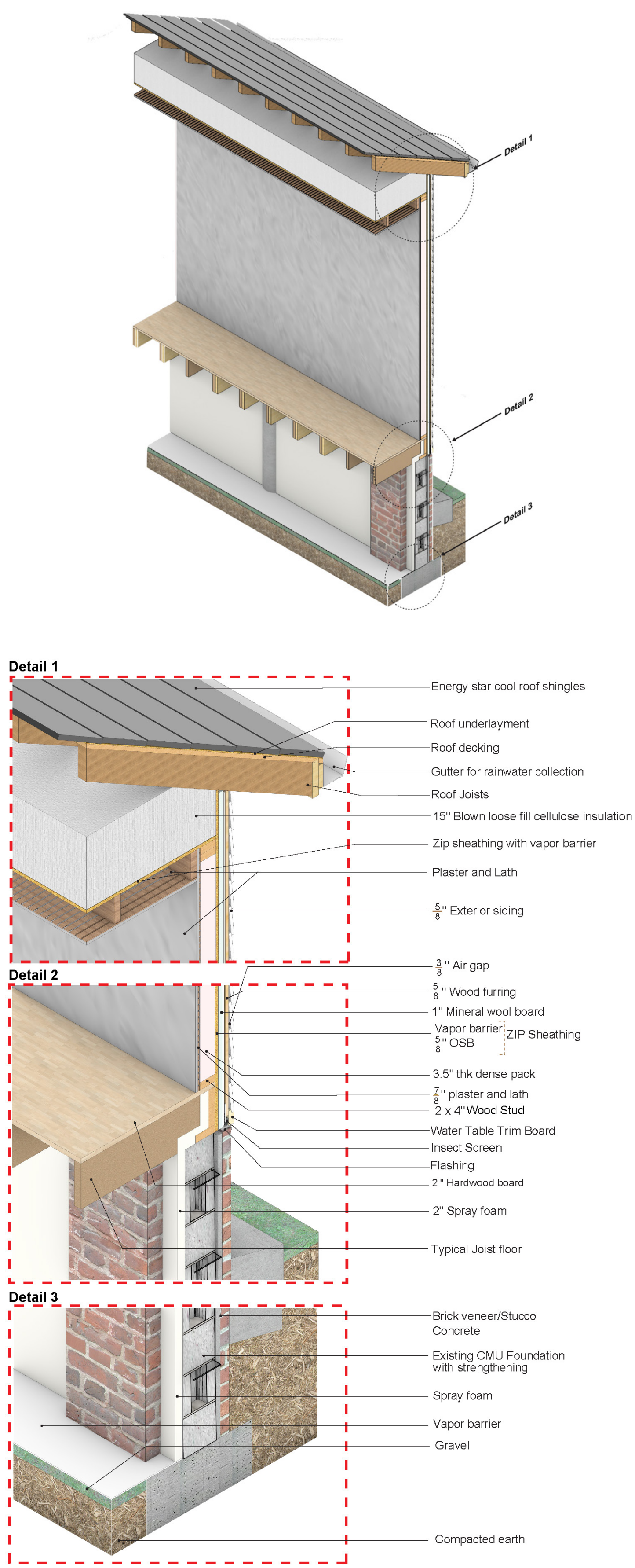
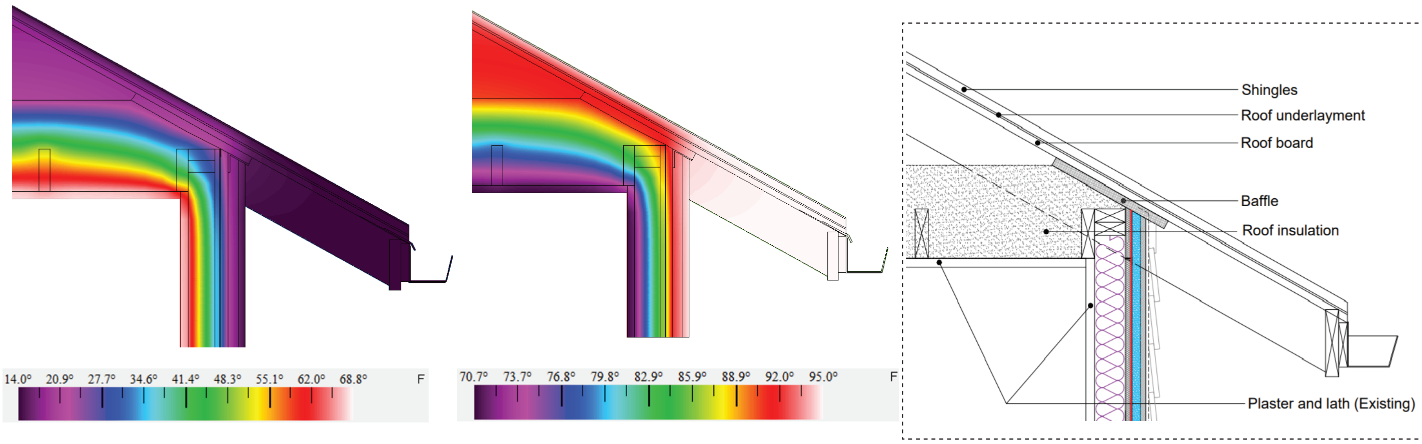
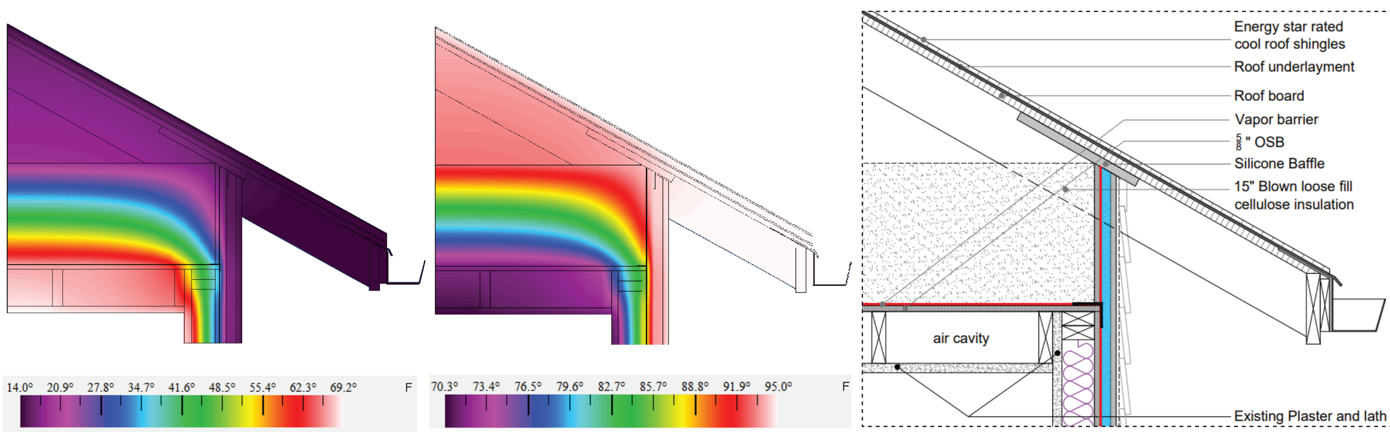


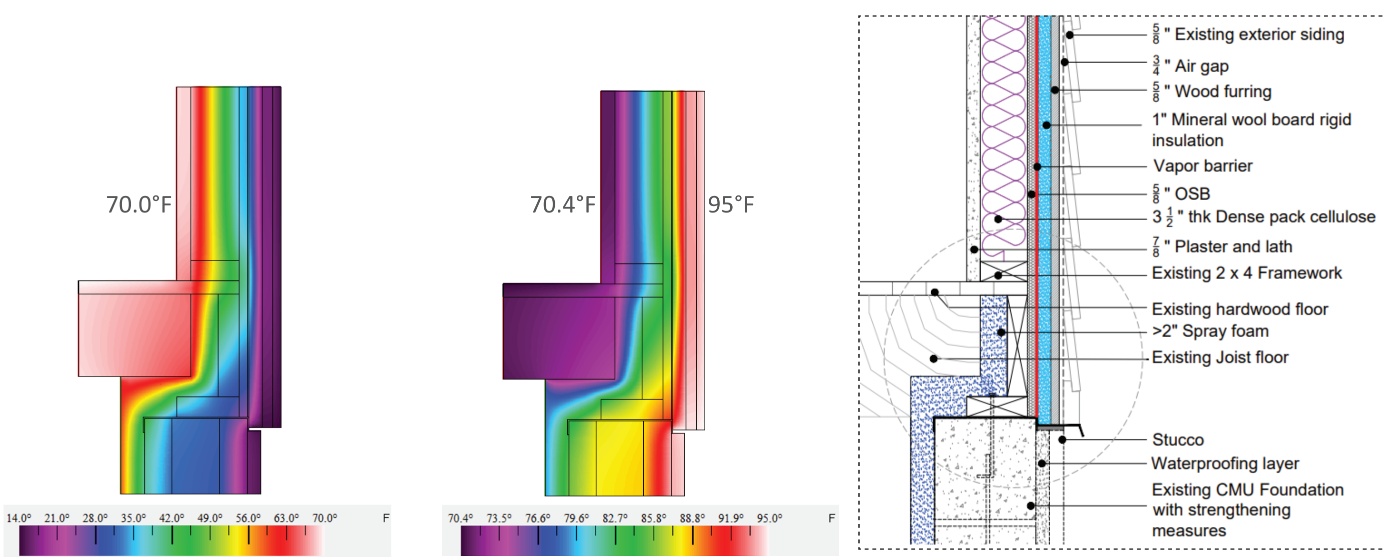

Figure 6: Typical wall section showing material assembly




Minimum code compliant roof thermal performance




Proposed roof thermal performance




Proposed foundation and wall junction thermal performance

Figure 7: THERM analysis of roof and foundation junctions

## 2.2.3 SYSTEMS

**Greywater Reuse and Rainwater Harvesting System**

Objectives

Currently available technical specifications are intended for new developments in the English Avenue neighborhood. They specify the design, installation, commissioning, operation, and maintenance requirements of greywater reuse and rainwater harvesting systems and are designed to ensure the effluent is fit for practical purposes and presents no undue risk to health.

The potential uses of greywater after treatment are:

- Drip Irrigation
- Toilet Flushing
- Sprayed Irrigation (Maximum. Safety)
- Water Features
- Fire Fighting

In this case, the sources of greywater are as follows:

- Washbasins
- Baths
- Showers
- Laundry Machines

**Greywater Collection**

The greywater from the sources mentioned above is collected and brought to a cistern, after which it goes for further filtration until that water can be reused again. Most of the cisterns in the market are made of High-Density Polyethylene (HDPE). In this case, the cistern needs to be submerged 3/4th in the ground with the option of removing it from its case. This allows for periodic inspection and maintenance. It is essential to check for leaks/sludge build-up every 6 months. There is also a need to cover the tank. That cover needs to be sealed or locked to avoid any accidental entries. Sewage backflow prevention is one of the main challenges to be aware of in submerged tanks. A valve usually is the cheapest and most effective alternative to check for backflow. It is recommended to have an air outlet in the main tank to give the toxic air build up within it. The rainwater and greywater will be collected in one tank, i.e., both will go through a similar process.

**Rainwater Collection**

With a catchment area of 1700 sq. ft. and a potential of collecting >20,000 gallons of water over a year, it is essential to have a detailed plan for rainwater collection. A covered duct to collect the rainwater makes it easier for the system's performance. The sieve of the covered duct should be no less than 5mm in diameter. This creates a steady flow of water into the duct while clearing debris.

**Treatment**

The collected water then goes through 4 processes:

- Pre-treatment
- Aeration
- Filtration
- UV Disinfection

Pre-treatment: This process is about filtering out particles bigger than 4mm2. This means particulates such as hair, debris, leaves, etc., will be filtered at this step. The treatment consists of letting the water through 4 sieves of varying capacities. The smallest one has a spacing of 2mm. All these sieves are self-cleaning to avoid regular maintenance and constant upkeeping. There is an option of using a grease trap for fluids with a higher viscosity than water, but the next step is using a biological aeration filter, which serves a similar purpose.

Aeration: Aeration filters out any organic matter in the water. It gets rid of microorganisms, petroleum-based aliphatic compounds, and complex hydrocarbons. Basically, after this, if the treated water is sitting idle, it won't smell.

Filtration: Although microorganisms have been removed from the water, there is still a possibility of smaller dust particles or any build-up being present in the water. In that case, a sand filter is the best solution. It requires less maintenance and is less costly than other alternatives, including mechanical and membrane filters. An ultrafiltration system after the sand filter can help decrease the possibility of a lot of bacteria and viruses passing through. Ultrafiltration systems have a pore size of around 0.01 micron. This would put less stress on the next process, which is the disinfection.

Designed to meet competing goals of performance and affordability

UV Disinfection: Disinfection essentially removes any remaining sediments of particles that can be harmful to consume. There are alternatives to UV disinfection, such as chlorine disinfection, but that requires significant human intervention, and since this whole system needs to be self-reliant, it is advisable to go with UV disinfection. There are not a lot of residues that remain after UV disinfection, so it is recommended to go through this process twice. Otherwise, the treated water needs to be used immediately.

Other Systems – At the end of the system's processes, treated water diverts into two lines, one going back to the house for reuse and the other in the backyard for drip irrigation. It is highly advisable to have pumps and small water collection tanks to check for overflow at regular intervals. The overflow tank goes into the ground to replenish the water table. Pumps should be chosen such that they can overcome the friction losses of the fluid in all systems. Since there is a high chance of infrequent water supply in the system, the level valve and pump should be set for a steady supply without the pumps switching on and off continuously. All components need to be securely fixed and provide ease of reach if they need maintenance or replacement.

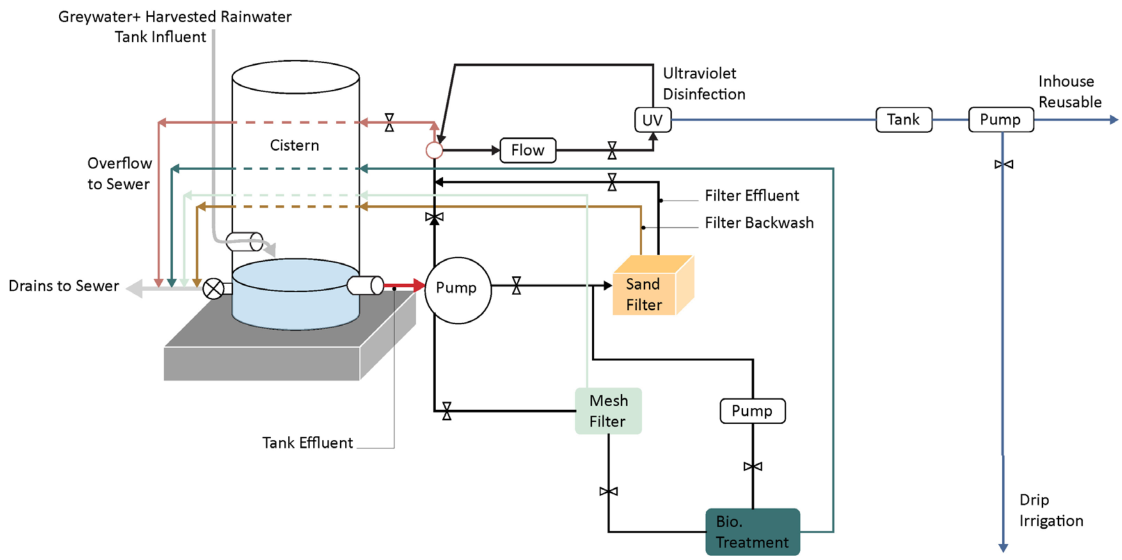


Figure 8: Process flowchart for geywater reuse and rainwater harvesting systems

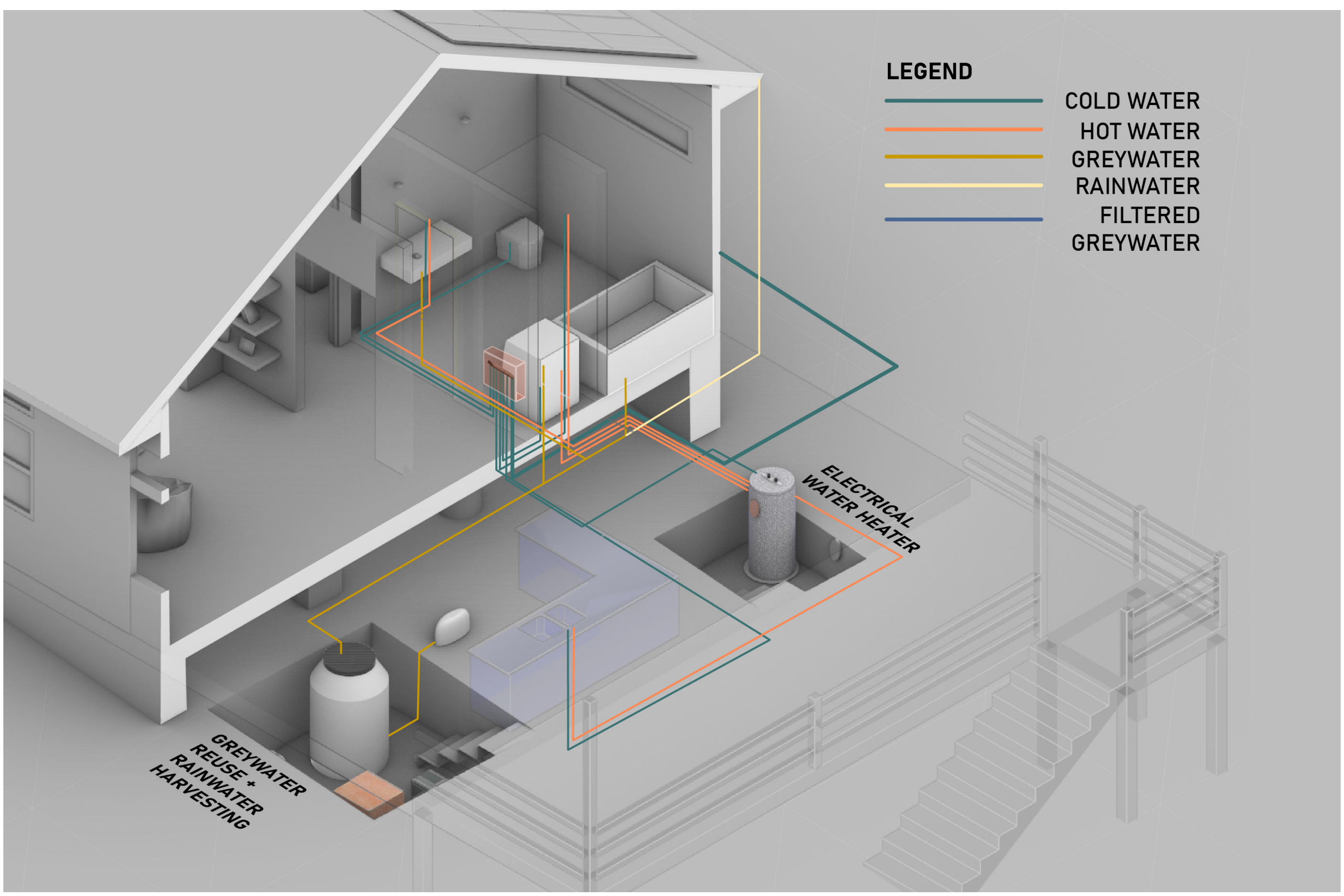


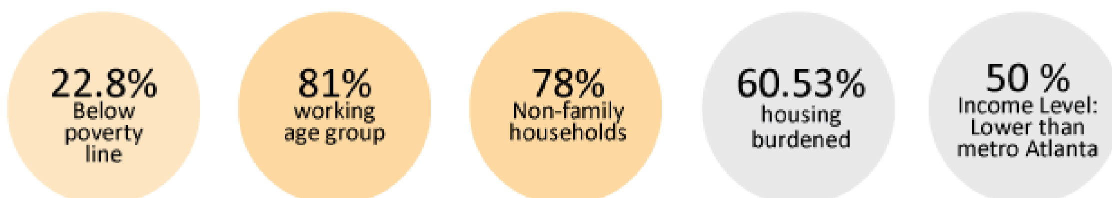
Figure 9: Greywater reuse and rainwater harvesting system

## 2.3 MARKET ANALYSIS

### 2.3.1 CURRENT MARKET ANALYSIS AND EXPECTATIONS

A review of the Census data for the tract encompassing the English Avenue neighborhood quickly depicts the existing community's composition. Per capita and median incomes are both approximately half the Metro Atlanta average, 22.8% of residents live below the poverty line (10% above the Metro Atlanta average), and 81% of residents are working age (18-64) (20% higher than the Metro Atlanta average). When you couple that with data showing that 78% of residents are either non-family households or female-led households, which is about 1.3 times the Metro Atlanta average, it becomes clear the English Avenue neighborhood is uniquely positioned as one of Intown Atlanta's enclaves of housing for essential workers.

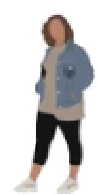
But the neighborhood is under threat. According to CitiBank's City Builder, 60.53% of residents are housing burdened, spending more than 30% of their household income on their mortgages and rents. Indeed, a cursory review of the housing comparable to the chosen house (102-year-old house, 946 square feet, 2 bedrooms, 1 bathroom) available on the west side reveals an average market rate of $315/sf, which would equate to this house having a market rate price tag of $299,880, which is well above the $232,800 maximum affordable price for a two-bedroom house at 100% of Area Median Income (AMI). In addition, it is important to bear in mind that this neighborhood's income levels are half the Metro Atlanta average and that housing costs in English Avenue are likely higher than the west side average due to gentrification pressures from the anticipated construction of a new 'tech giant' campus in the nearby Grove Park neighborhood. Therefore, first and foremost, the main charge of this project is to carve out enough affordable housing within the community to guarantee English Avenue can survive into the future as a diverse, mixed-income neighborhood




English Avenue at glance

**AMI 50-80%**

Ray (28) is a fire fighter at Atlanta Firehouse #16 and Tamika (26) is an elementary school teacher for Atlanta Public Schools at Herndon Elementary School. Together, they have a household income of $109,476 (127% AMI). They have a toddler, Ray, and Tamika is still paying off the last of her student loan debt.



Kia (40) is a construction worker who works with a local builder in Vine city, another Westside neighborhood. She got married recently and currently earns about $44,820 a year (52% AMI).

| Resident | AMI | Monthly income | Taxes | Rent | RI | Utilities | Comm. | Transport | Food | Leftover |
|---|---|---|---|---|---|---|---|---|---|---|
| Ray & Tamika (Family of 4) | 127 | 9123 | 1368 | 1552 | 25 | 250 | 150 | 750 | 800 | 4227 |
| Kia (Single person HH) | 52 | 3735 | 560 | 1294 | 25 | 150 | 100 | 500 | 350 | 756 |
| Sonja (Single parent) | 68 | 4885 | 733 | 1294 | 25 | 150 | 100 | 350 | 300 | 1933 |
| Kofi (Single person HH) | 83 | 5961 | 819 | 1552 | 25 | 210 | 100 | 250 | 250 | 2755 |

Sonja (31) is Registered Nurse at Grady and a single parent of two (Rico – 5, and Carmen- 6) who just moved to Atlanta. She makes $58,620 a year (68% AMI) but struggled to find a house she could afford ITP.

Kofi (22) recently graduated from college and is making $71,541 (83% AMI) a year as an entry level programmer working at a financial technology startup.

Figure 10: Residents monthly cashflow

## 2.3.2 FINANCIAL FEASIBILITY AND AFFORDABILITY

In order to meet the affordability challenge, we felt it critical to build upon the existing work of Westside Future Fund, a non-profit that represents the neighborhood's interests in trying to help protect and build a diverse, multi-income, livable community. The typical Westside Future Fund (WFF) project is built for $320,000, including land and vertical improvements, using a mix of 50% equity and 50% low-interest financing. When Westside Future Fund completes construction, they identify potential homeowners and offer them a package of down payment assistance that includes up to $90,000 that includes $10,000 from the Atlanta Housing Authority, $20,000 from Invest Atlanta, and $33,000 from a recent New Markets Tax Credit grant that WFF has secured. While WFF's program has been highly successful, it's important to note that even with the homeowner subsidies made available, the cost of these homes still exceeds most affordability criteria used by most affordable housing advocates. Part of the problem lies in that WFF's model includes both the house and the underlying land in the real estate transaction. A review of the tax assessments of some of the older homes on the same block as this project's subject property reveals that the underlying land is worth anywhere from 42-49% of the overall assessment. And while it is true that a renovated property may have a ratio of land less than that of those legacy properties, the problem is still clear. To maximize, dollar for dollar, the quality of the vertical improvement in a low-income community, one approach is to get the land out of the real estate deal. We want our homeowners seeking afford able housing to use their limited dollars to pay for their house, We want our homeowners seeking affordable housing to use their limited dollars to pay for their house, not the dirt it sits on.

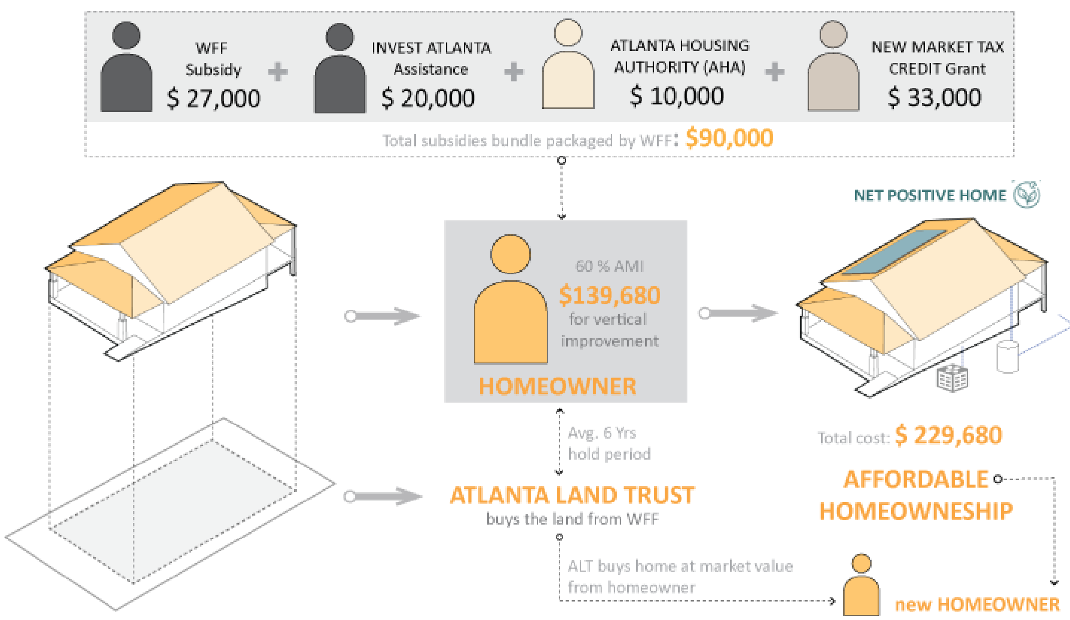



Figure 11: English Avenue affordable home financial model

To that end, we propose taking the 588 James P. Brawley property and selling the underlying property to Atlanta Land Trust to attach its typical affordability deed restrictions and covenants to the renovated house and enroll it into Atlanta Land Trust's stewardship program. Community land trusts have been around in the United States for approximately 50 years and help promote affordability by decoupling the cost of housing from the underlying value of the land. This is achieved by the community land trust splitting the land from the vertical improvement built upon it and then offering to sell the home only if the homeowner agrees to pay a modest monthly ground lease and to the land trust's deed restrictions and covenants, which enshrine long term affordability into the legal framework of the real estate transaction. This iteration of the Atlanta Land Trust was relaunched in 2018, and the typical Atlanta Land Trust house is offered at 80% of AMI, which for this house would be a maximum list price of $186,240. In exchange for their monthly ground lease payment, homeowners also benefit from Atlanta Land Trust's stewardship fund, which assumes all major operations and maintenance expenses for the property, such as periodic re-roofing or the periodic repair of building HVAC systems. When homeowners are ready to move on, which typically occurs after an average hold period of six years, the land trust's covenants stipulate they are allowed to list the property for its original purchase price plus 25% of the difference between that original purchase price and the prevailing market rate, with the homeowner allowed to keep that difference as their share of the equity.

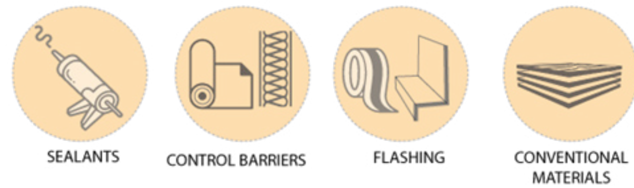
The program creates an excellent entry-level mechanism for households where they can secure an affordable home while also gaining access to the land trust's stewardship fund, which handles all of the home's major maintenance costs. Additionally, the underlying covenants of the land trust reduce the annual property tax assessment on the homes, thereby further reducing the cost of ownership. Atlanta Land Trust also requires homes to meet min imum sustainability and efficiency criteria by achieving certification in programs such as Southface's regional EarthCraft program, which reduces utility burdens. Overall, the land trust program helps low-income households grow a nest egg so that they can eventually step up to market-rate housing or for their other financial goals, whatever they may be.

With the home entered into the land trust program, we consider all of the home's purchase price at 60% AMI of $139,680 to be a reasonable assumption as a construction budget. This is not sufficient to build even a bare-bones affordable home, so to reach the performance goals prescribed by the Solar Decathlon, we needed to secure additional capital by repositioning Westside Future Fund's existing subsidies. That $90K in subsidies ultimately gives the team a budget of $229,680 or over $243/sf with a 10% contingency of over $23K that, if unused, can be moved back to the homeowner's side of the ledger as additional down payment assistance and push the cost of the home down to the 50% AMI level at $116,400. This utilization of Atlanta Land Trust's community land trust model and the existing subsidy and capital streams of Westside Future Fund is how we manage to thread the needle of building a high-performance, net-positive energy building that is still affordable at 50-60% of AMI. And because these are two existing, well-established, and reasonably well-capitalized non-profit programs, and our subject house was specifically selected because it is typical of the west side of Atlanta, this model is potentially scalable and replicable.

The house is affordable at 60% of AMI and lowers utility bills by over 72%

### 2.3.3 APPLICATION OF MARKET-READY CONSTRUCTION MATERIALS

We see "Market-ready" as an approach to training the local construction workforce to employ high-performative building technologies to their existing construction practices. Most of the materials proposed can be procured within 350 Miles and can be executed by the local construction team, with the necessary training for performance measures. Some of the aspects include materials that act as control barriers. The investments toward these components are returned with utility savings over the payback period.




### 2.3.4 LIFE CYCLE COST COMPARISON

Methodology: To determine the additional first cost investment in the home, we compared the cost per square foot of our project against the average cost per square foot of a typical Atlanta home as reported by construction consultant Cumming Insights.

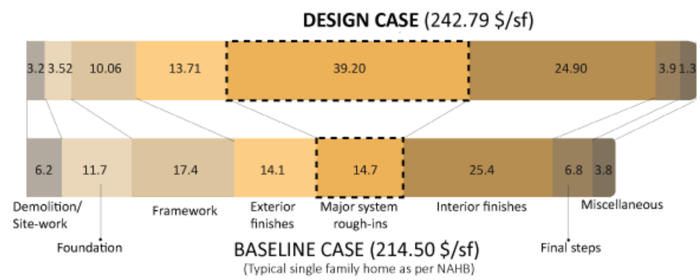


Figure 12: Cost comparison for baseline and design case

The delta between the two, when applied to the square footage of the home, we can reasonably assume is equivalent to the additional construction cost needed to make this a high-performance home.

We then used our calculated energy, water, and sewer utility savings for year one and the average inflation rate from the past 20 years (3.1%) to ascertain the payback period for that additional investment before additional operating expenses.

For operating expenses, the design and baseline case homes are largely similar with the exception of three areas: additional HVAC filtration for improved indoor air quality, a PV system, and water conservation systems. We accounted for those additional operating expenses at current rates and added them to the payback period calculation as an offset to the utility savings.

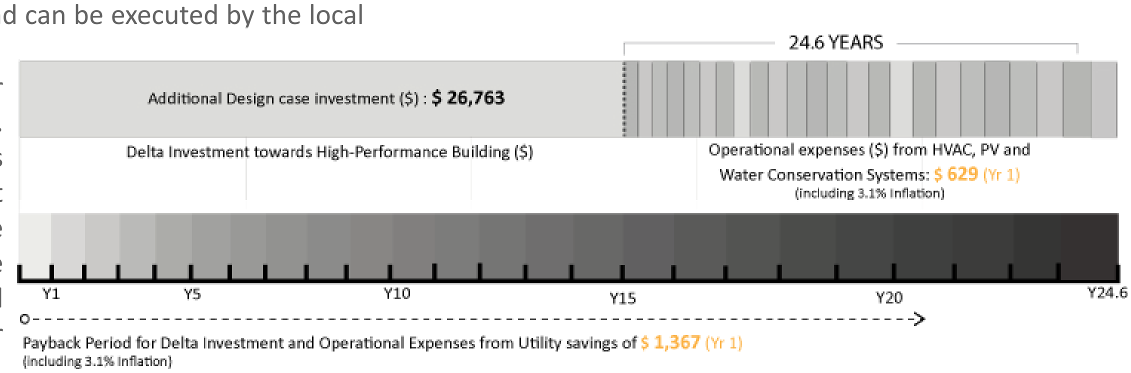


Figure 13: Life Cycle Cost and payback period for additional investment on net positive home

## 2.4 DURABILITY AND RESILIENCE

### 2.4.1 STRUCTURE

With the improvement in the foundation walls and adding concrete piers, the house stands as a great example of settlement repair. This increases the chances of the house being against wind loads. Since this area is prone to flooding, it is suggested to add a curb around the perimeter of the house to prevent any future damage to the foundation in case of extreme flooding. This is in addition to the sloped pavement grass pathway leading up to the backyard. This pathway keeps the water away from the foundation while installing an erosion control method. The PV panels ensure a consistent amount of electricity passing through the house even during power interruption situations. Every system has its manual override switch. This becomes extremely important in case of power outages. The greywater reuse and rainwater harvesting system will ensure the normal functioning of the water facilities in case the municipal water system is terminated due to maintenance or a calamity. Given the high volume of annual rainfall in Atlanta, our team has prioritized best practices in waterproofing detailing and has specified the validation of all waterproofing assemblies with performance testing before turnover to the homeowner. This includes careful detailing of building openings such as the inclusion of metal pan sill flashing at all windows and the proper transitioning of flashing, waterproofing membranes, and building wraps through out the building enclosure. In addition, we are requiring AAMA 501.2 water nozzle testing to be performed on an in-situ mock of one of each type of window and door assembly. Once the mock-up has passed testing, validating the General Contractor understands the proper installation procedure, the remaining windows and doors may be installed. Afterward, additional water nozzle testing will be performed to ensure all windows and doors are watertight. In doing so, we will address and remediate any issues with bulk water and its downstream impacts on durability and indoor air quality before a homeowner ever steps foot in their new house. The backyard of the house has the flexibility to host the members of the community which results in increased interactions and a strengthening bond in the community.

### 2.4.2 MATERIALS

The project's material selection focuses on lower embodied energy and environmental impact in terms of global warming and ozone depletion potentials (GWP and ODP). Apart from these characteristics, emphasis is also given to selecting materials from manufacturers with sustainable production practices. The list of materials considered for the project in different areas as a part of the retrofitting proposal is as follows:

| Location | Product Name | Product Type | Product Features |
|---|---|---|---|
| Foundation | FOAM-LOKTM 2000-4G closed cell spray insulation | Closed-cell spray foam | Extremely low GWP, Superior air-sealing performance, long term durability. |
| Wall Assembly | ZIP System wall sheathing | Mineral wool board | One less building material (integrated WRB) has superior air sealing performance. |
| Ceiling | AFT Carbon smart loose-fill cellulose insulation | Dense pack cellulose | +23% improvement on ODP, +16% improvement on GWP, ease of installation. |

Figure 14: Material specifications

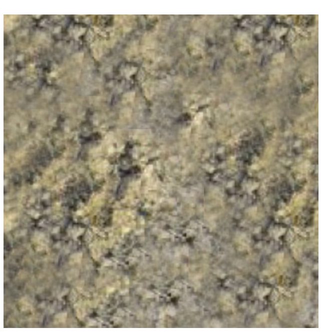


Figure 15: Dense Pack cellulose, Closed-cell spray foam, ZIP system wall sheathing

## 2.5 EMBODIED ENVIRONMENTAL IMPACT

### 2.5.1 LIFE CYCLE ASSESSMENT

While addressing the retrofitting proposal, our primary design goal was to reduce the overall embodied environmental impact at different project stages. We have considered a holistic approach by evaluating the embodied carbon from the production of materials, transportation, and construction to the end of building life. Our design proposal reduces carbon emissions from transporting materials to only 1.2%, whereas the construction installation phase accounts for 4.4% of the total carbon emissions. The end-of-life phase accounts for 9.3%, whereas the biggest contributor to the carbon emissions is the production of materials which account for 85.1% of the total emissions. Our retrofitting design proposal produces 18,821 kg of CO2 and contains 10,010kg of biogenic carbon storage. We achieved a score of 214 kg CO2e/m^2 and 19.90 kg CO2e/sqft, which falls in grade-A as per the Carbon Heroes Benchmark Program.

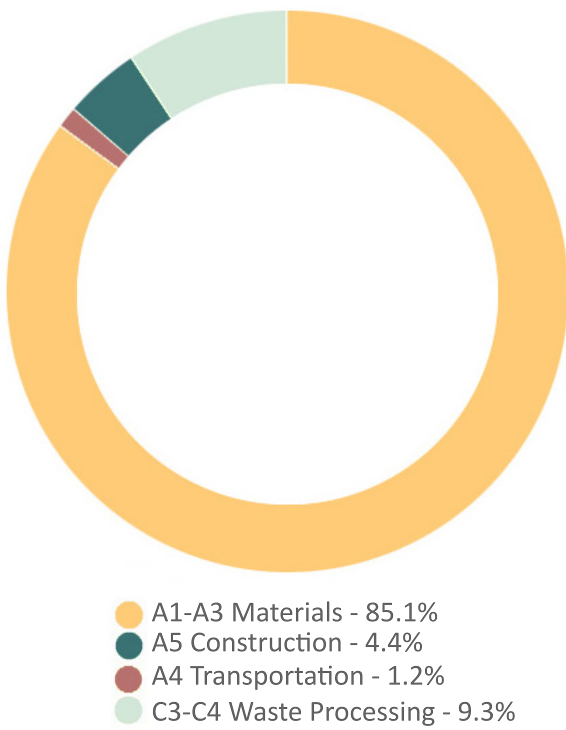



Figure 16: Global Warming kg $CO_2e$ - life Cycle Stages

### 2.5.2 DESIGN DECISIONS

The retrofitting exercise posed a unique set of challenges based on the initial site analysis. This resulted in developing a holistic approach toward formulating design strategies at both macro and micro levels. Some of the design decisions adopted as a part of retrofitting proposal involved addressing temperature, flood and drought mitigation, eliminating the use of toxic materials, and reducing the lead content in the soil.

Various passive cooling techniques have been incorporated into the design to lower mechanical systems loads for temperature mitigation. The design also incorporates the revival of the shaded porch at the house's entrance, apart from incorporating light colors on the exterior facades to minimize heat absorption. Strategic fenestration strategies have been adopted to facilitate ambient daylighting and cross ventilation in the habitable areas.

As a part of the low-impact development and green site infrastructure, the soil will be treated with a layer of a porous paving block with grass towards the rainwater catchment zone. The house's foundation will be protected by a 12" deep curb surrounding the house's perimeter to avoid future damage in the event of harsh weather conditions. This curb around the foundation will have a waterproofing layer and effectively keep the dampness away from the foundation. Reusing greywater for irrigation and toilet flushing will result in significant savings on water utility costs and will financially benefit the occupants, apart from saving water in general.

> Reusing the existing footprint and adding new materials with low ODP and GWP

As the structure was built a century ago, the toxic materials which are a part of the house in the form of lead-based exterior paint, lead pipes, and harmful insulation materials, which have been proven to cause different types of diseases and poisoning, will be removed as a part of the retrofitting proposal. This will improve the indoor comfort environment and health of the occupants.
The paints used on the house's exterior were lead-based paint and, over the years, have been scraped off and are now mixed with the soil. This has resulted in a 2 to 3-inch layer of contaminated soil, with the scrapped lead-based paint remaining on top. Since the soil is clay and not soluble, it might have a higher PH value. For these kinds of soils, there are effectively three methods for remediation will be adopted, which include Phytoremediation, Vitrification, and Soil Washing.

### 2.5.3 TRADEOFFS

In order to understand the potential tradeoffs, we refer to the Sankey diagram for the retrofit proposal, which indicates that materials have the highest global warming potential (GWP) out of all the components. To minimize the GWP, we focused on reusing the structural footprint and materials to the maximum possible extent based on their state. Furthermore, utilizing locally available materials and having a low GWP (e.g., dense-pack cellulose) and providing efficient systems.

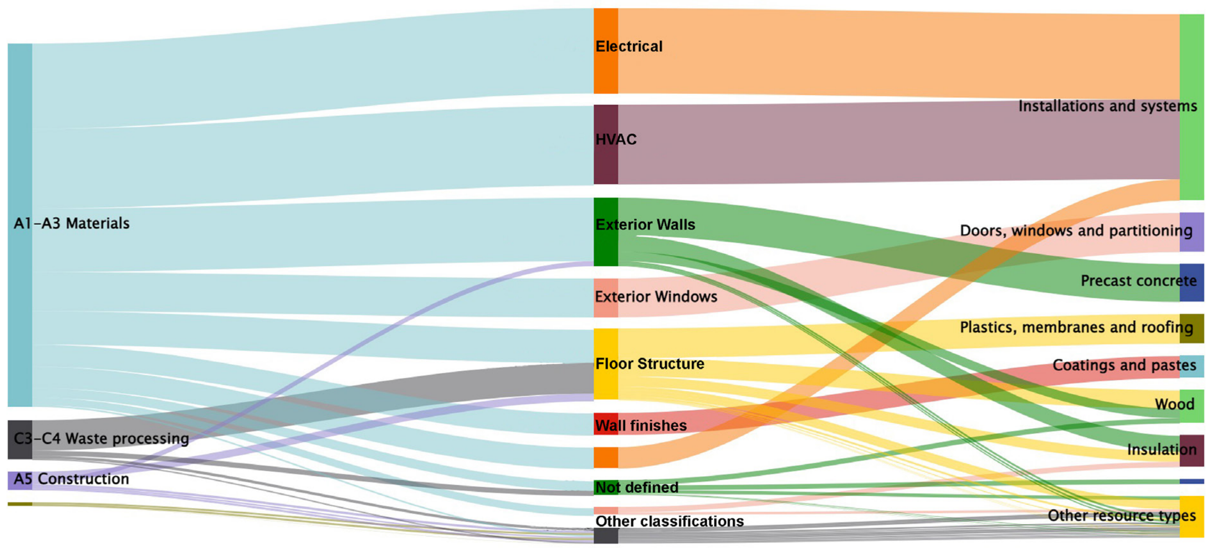



Figure 17: Sankey diagram of embodied carbon

## 2.6 INTEGRATED PERFORMANCE

### 2.6.1 INTEGRATED INTERDISCIPLINARY SOLUTIONS

The gabled roof is a part of the architectural identity of English Ave., so preserving it was a priority. By turning it into an unconditioned (vented) attic, the EUI dropped because there is no longer a direct heat gain through the roof and extending the sides of the roof to provide shading for the openings. This also provided the opportunity to insulate the roof better and reduce HVAC loads. We optimized the tilt of the roof to be exposed to high solar incident radiation, then adding PV panels facing the southern orientation to maximize the energy produced by the system. Furthermore, the roof also provides water for household users with the rainwater harvesting system. The roof is the centerpiece of the design in which it preserves the architectural identity, protects the house from solar heat gain, protects the windows from direct sunlight, creates a volume for insulation, and provides energy through the PV system and water through the rainwater harvesting system.

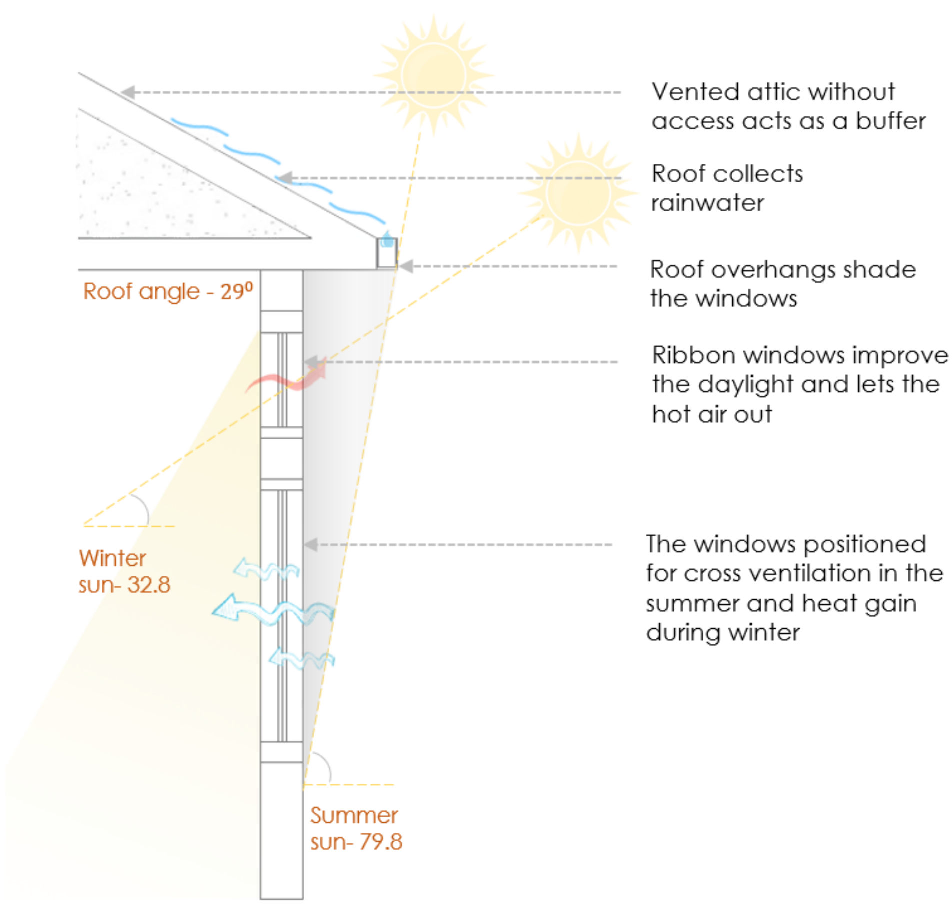



Figure 18: Passive design strategies

### 2.6.2 PASSIVE DESIGN STRATEGIES

Ribbon windows, famously noted for in the Villa Savoye, are taken inspiration from and are placed to enable privacy and, at the same time, formulate a daylighting strategy that paints a stream of direct and reflected light into deeper sections of the house. Selectively framing daylight designs helps in customization based on the type of climate. The sun angle is 79.8° in summer and 32.8° in winter in Atlanta. The roof overhang prevents the entry of direct rays and decreases concerns of overheating due to the summer sun. On the other hand, the winter sun is less harsh and is let in through the windows at eye level while controlling glare through blinds. These strategies maintain daylight

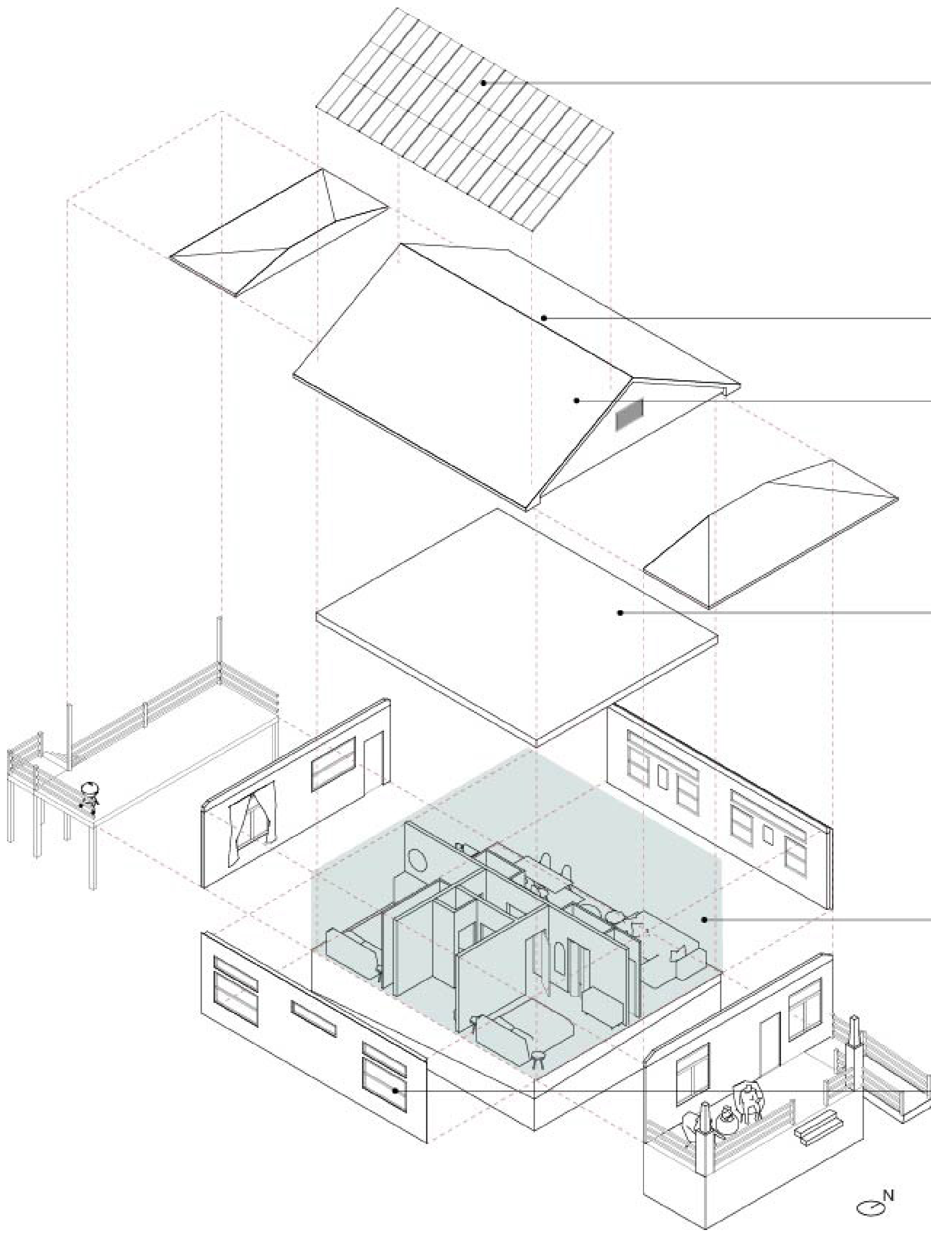



Figure 19: Integrated performance

quality and reduce electric lighting and cooling load demand. They also help improve daylight autonomy levels in the space to 72% and meet the illuminance target of achieving 300 lux and ASE being 6% which meet LEED recommendation. As the interior wall and ceiling are painted white they reflect light internally and improve visual comfort.

With the south and north-facing walls having overhangs that shade a large portion of the wall, the east and west-facing sides have covered front and back porches that allow for the design of larger windows on these elevations, thus increasing daylighting and blocking out glare. Additional to daylighting, these windows behave synchronously for cross ventilation during the summer months and heat gain during the winter months. Cool air is let in from the exterior to the interior and is heavier in weight and thus, settles in the lower region. Due to its lighter weight, the warm air transitions upwards through displacement ventilation and is eventually let out through the ribbon windows. This strategy is functional during the summer to keep the indoors comfortable and cool and decrease cost burden and dependencies on heating, air-conditioning, and ventilation systems.

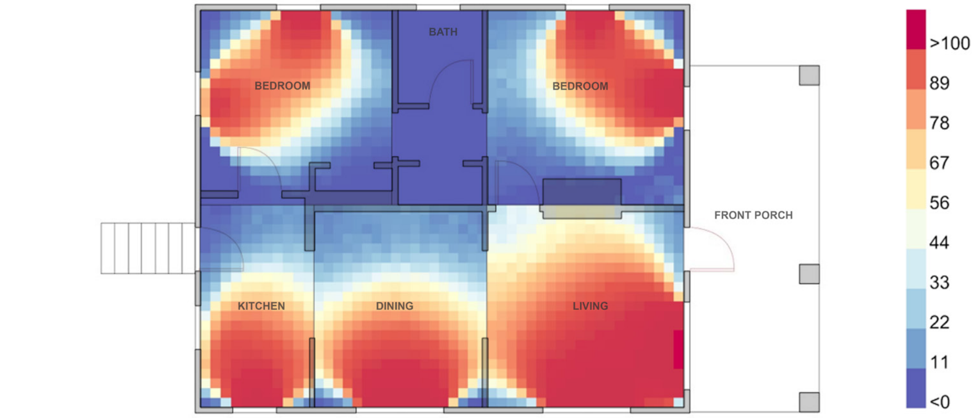



Figure 20: sDA analysis of existing design - 54% at 300 lux

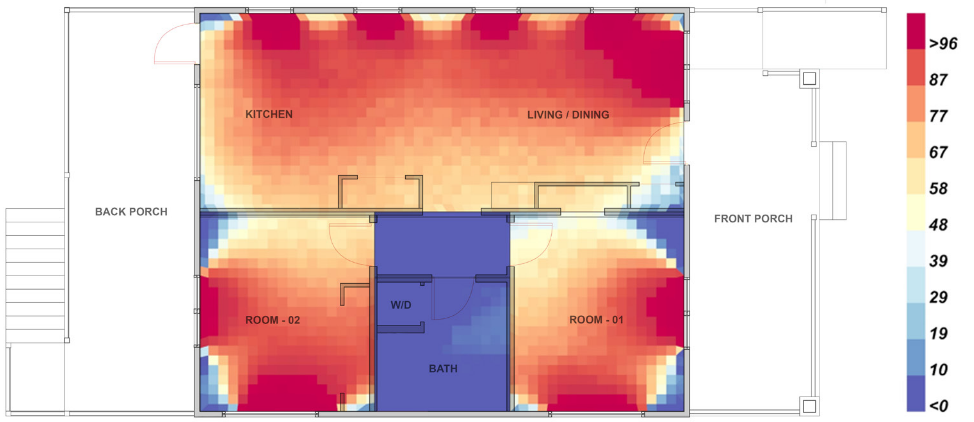



Figure 21: sDA analysis of proposed design - 72% at 300 lux

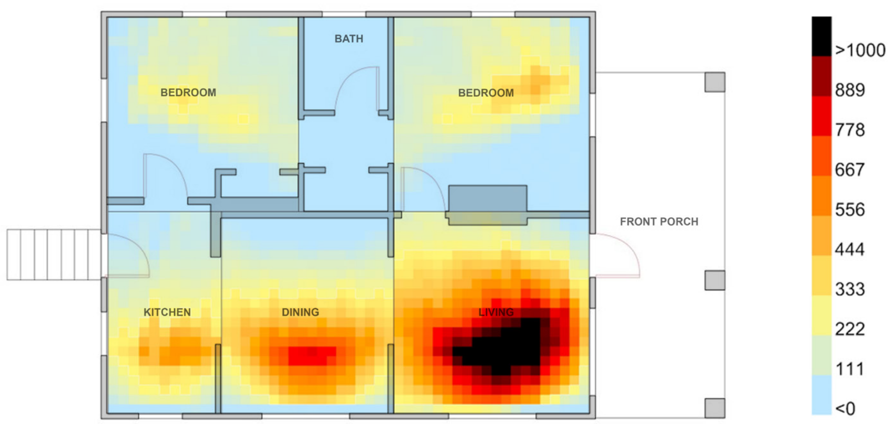



Figure 22: ASE analysis of existing design - 29%

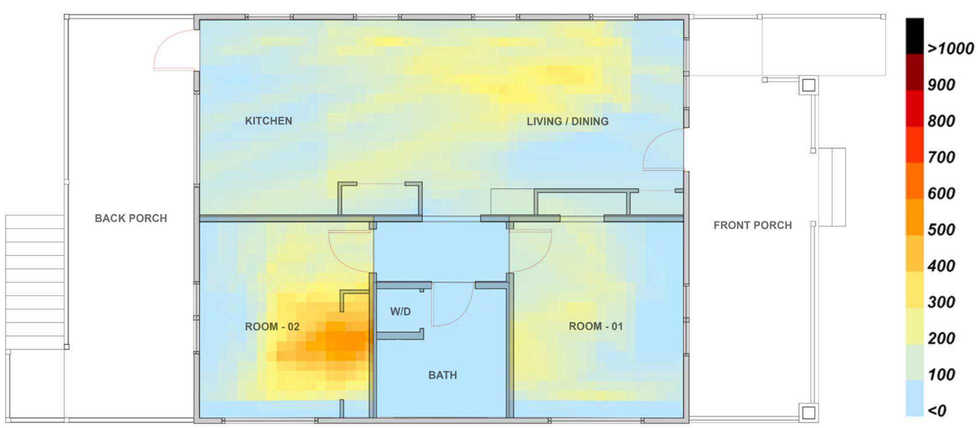



Figure 23: ASE analysis of proposed design - 6% (LEED recommendation <10%)

### 2.6.3 SPACE CONDITIONING AND BUILDING STRUCTURAL SYSTEMS STRATEGIES

The home's structural system was enhanced from the original 2 x 4 wall assembly to a thicker 2 x 6 system that allows for greater insulating strategies to be utilized. With this added insulated cavity, the home can operate at a lower energy consumption level, especially with the added impact enhanced the HERS rating and EUI score. The overhang added to the rear of the home aids in reducing abundant western radiation during the summer season, which helps the HVAC system in reducing energy consumption. Furthermore, creating three volumes (attic, living space, and crawl space) helps reduce HVAC loads.

> The Roof is the principal vernacular element that combines solar and rainwater capture while providing shelter for the occupants.

### 2.6.4 RENEWABLE ENERGY SYSTEMS OPTIMIZATION

The roof tilt angle is optimized using evolutionary solvers in the Galapagos optimizer of Grasshopper for Rhino to capture maximum solar power throughout the year and to merge with the neighborhood architectural language at the same time. As the energy purchase costs are much higher than the selling costs, we have precisely sized the PV panels to generate only the required amount, with an additional 20 % for resiliency. The energy consumption of the proposed house is 24000 KBTU, and the energy produced by PV panels is 29800 KBTU. We are achieving a net positive house, and the excess energy generated can also be used for charging Electric Vehicles (EVs).

### 2.6.5 LIGHTING SYSTEM EFFECTIVENESS

The lighting system has been designed to consider occupant comfort, energy reduction, and utility costs minimization. Some of the principles adopted for an efficient Indoor lighting design are as follows:

•Maximize daylighting during the morning hours to reduce dependency on electrical lighting.
•A balance of task and ambient lighting points maintains the threshold lux levels during the morning and evening hours of the day.

In order to understand the lighting system's effectiveness, a simulation study on dialux provides the illumination and lighting intensity levels in each room.

### 2.7 OCCUPANT EXPERIENCE

Daylighting is one of the essential strategies utilized to deliver good-quality lighting that is crucial for activities carried out in the daytime without depending on lighting fixtures. Dependency on natural light promotes mood enhancement, regulates circadian rhythm patterns, and decreases energy load. Overheating and glare concerns are addressed through overhangs that shade a substantial portion of the wall and windows, thus addressing energy efficiency and indoor comfort. The modified layout prioritizes thermal comfort by orienting rooms usually occupied during daytime hours to face the North wall and the other rooms towards the south. The open plan also makes the house feel spacious to the occupant.

### 2.7.1 DESIGN FUNCTIONALITY

The occupant experience forms a central aspect of our project and interlinks with our performance goals. By providing a design that enables the occupants to feel in control of the operating systems that mediate light entry and aspects of comfort and flexibility, allowing the user to take control of the decision-making process.

Based on the occupant characteristics of English Avenue's community, we analyzed the requirements and needs of the varied user groups to create a home that caters to the concerns of its users. The primary goals of a holistic occupant experience are comfort, both thermally and spatially, occupant health, affordability, security, and an engaging outdoor experience.

### 2.7.2 ADVANCED BUILDING CONTROL TECHNOLOGY

**Privacy Accessibility and Familiarity**

The porch is a concrete element that has been designed to provide a safe and secure environment for the occupants to stay within the boundaries of their homes and interact with the outdoors. This has been thought of as a familiar architectural element, and this familiarity is introduced to make occupants feel comfortable and akin to their previously inhabited 'home' as the porch is commonly seen as an extension of Craftsman houses.

Covered porches with measures for accessibility are incorporated towards the east and west faces of the house, which provides shading and comfort for residents to spend time outdoors. The front porch facing east in terfaces with James. P Brawley Street allows for social interaction, whereas the back porch facing west serves for private gatherings and is customizable for events that differ for varied family types.

**Security, Appliance Selection, and Maintenance Targets**

By selecting appliances from fewer and more common vendors, discounts can be applied for bulk orders if this is applied to multiple households. Household appliances are chosen based on annual energy consumption and cost savings compared to other systems based on the Energy STAR certification.

WaterSense certification is considered for kitchen and bathroom fixtures to reduce unaddressed water usage, ensuring efficiency and decreasing utility bills. The kitchen faucet system is proposed to be ADA compliant and low lead compliant with efficient sealing technology that prevents leaks.

The efficiency of appliances ensures good functioning solutions, which reduce the need for appliance maintenance and occupant concerns. Efficiency targets address occupant concerns that arise from appliances not functioning well eventually and having to contact people

Dependency on natural light regulates circadian rhythm patterns, and decreases energy load.

to solve these issues and the hassle cycle repeating. Efficiency and maintenance targets are applied coherently and synergistically.

The security system is designated to conform to a one-time basic payment setup that can be upgraded based onthe user's needs. It is equipped with a 95dB base station, keypad, entry sensor, and motion sensor. Our affordability goals for the user are a priority to ensure low-cost burdens, expenditure in the long run, and minimal maintenance concerns.

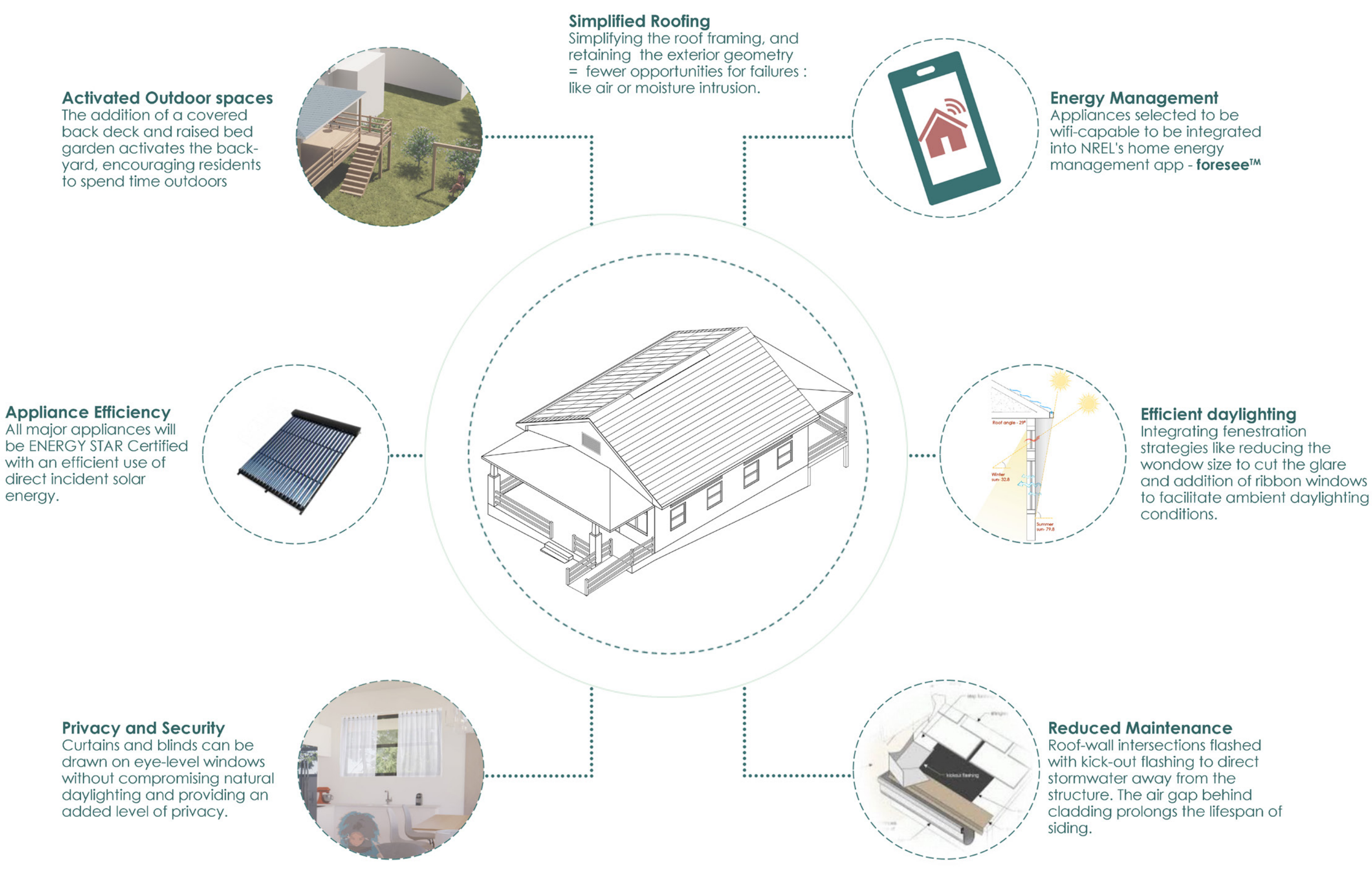


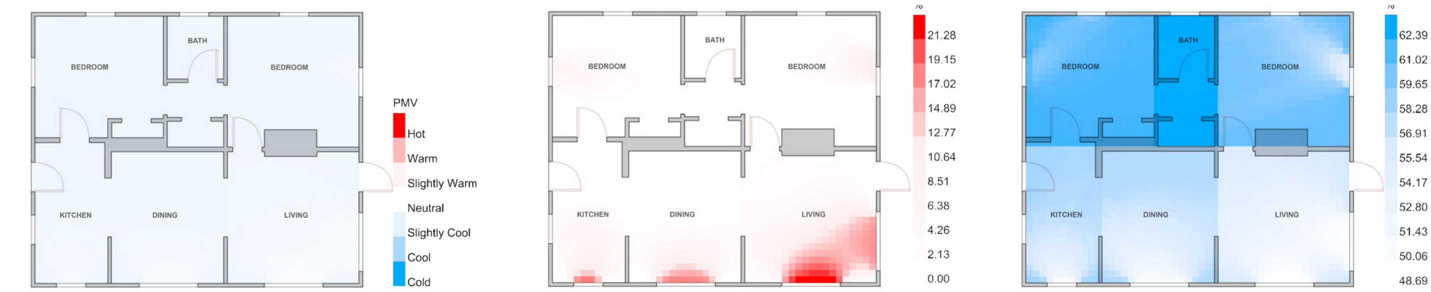

Figure 24: Occupant experience framework

## 2.8 COMFORT AND ENVIRONMENTAL QUALITY

### 2.8.1 PREDICTED MEAN VOTE

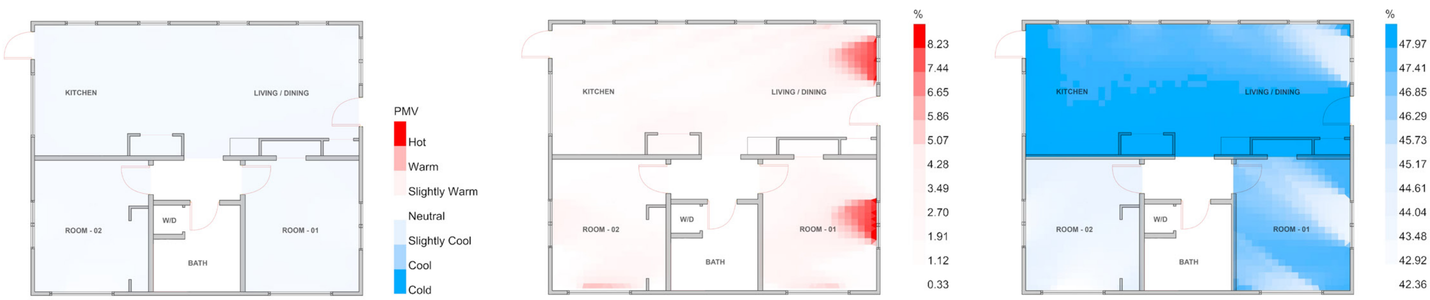
We are using PMV as a proxy for thermal comfort, simulated spatially using Ladybug Tools for Rhino. We morphed the TMY climate file through CCWeatherGenerator to emulate climate change scenarios and used three weather files accordingly (TMYx, 2050 and 2080). PMV values range from -0.6 for the existing model before our retrofitting design to an increase in the 2050 and 2080 projected years having values of -0.38 and -0.28, which is comfortable for the occupants as they approach the neutral point. Heat sensation values improve from the existing value of 2.1 to a simulated value of 1.2 in 2020, 1.78 in 2050, and 4.8 in 2080.

The improvement in cold sensation percentages starts with the existing condition having a value of 60% and




Predicted Mean Vote (PMV) comfort analysis for existing condition-year 2020


Predicted Mean Vote (PMV) comfort analysis for proposal-year 2020




Predicted Mean Vote (PMV) comfort analysis for proposal-year 2050


Predicted Mean Vote (PMV) comfort analysis for proposal-year 2080

Figure 25: Predicted Mean Vote (PMV) comfort analysis

decreasing to 45.9 in 2050 and 40.5 in 2080. The concentrations of higher cold sensation percentages are located in the areas occupied during the day, which is favorable due to the climatic conditions of the context.

### 2.8.2 HVAC SYSTEM DESIGN

Upon analysis of the home's conditioning needs based on the sensible and latent loads, drawing from the envelope's enhanced U and R values, the home exhibited a need of 10,102 BTUH for the winter season and 24,001 BTUH for the summer season, with an off-season average of 17,051 BTUH. Therefore, the home has an actual need of 1.38 tons, making it a nominal need of 2 tons. Considering the system's various sizing capacities and cost, the home was sized for 95% load, which allows the system to operate without short cycling, ensuring optimal indoor environmental quality. The home strategically integrates the HVAC system with the structural composition of the building as well.

The home utilizes an energy-efficient 18 SEER, 11 HSPF, 24,000 BTU ducted mini-split heat pump system with short duct runs and integrated mastic to reduce friction and enhance airtightness. The system is accompanied by an energy-efficient air handler located at the center of the home in the crawl space to aid in the reduction of duct runs. All ducts are placed in the semi-encapsulated crawl space where an Energy Recovery Ventilator (ERV) with automatic humidity and temperature controls is located, intaking and exhausting air as necessary with vents located under the back deck. The condensing unit is also located under the back deck to encourage airflow while strategically hiding from plain sight. The system utilizes five fresh-air supply registers and four stale-air return grilles, along with a main forced-air return grille located in the main larger section of the home.

> ERV provides fresh, filtered air without a large energy penalty

### 2.8.3 SPOT VENTILATION STRATEGIES

Along with the passive strategies used, active strategies include the kitchen being equipped with an overhead exhaust air vent hood, which aids in maintaining air quality in the largest space of the home, while the bathroom has an exhaust air vent that assists in the reduction of humidity within the space, therefore preventing the build-up of mold and mildew. There are two additional vents in the laundry alcove which promote the removal of hot and dusty air from the dryer and hazardous fumes from the washer. There are also three ceiling fans in the two bedrooms and the living room to assist air circulation. The home is designed for an indoor air environment with all these strategies combined.

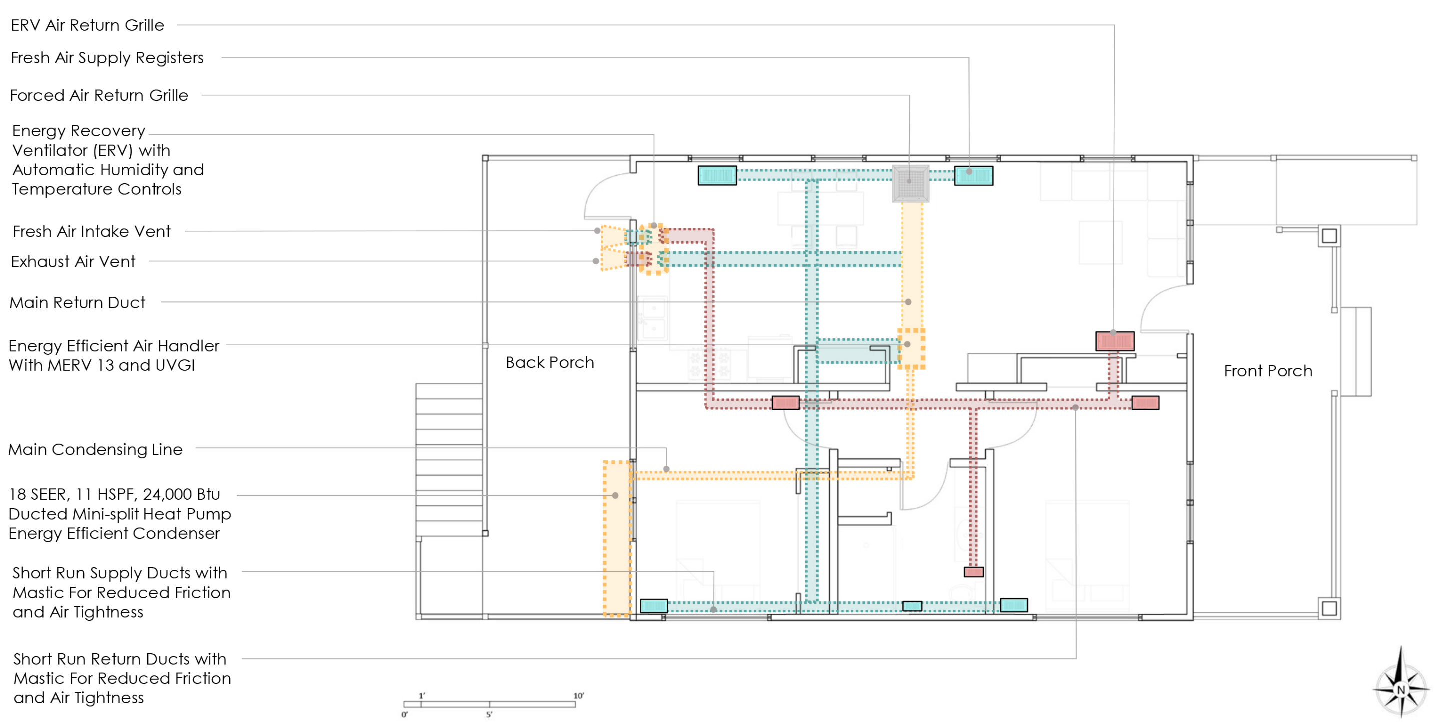



Figure 26: Duct layout

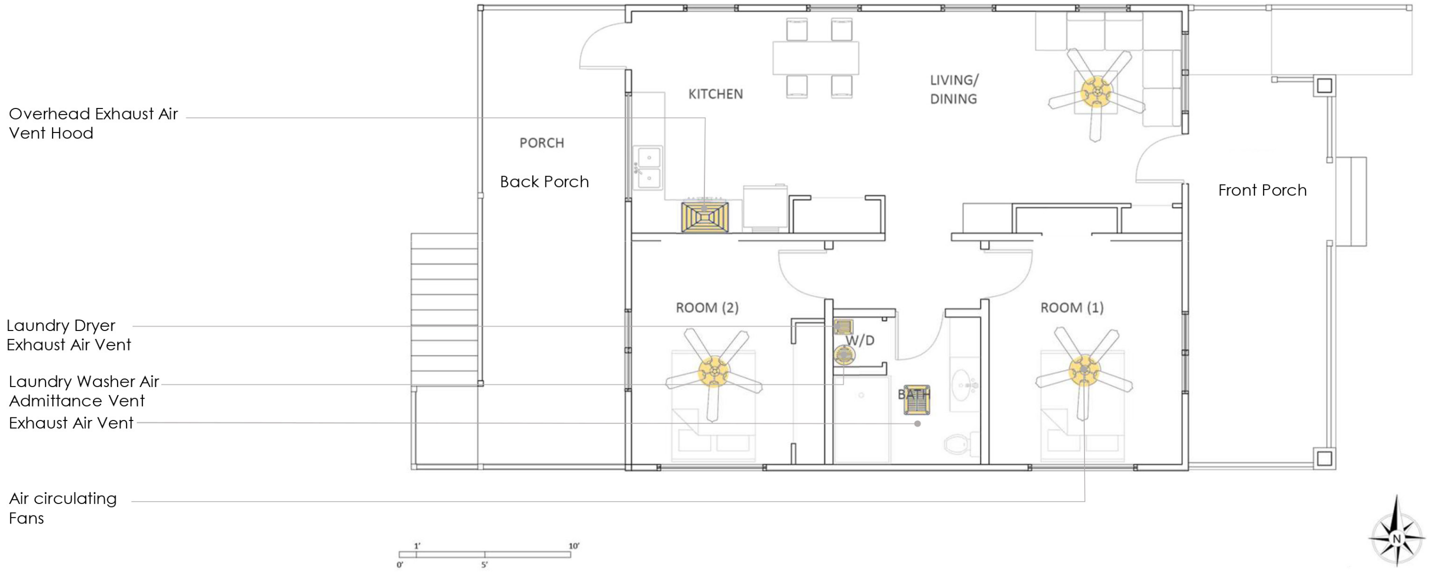



Figure 27: Air circulation and spot ventilation strategies

### 2.8.3 MECHANICAL SCHEDULE

The list of mechanical system components and their specification are as per the table below

| COMPONENT | SPECIFICATION |
|---|---|
| CONDENSER | 18 SEER, 11 HSPF, 24,000 Btuh Heat Pump based on Manual J & S |
| 5 FRESH AIR SUPPLY REGISTERS | Sized based on Manual D with total duct run of 85' and mastic |
| 4 STALE AIR RETURN GRILLES | Sized based on Manual D with total duct run of 60' and mastic |
| FORCED AIR RETURN GRILLE | Sized based on Manual D with total duct run of 10' and mastic |
| ENERGY RECOVERY VENTILATOR | Automatic humidity and temperature controls with both Intake and Exhaust Vents |
| AIR HANDLER | Energy Efficient and Centrally Located |
| CONDENSING LINE | 30' Insulated Line |
| AIR HANDLER FILTER | MERV 13 |
| UVGI BULB | 18 W, 254NM, 8.66 in, 10,000 hours |
| OVERHEAD KITCHEN HOOD EXHAUST VENT | 36", 2 Speed, 120 volts, 390 CFM, 2850 RPM |
| 3 FIVE BLADE CEILING FANS | Remote control 120 volts, 59 W, 6 Speed, 4848 CFM, Air Flow Efficiency of 78 |
| BATHROOM EXHAUST VENT | 120 volts, 17.9 W, 80 CFM, 4" Duct |
| LAUNDRY DRYER EXHAUST VENT | Passive 4" |
| LAUNDRY WASHER AIR ADMITTANCE VENT | Passive 3" |

Figure 28: Mechanical Schedule

## 2.8.5 COMPREHENSIVE SOURCE CONTROL STRATEGIES

Non-VOC GREENGUARD paint is chosen as a coating for walls, ceilings, and floors as the possibilities of VOC levels from regular paint are two to three times higher indoors than outdoors. Long-term exposure to VOC-based paint may lead to chronic diseases and are toxic at higher concentrations.

In addition to the optimally sized HVAC system, which prevents short cycling, other passive strategies ensure comfort, health, energy efficiency, and environmental sustainability. The window with overhangs located in each room of the home allows for airflow to passively ventilate the home with a reduced adverse effect of glare and direct heat gain. The integration of a self-moderating Energy Recover Ventilator also ensures that the indoor environmental air quality is at its optimal level.

## 2.9. ENERGY PERFORMANCE

## 2.9.1 COMPREHENSIVE ENERGY ANALYSIS

**Home Energy Rating System - HERS**

The house we designed needed to reach an index of 50 or less (before PV) to adhere to the design challenge requirements. In order to accomplish this target while still prioritizing affordability, we aimed to take a lean approach. Lead-contaminated siding is "removed", and exterior walls are insulated from the outside. This allows us to keep the plaster and lath finished walls a significantly durable finish. By using a " net-and-blow " method, exterior walls are insulated with dense-packed cellulose, using a "net-and-blow" method. ZIP sheathing is added to the existing framing, and the integrated weather-resistant barrier (WRB) is sealed with the associated tape. One inch of the mineral wool board is added to create a layer of continuous exterior insulation, followed by furring, an air gap, and new fiber cement siding. This entire wall assembly is modeled in Ekotrope.

The crawlspace encapsulates one-inch closed-cell foam on the interior foundation walls and rim joists. The ceiling is insulated with 15 inches of loose-fill cellulose to complete the thermal envelope to create an R-60 ceiling. Windows were updated to match the total areas in the design and had less aggressive efficiency values for the glass to keep costs reasonable.

The HVAC was designed to be highly efficient, with minimal losses. This was accomplished using rigid, metal ductwork and sealing all seams with mastic. The designed leakage rates are 10 cfm of total duct leakage and 0 cfm leakage to the outside. These targets are not un reasonable given that the air handler is a mini-split, the duct runs are minimal, and the metal ductwork allows an even surface for the mastic to be applied. Mechanical ventilation is supplied with an ERV that runs to meet local ASHRAE standards.

Plumbing fixtures are low-flow, and the hot water lines are insulated to conserve energy. The water heater is located central to the fixtures to minimize the distance from the tank to the fixture. All of the home's fixtures are LED, the appliances are all ENERGY STAR, and to further ease the utility burden, the house only uses electricity. The stove is an induction top, and the oven has convection capabilities

Due to the unique construction in the attic, the ZIP system, and an extensive air sealing package, this house would be capable of reaching 1 ACH50. The solar panels installed onsite produce 6 kW of energy. Our final HERS Indices: 44 w/o PV, -1 with PV

**Energy Use Intensity - EUI**

We generated an energy model of the house in grasshopper using Ladybug tools. After Modifying the layout, we changed the occupancy, equipment, and lighting schedule. Next, we decided on the materials and created different assemblies. Later we modified the windows and shading to get maximum daylighting and minimum glare. After making the best use of all passive design strategies, we moved on to active strategies like deciding the suitable HVAC system and set points,reducing LPD and equipment load densities, and using energy-efficient fixtures. After minimizing the total loads, we introduced renewable energy to achieve a Net positive house.

We considered the existing house functioning and modeled it as per IECC 2015 as followed in Georgia. The EUI of the Existing house is 49.5 KBTU/sf. With our proposed design EUI is further reduced to 12.09 KBTU/sf. It can be observed from the existing chart that in Atlanta, heating loads are higher than cooling loads.

We produce 29,785 kBtu of energy on-site and achieve a Net positive house. As we completely depend on On-site energies, we will not be using off-site renewable energy to offset annual energy consumption. The EUI of the house after including PV is – 2.9 kBtu/sf

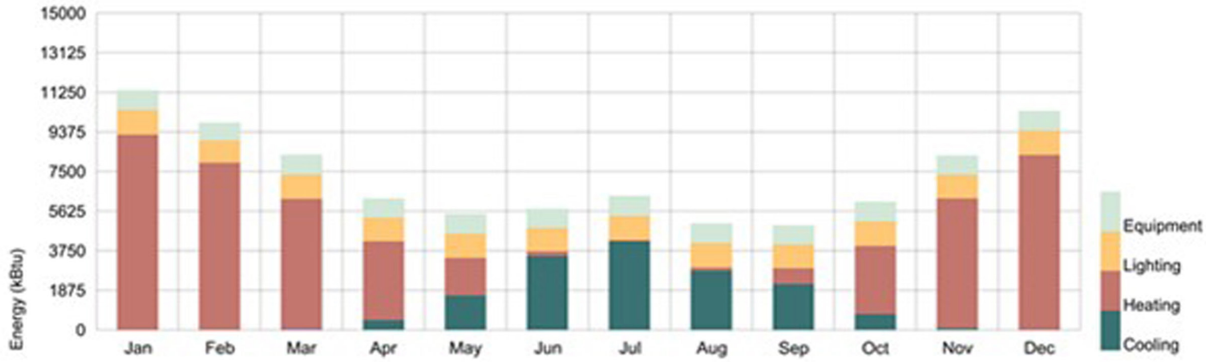



Figure 29 : Energy chart of existing house with EUI value 49.5 kBtu/sf

We reduced the energy consumption significantly using passive and active strategies. The heating loads have reduced drastically, and we have analyzed it using morphed weather files for future scenarios.

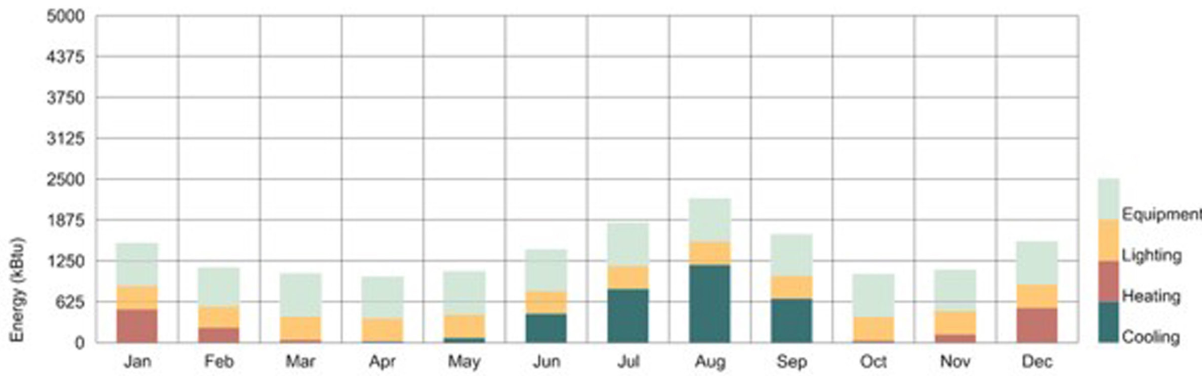



Figure 30 : Energy chart 2020 for proposal with EUI 12.09 kBtu/sf

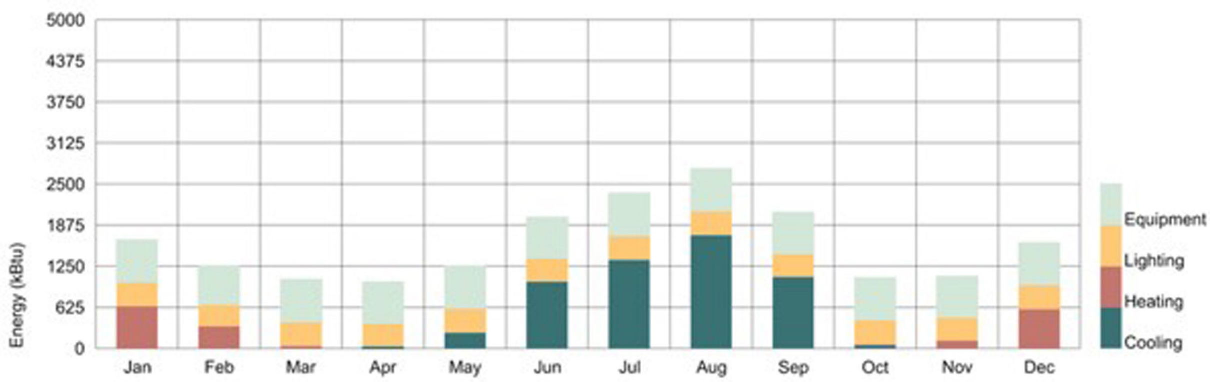



Figure 31 : Energy chart 2050 for proposal with EUI 12.5 kBtu/sf

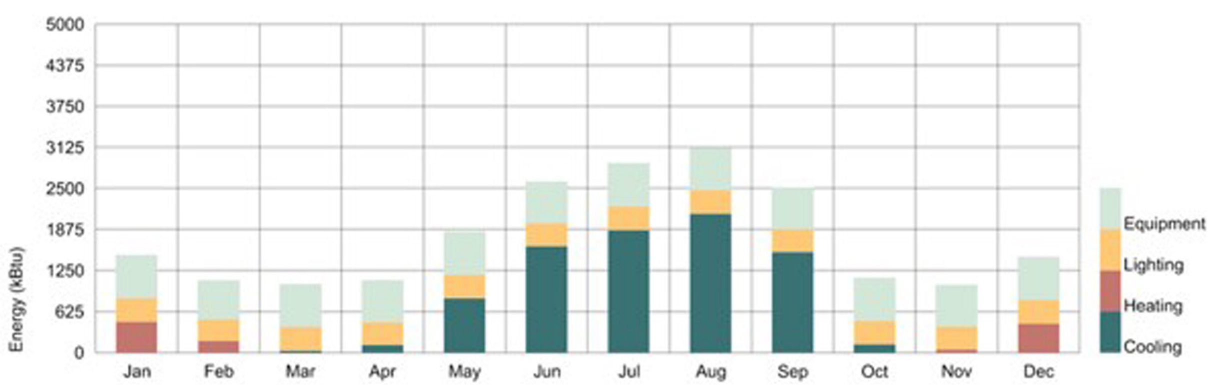



Figure 32 : Energy chart 2080 for proposal with EUI 13.2 kBtu/sf

We analysed and compared different window options with variation of sizes and positions for the new layout. Adding Ribbon windows improve thermal comfort by allowing the solar sun in winters, reducing energy loads and EUI. Simultaneously, they provide better DA and lesser ASE, which reduces lighting loads.

| | OPTION 1 | OPTION 2 | OPTION 3 | OPTION 4 | FINAL OPTION |
|---|---|---|---|---|---|
| EUI | 12.68 | 12.707 | 12.743 | 12.39 | **12.09** |
| ASE | 3% | 17% | 16% | 5% | **6%** |
| DA | 48.1 | 63.36 | 67.72 | 65.8 | **72** |

Figure 33 : Fenestration design exploration

## 2.9.2 RENEWABLE ENERGY INTEGRATION STRATEGIES

We are installing a 6 KW Mono crystalline Silicon PV system mounted on an optimized roof angle of 29 degrees. This system consists of 15 panels and each panel requires an area of 22 sft. The total roof area required for PV panels is 330 sqft which is 55 % of the southern roof. The maximum power generated per hour is 400 watts, and panel conversion efficiency is 15 %. We are proposing a 14.4 KW battery with a 6 KW hybrid inverter.

Battery Sizing calculations

Daily energy usage average - 20 kwh from 7035 kwh annually
Number of days autonomy for battery bank – 1
Battery rating to be used for 400 W PV panels – 250 Ah
Total battery Ah required is – 417
Proposed battery Ah – 500
Nominal voltage – 48 V
Proposed Battery size – 14.4 KW

## 2.9.3 GRID INTERACTION CAPABILITIES

By connecting the PV system to a hybrid inverter combines the features of a standard solar inverter and a battery inverter into a single low-cost and smart charging electricity routing unit. This Hybrid inverter includes a built-in charge controller that determines when it is best to send electricity from the grid to battery or from solar panels. Load shifting and peak shaving can be pro-grammed as well. This system can power critical loads with smooth, reliable electricity from battery storage systems. In the event of a blackout, and power outages they provide resiliency.

> Keeping with the idea of retrofitting we achieved net positive performance with affordable interventions.

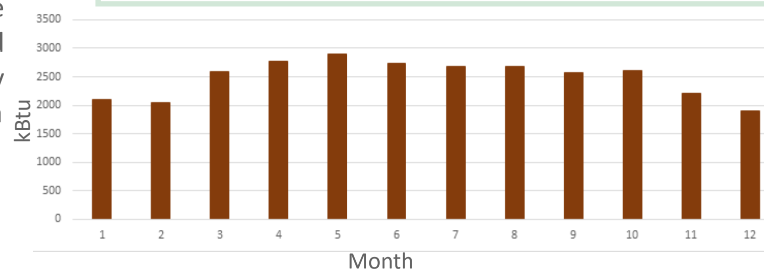



Figure 34 : Monthly solar power generation

## EPILOGUE

This project represents the culmination of an exhaustive, multidisciplinary effort that combines the very best of our collective ingenuity and building science skills. More importantly, though, this project reflects a deep moral commitment to apply our team's talents to address the urgent problems of an underserved community. This house renovation is Sustainable, with a capital S, addressing and balancing all three of its conceptual elements: environmental performance, social equity, and economic viability. Together, we have achieved our goal to create a replicable model for renovating the many vacant and derelict houses in the English Avenue neighborhood into affordable, healthy, and energy-efficient homes. In doing so, we have helped contribute to the neighborhood's future and the promise that in the very near future it will not only be a vibrant place to live but also a platform for the upward mobility and prosperity of its residents.

# CHAPTER 3 APPENDICES

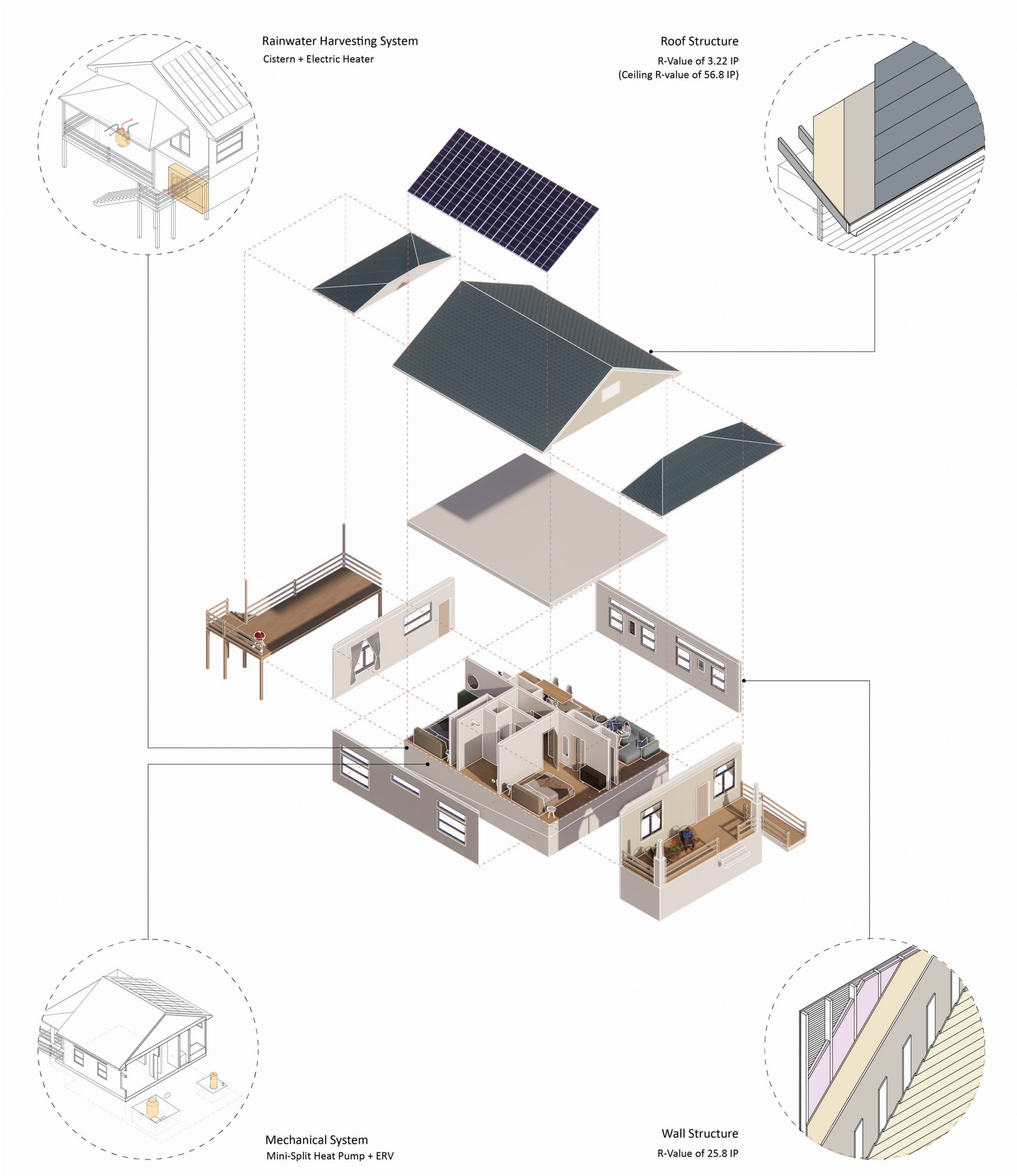
## Appendix A - Design renders

Front porch and street connection

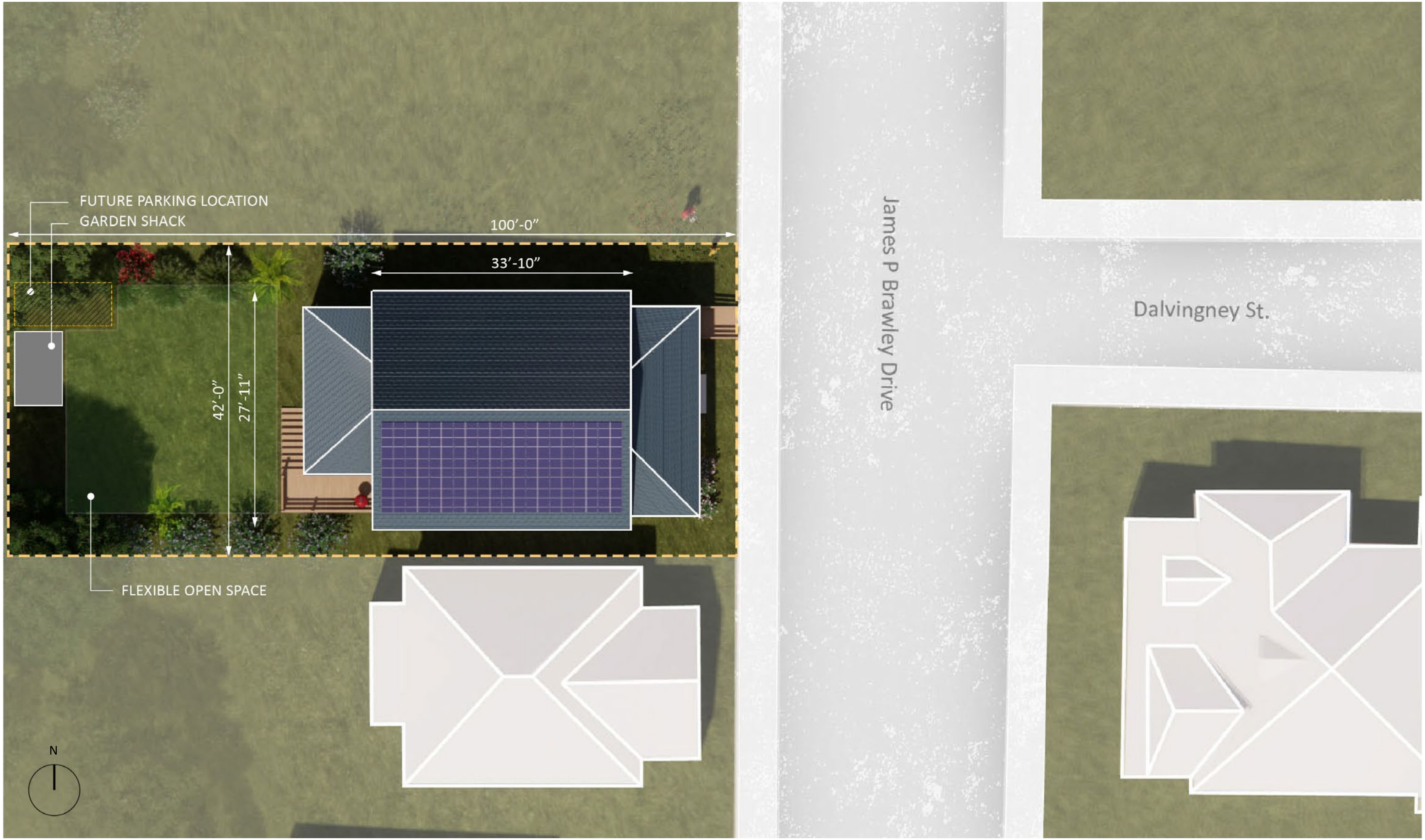
Activated outdoor space in the backyard

Living room, dine and kitchen space

Room - 1

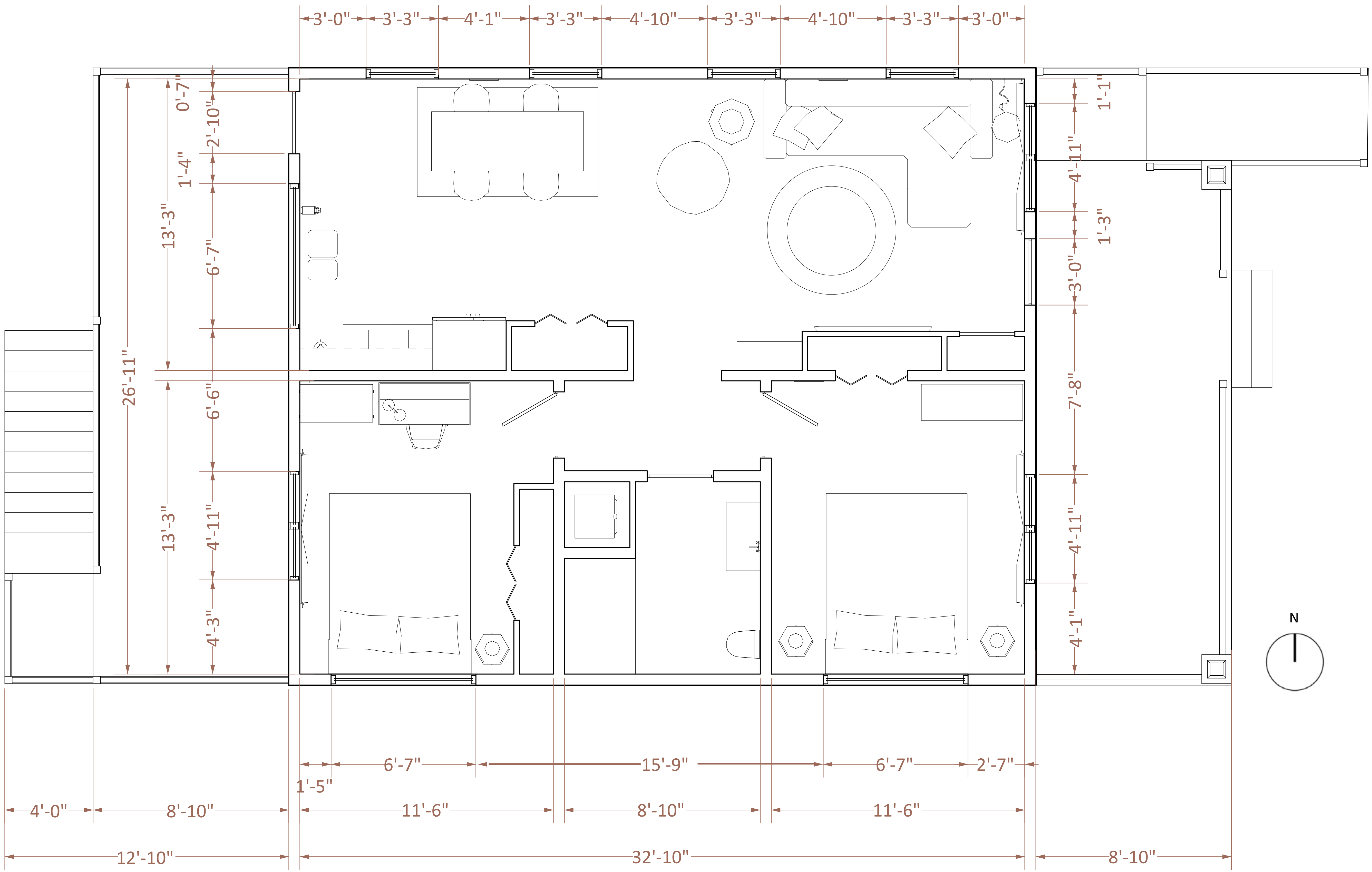



Exploded axonometric drawing

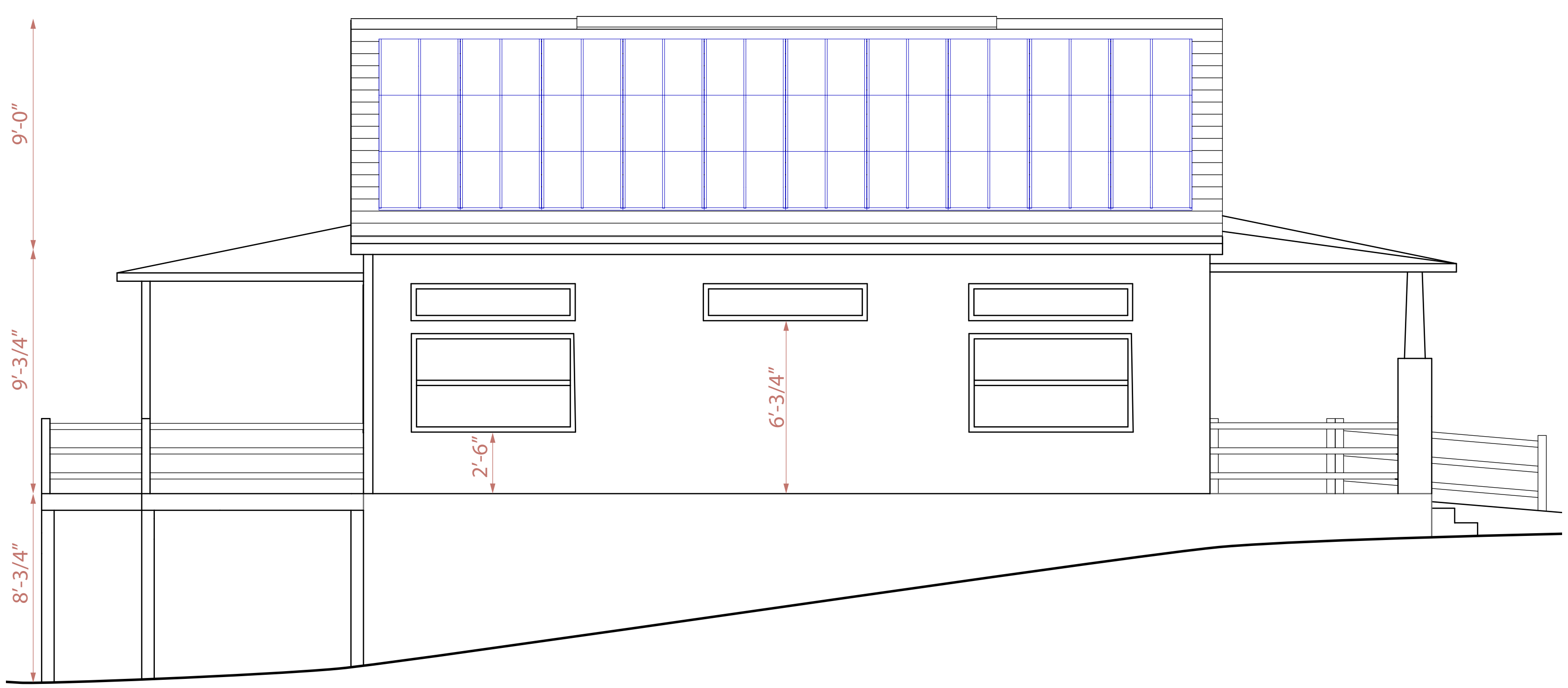

FUTURE PARKING LOCATION
GARDEN SHACK
100'-0"
33'-10"
42'-0"
27'-11"
FLEXIBLE OPEN SPACE
James P Brawley Drive
Dalvingney St.
N

Site plan

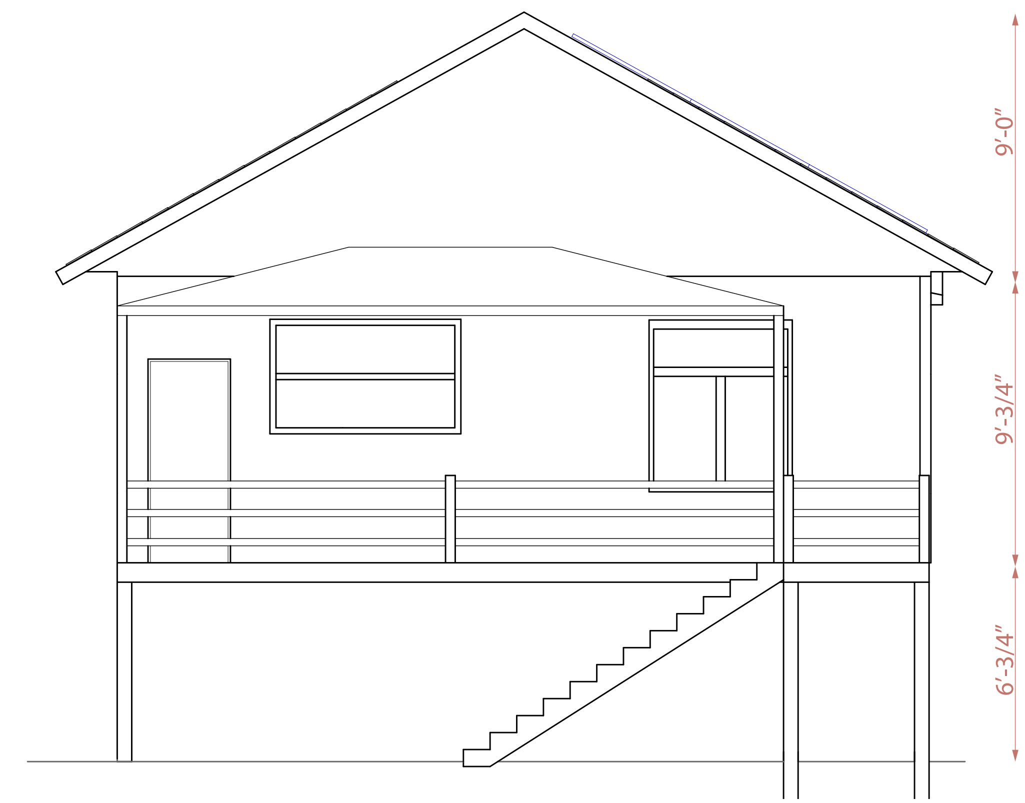

Layout plan with room-2 options



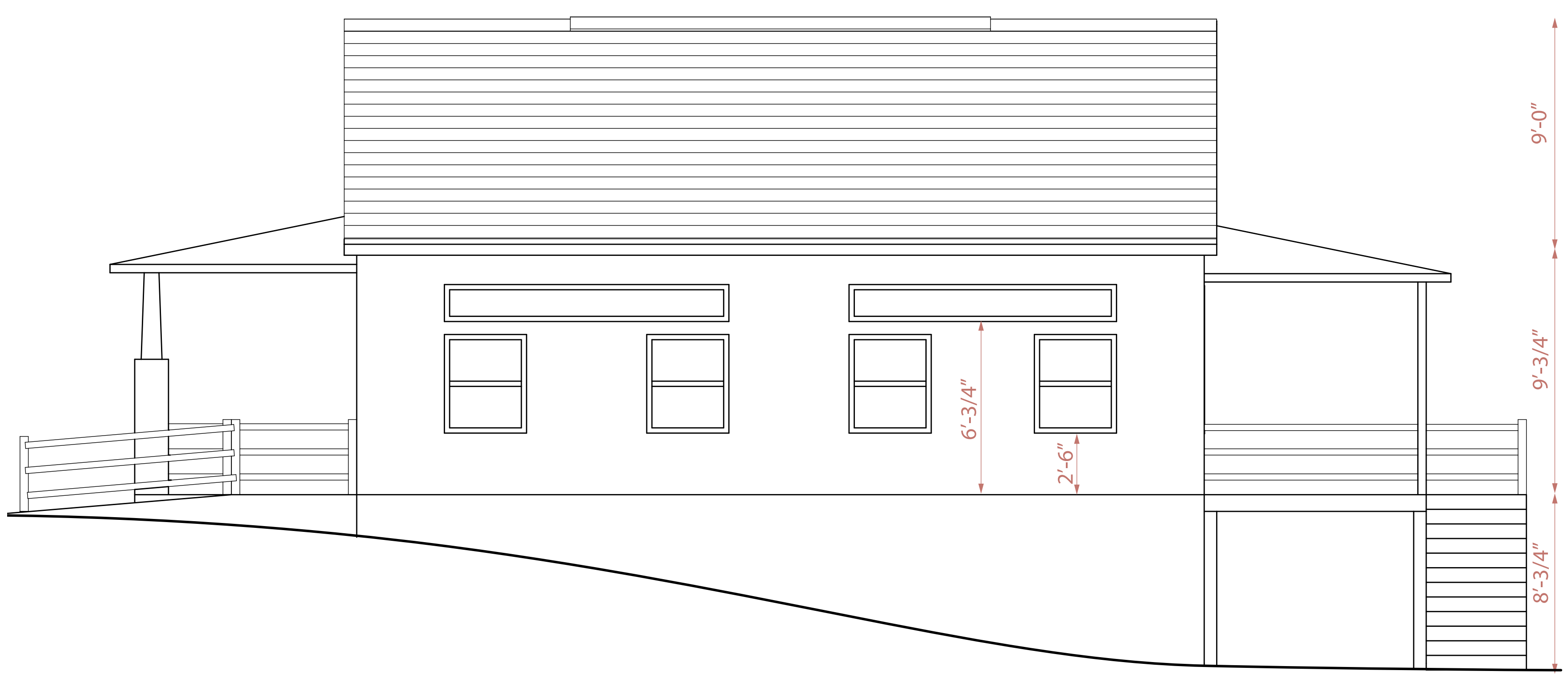

House plan with dimensions



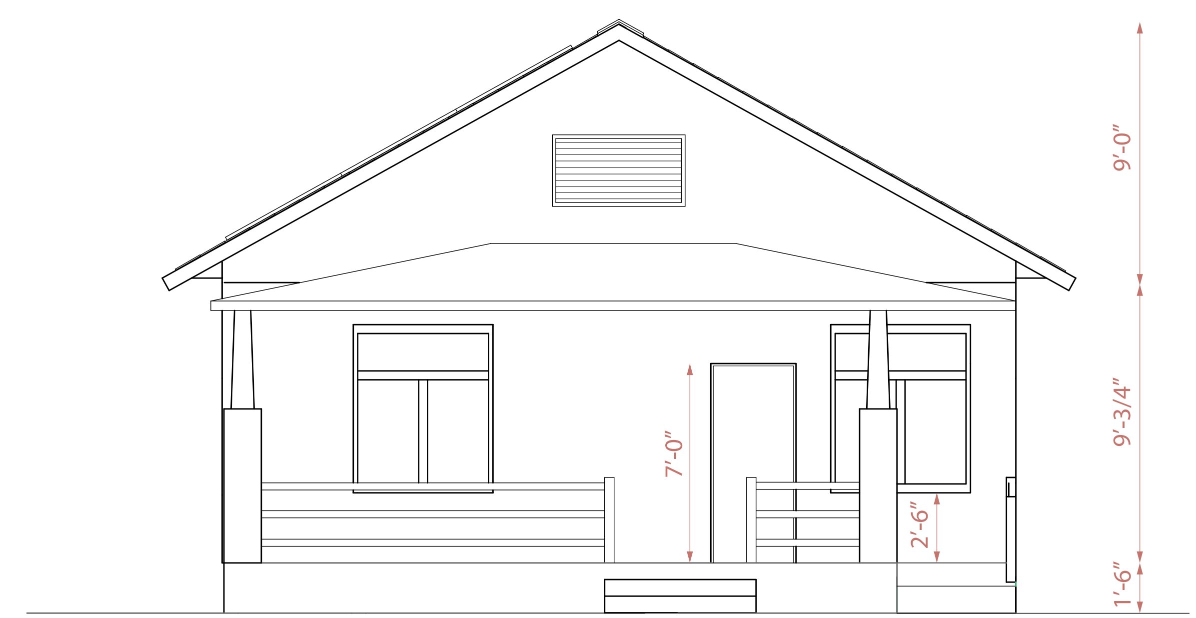

South elevation



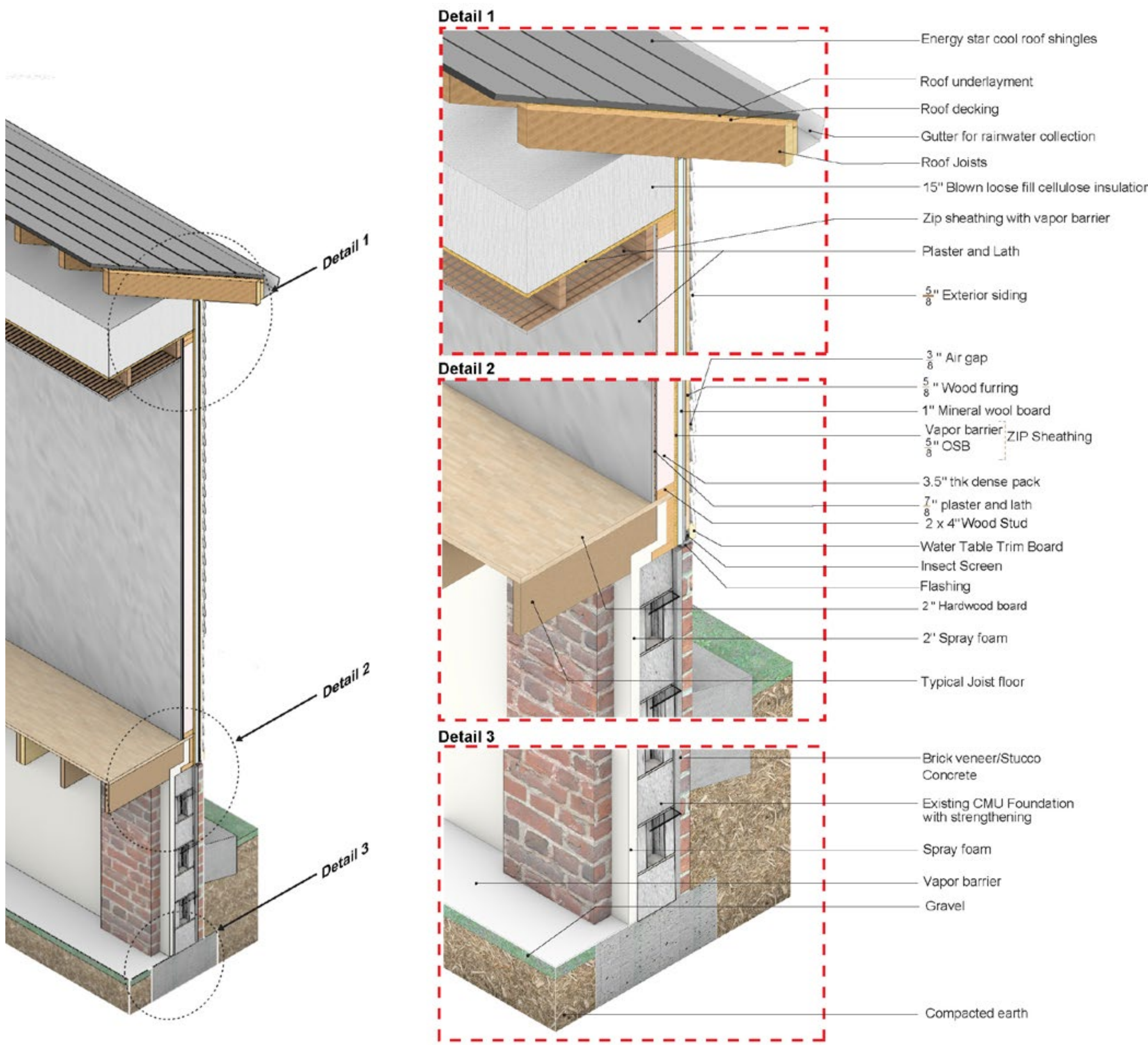

West elevation



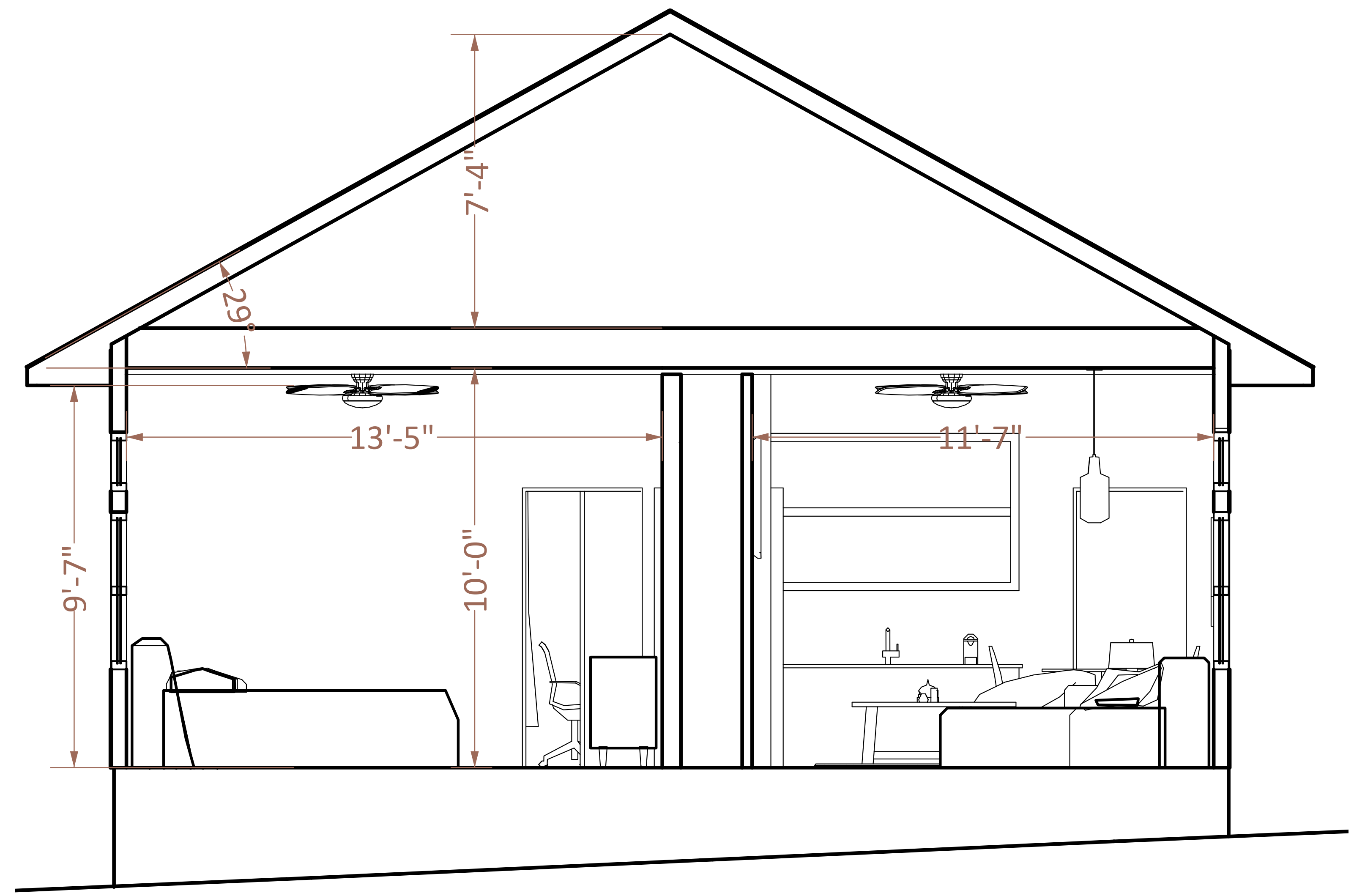

North elevation



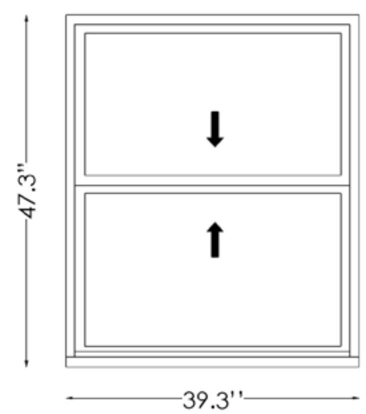

East elevation




Wall section



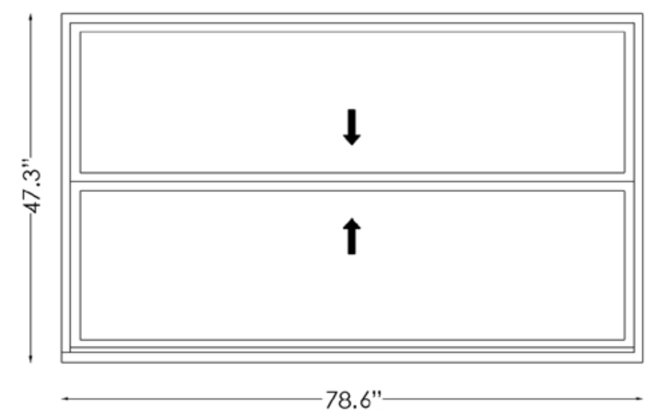

Section along North South axis




**W1**: Double hung, double pane, low-e window

39.3''x47.3''

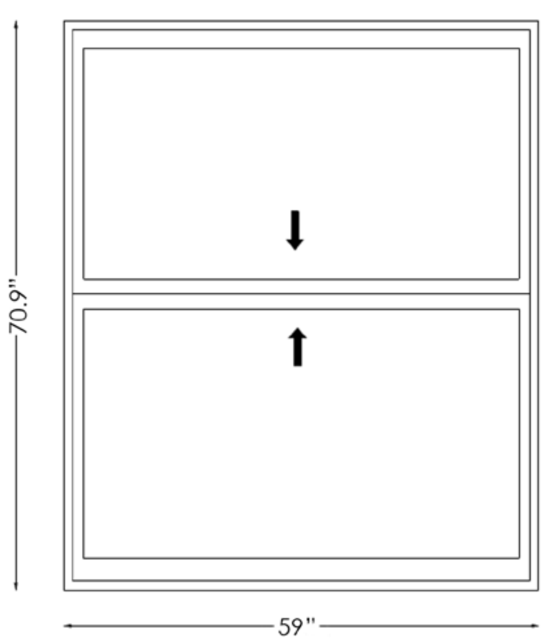
**U Value (IP)– 0.27**
**SHGC – 0.21**
**VLT – 0.49**




**W2**: Double hung, double pane, low-e window

78.6"x47.3"

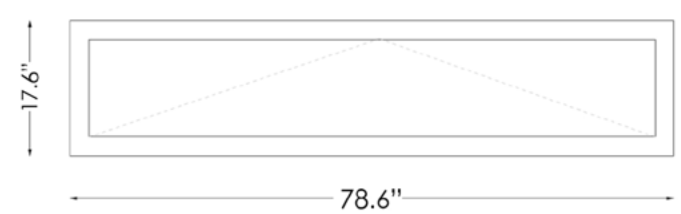
**U Value (IP)– 0.27**
**SHGC – 0.21**
**VLT – 0.49**




**W3**: Double hung, double pane, low-e window

59"x70.9"

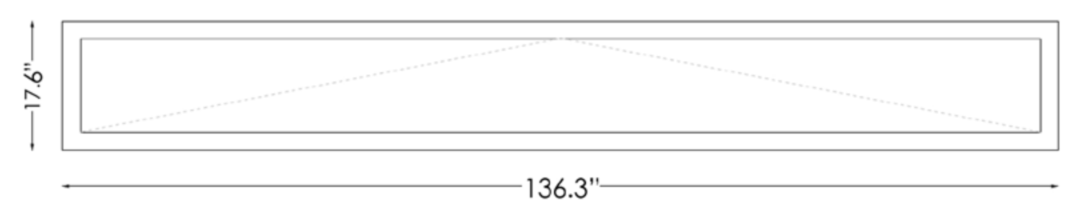
**U Value (IP)– 0.27**
**SHGC – 0.21**
**VLT – 0.49**




**W4**: Ribbon hinged window, Low E, double pane

78.6"x 17.6"

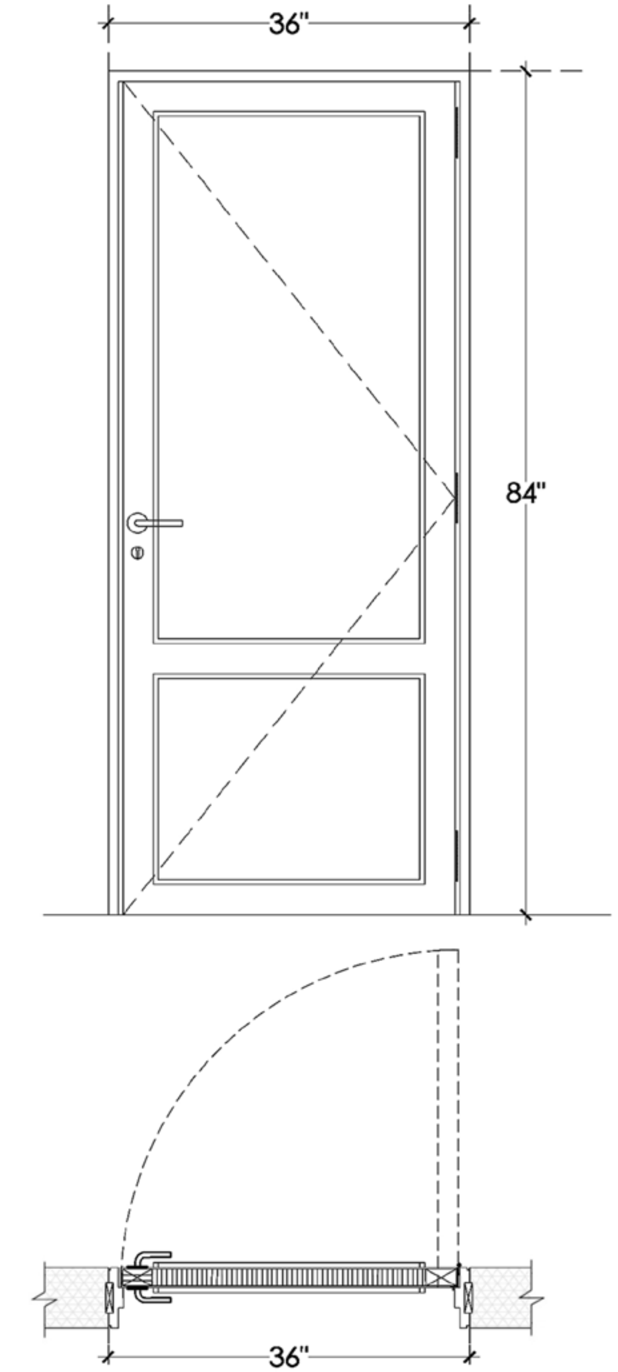
**U Value (IP)– 0.27**
**SHGC – 0.21**
**VLT – 0.49**




**W5**: Ribbon hinged window, Low E, double pane

136.3"x 17.6"

**U Value (IP)– 0.27**
**SHGC – 0.21**
**VLT – 0.49**




**D1:** Solid core door
**R Value: 5.88**

**WINDOW SPECIFICATIONS**

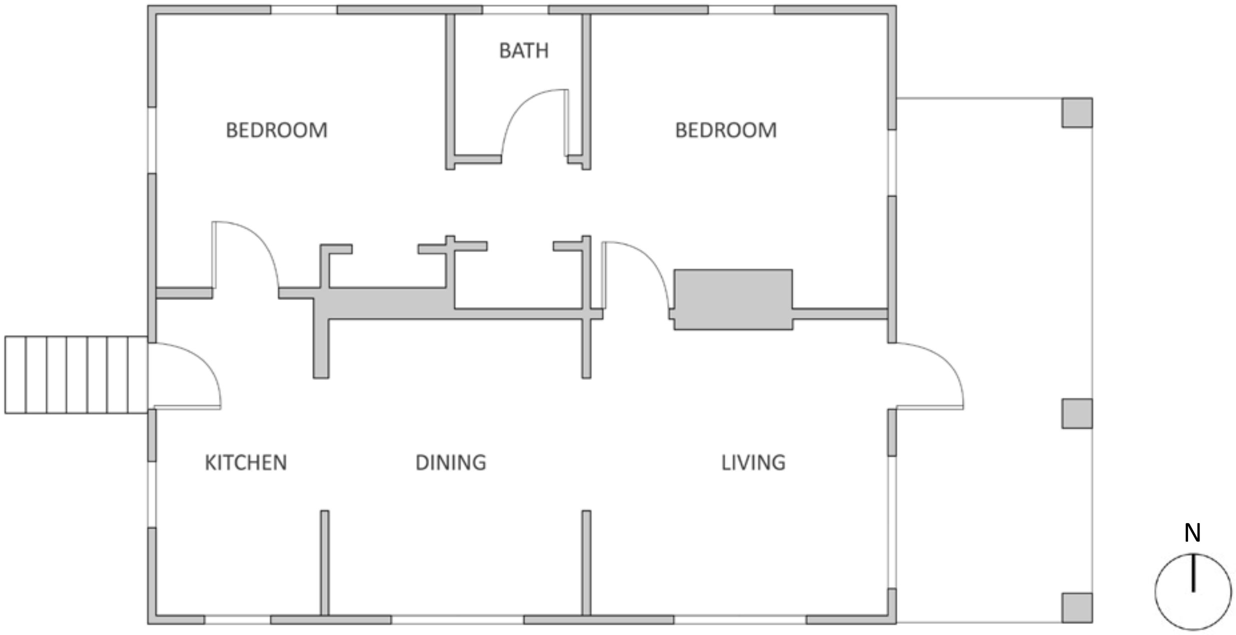
1. Construction:
   - Exterior frame: Composite pre-consumer wood fibre
   - Interior frame and sash: Preservative treated solid lumber(WDMA), painted finish
2. Type
   - Tilt-wash double-hung full-frame
   - Low-E4 with Heatlock, no grilles
   - NFRC certified values
     **U Value (IP)– 0.27**
     **SHGC – 0.21**
     **VLT – 0.49**

| Window type | Quantity | Height (in) | Width (in) | Placement |
|---|---|---|---|---|
| W1 - Double hung | 4 | 47.3 | 39.3 | North wall |
| W2 - Double hung | 3 | 47.3 | 78.6 | South wall |
| W3 - Double hung | 3 | 70.9 | 59 | East and west wall |
| W4 - Ribbon window | 3 | 17.6 | 78.6 | South wall |
| W5 - Ribbon window | 2 | 17.6 | 136.3 | North wall |

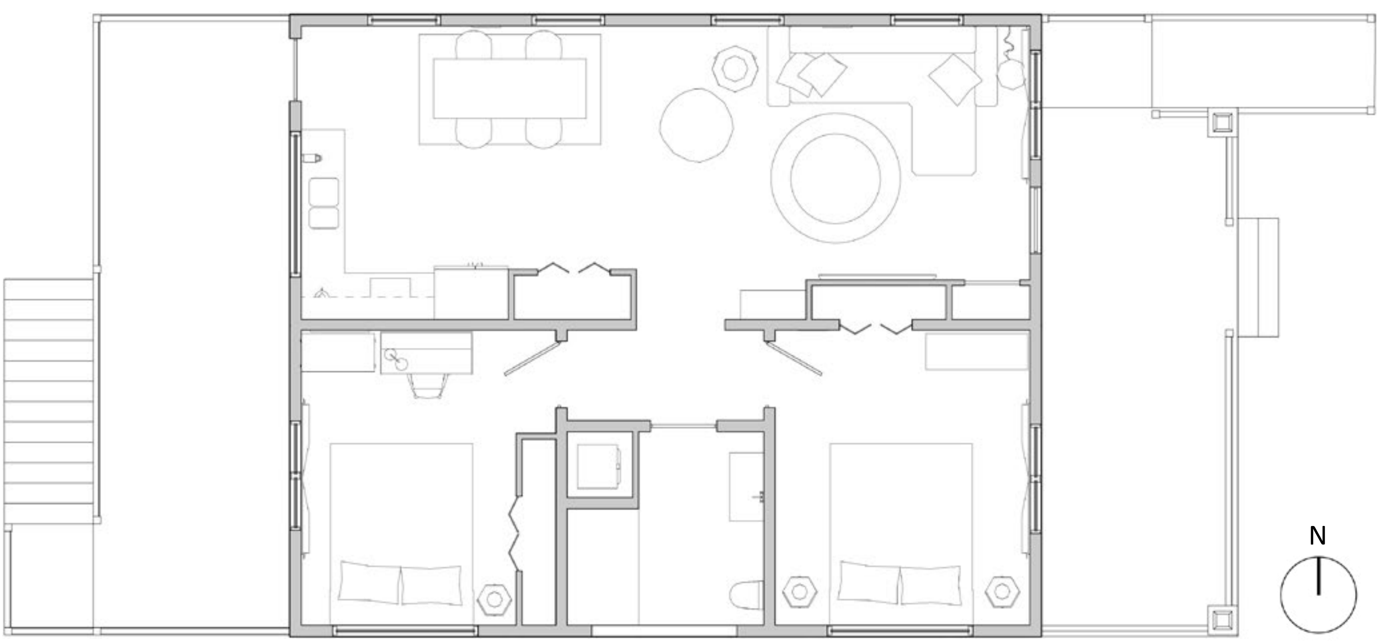
| Door type | Quantity | Height (in) | Width (in) | Placement |
|---|---|---|---|---|
| **D1**<br>*R Value: 5.88* | 5 | 84 | 36 | Main entrance, Backyard door, bedrooms and washrooms |

Door and window schedule

**Existing and proposed design**

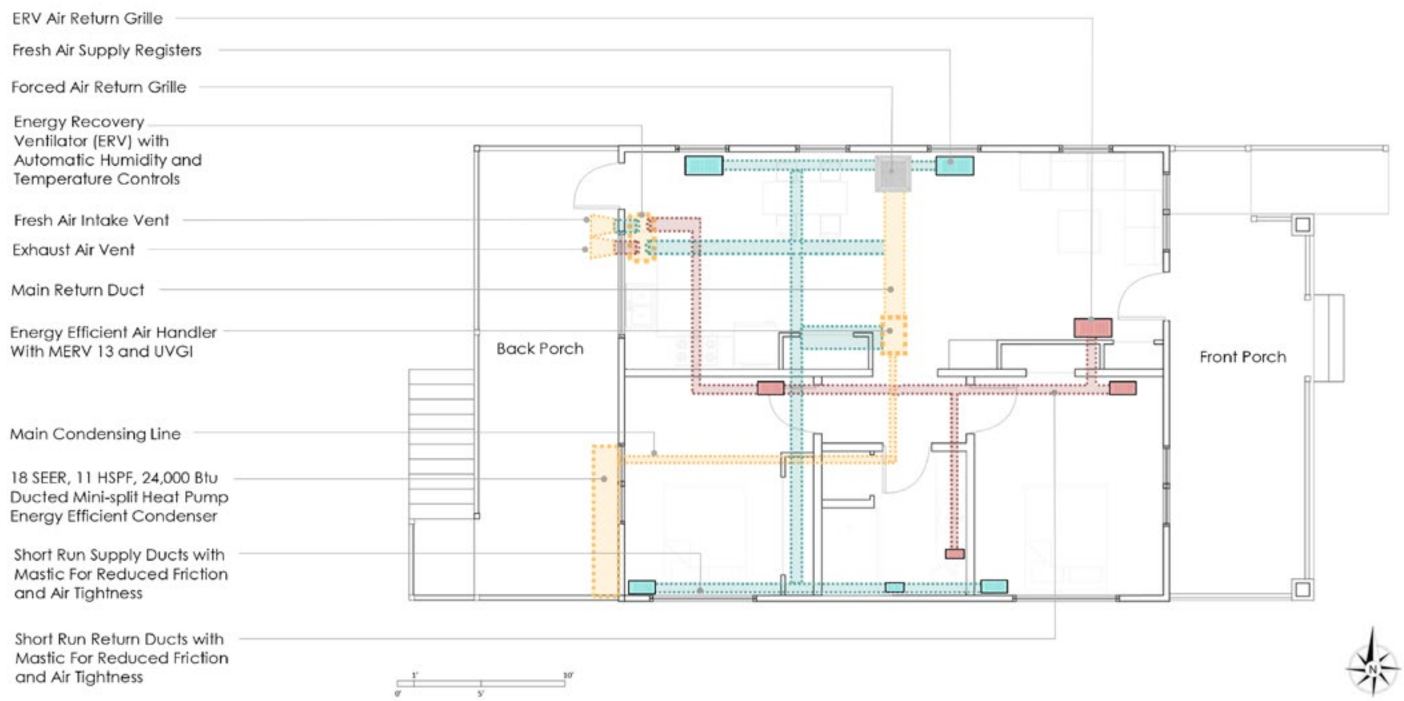



Existing house plan

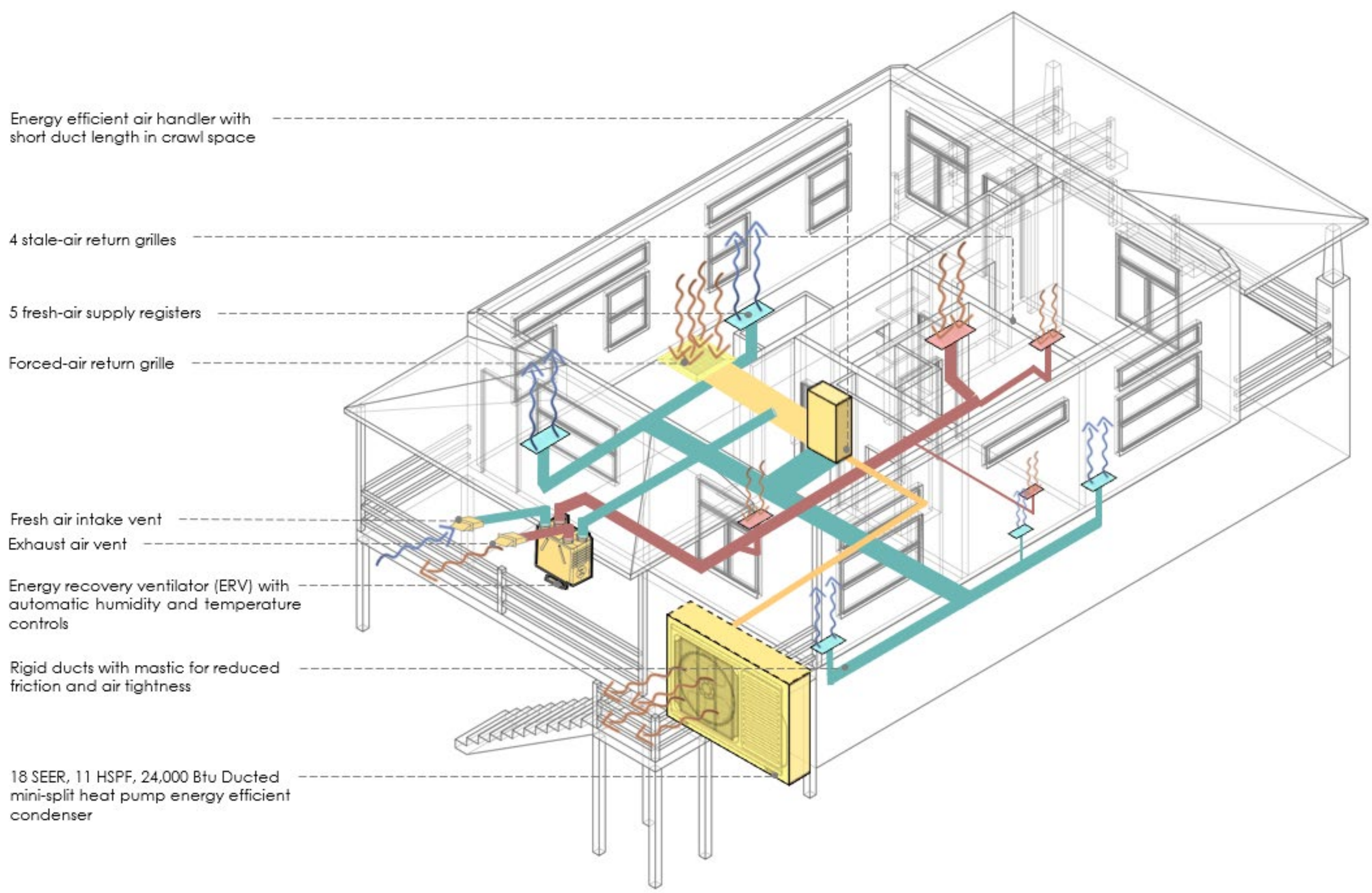



Proposed house plan

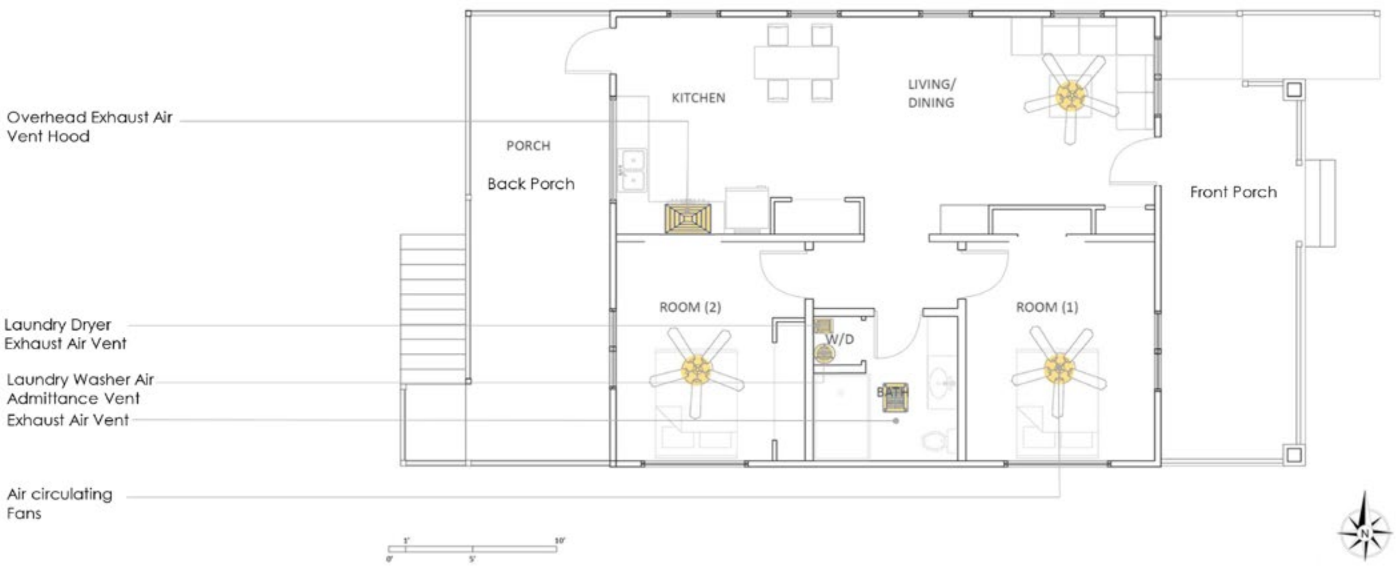
## HVAC system




Duct layout plan




Isometric view of Duct layout




Air circulation and spot ventilation strategies

| COMPONENT | SPECIFICATION |
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| ENERGY RECOVERY VENTILATOR | Automatic humidity and temperature controls with both Intake and Exhaust Vents |
| AIR HANDLER | Energy Efficient and Centrally Located |
| CONDENSING LINE | 30' Insulated Line |
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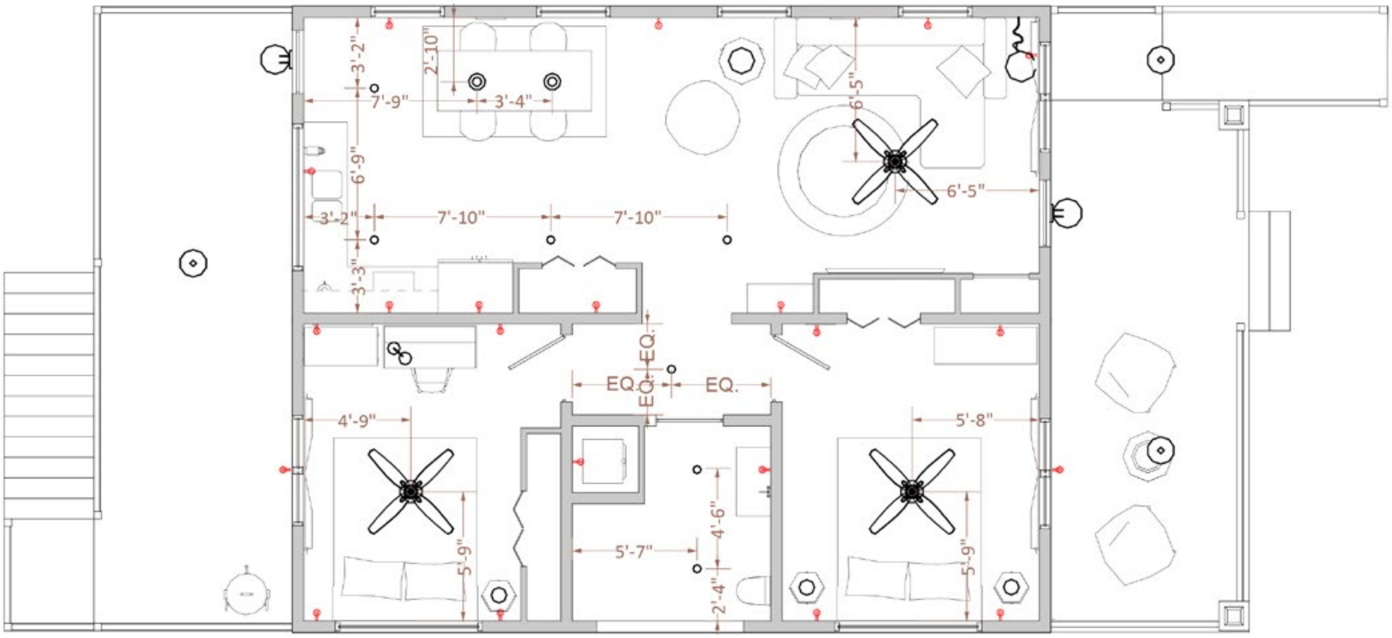
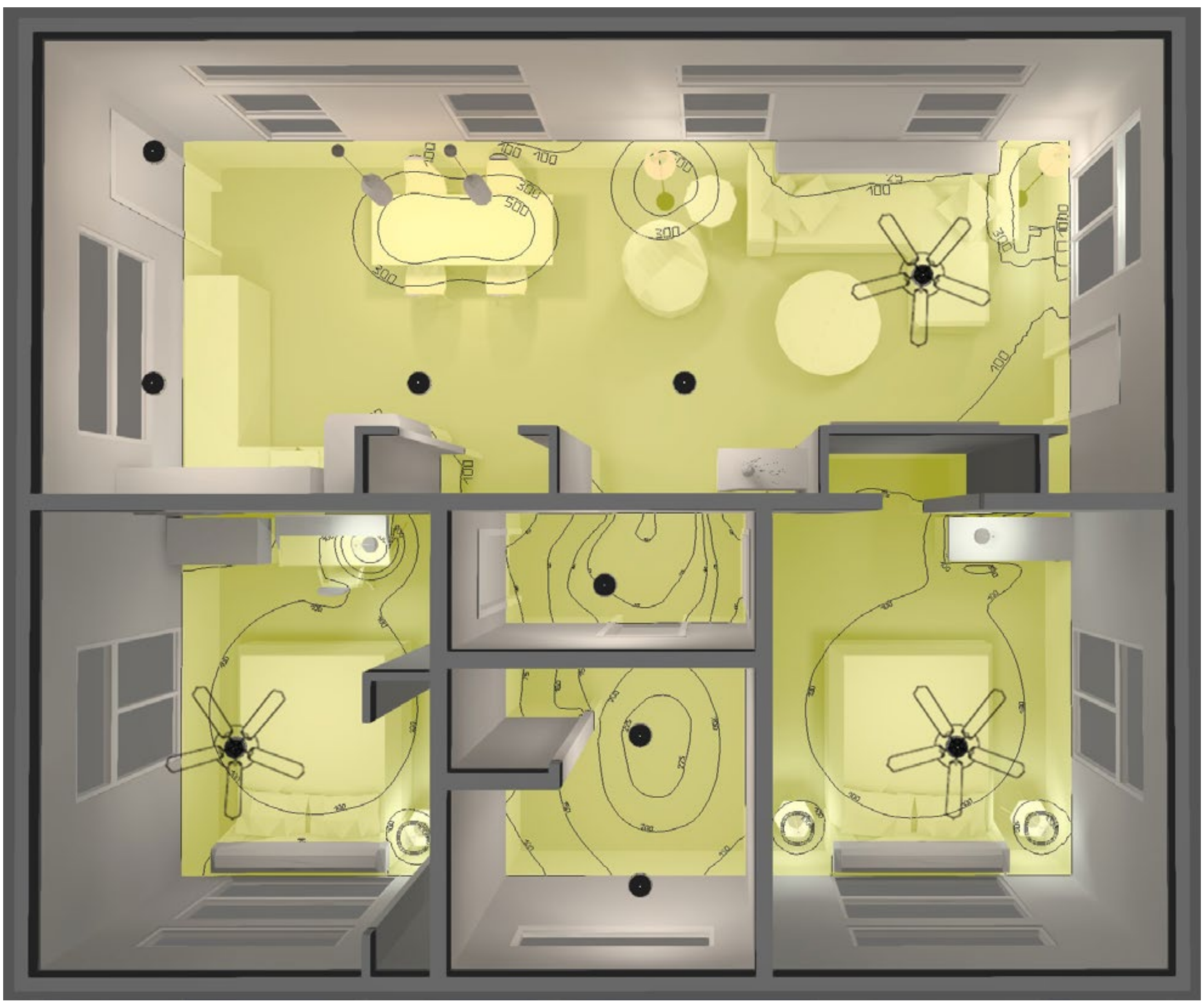
| UVGI BULB | 18 W, 254NM, 8.66 in, 10,000 hours |
| OVERHEAD KITCHEN HOOD EXHAUST VENT | 36", 2 Speed, 120 volts, 390 CFM, 2850 RPM |
| 3 FIVE BLADE CEILING FANS | Remote control 120 volts, 59 W, 6 Speed, 4848 CFM, Air Flow Efficiency of 78 |
| BATHROOM EXHAUST VENT | 120 volts, 17.9 W, 80 CFM, 4" Duct |
| LAUNDRY DRYER EXHAUST VENT | Passive 4" |
| LAUNDRY WASHER AIR ADMITTANCE VENT | Passive 3" |

Mechanical Schedule

## Electrical system



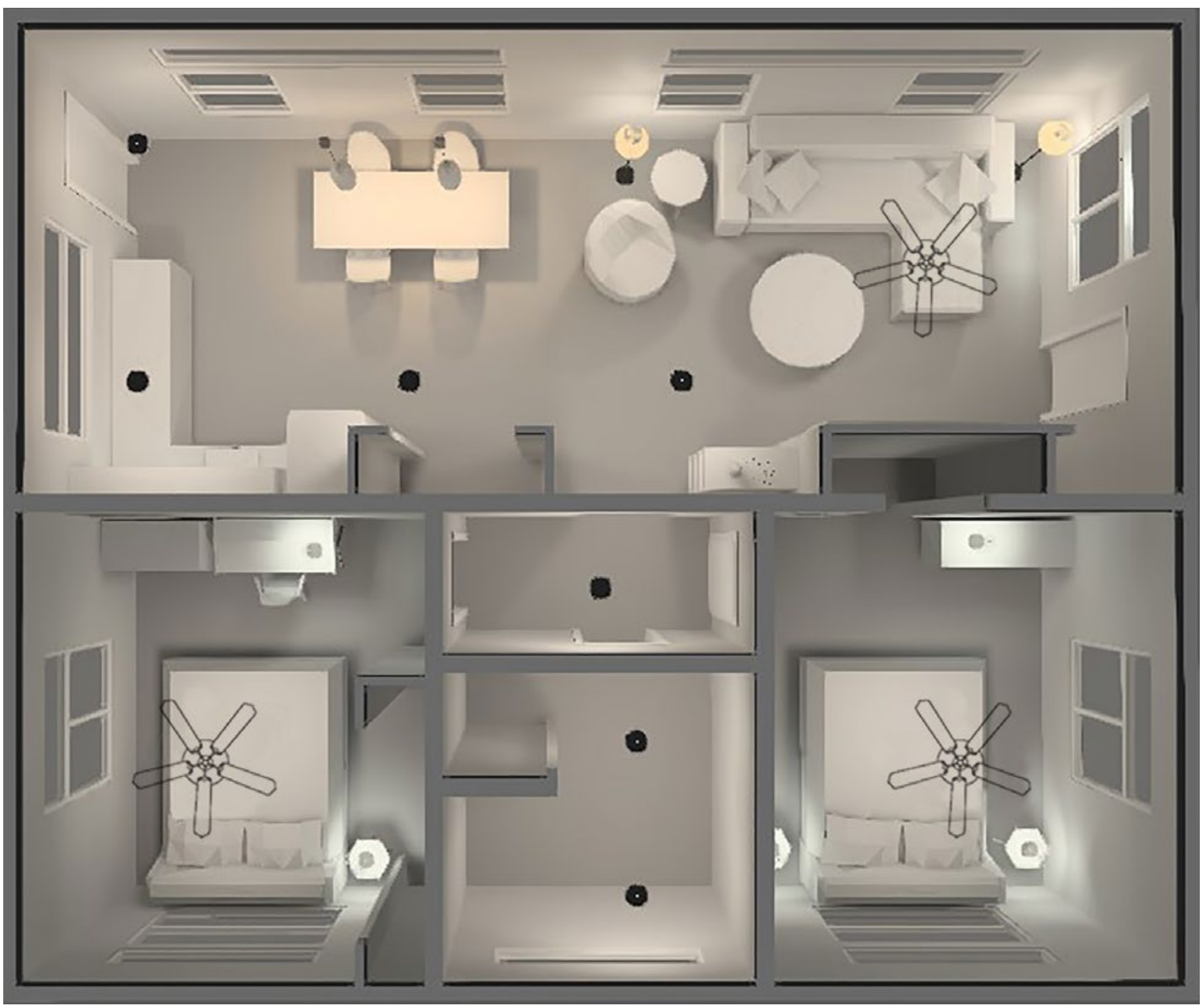

Electrical layout



DIALux analysis of lux level contours for indoor lighting

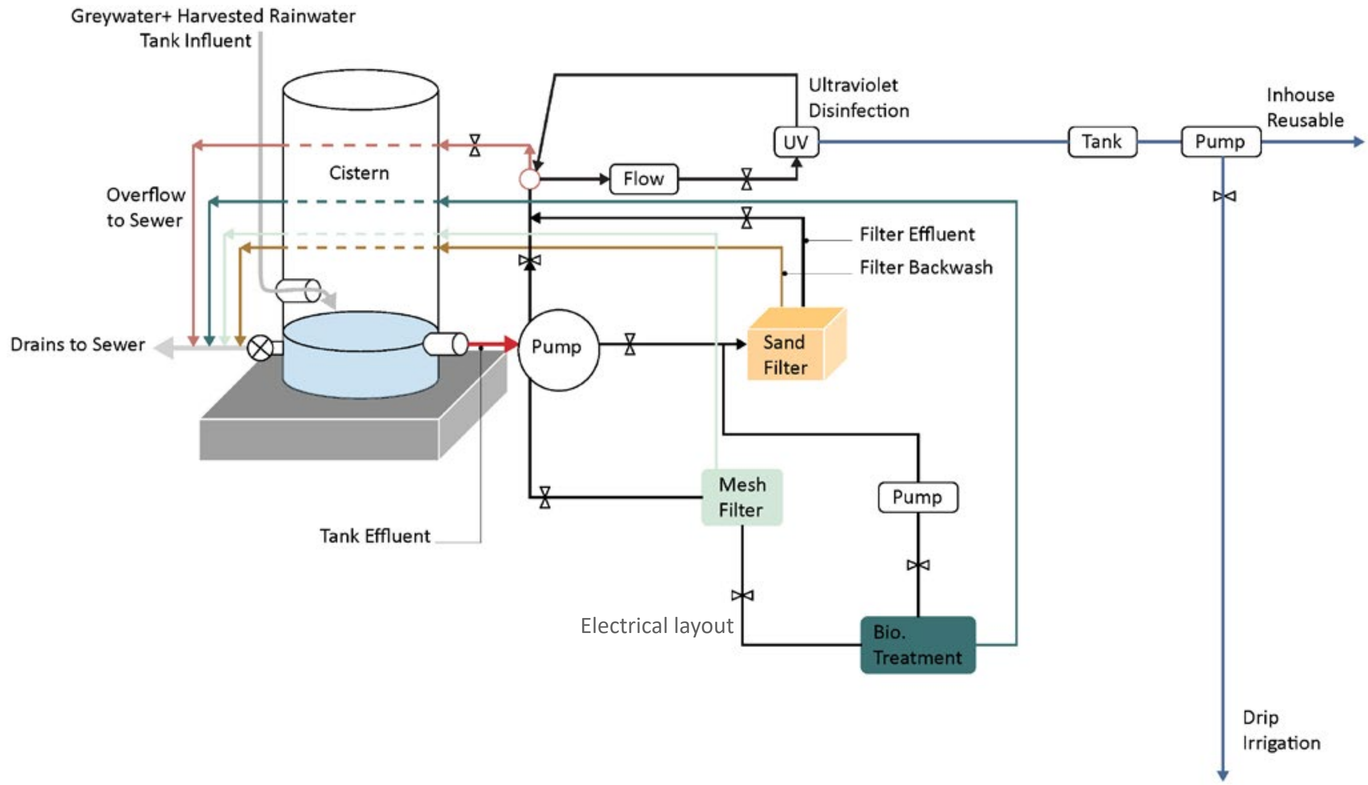
| English Avenue Retrofit house - Luminaire list | | | | | | | |
|---|---|---|---|---|---|---|---|
| No. of pcs. | Liminaire Article No. | Luminaire Article name | P (W) per fixture | P (W) total | 0 (lm) per fixture | 0 (lm) total | Luminous efficacy |
| 10 | A1980141<br>WT | STRAM PRISMATIC 1 DIM DALI 3000K WT | 10.5 | 105 | 1435 | 14350 | 136.7 lm/W |
| 1 | 1137020A | Floor Fluorescent lamp with diffuser that is covered by parchment paper | 14 | 14 | 1527 | 1527 | 109.1 lm/W |
| 1 | 1137020A | Floor Fluorescent lamp with diffuser that is covered by parchment paper | 28 | 28 | 1527 | 1527 | 54.6 lm/W |
| 2 | HCC6W10<br>DO1OMB-<br>HM612935 -<br>61 N DH | HCC6 LED 6" Cylinder Downlight Series | 10 | 20 | 7981 | 15962 | 79.8 lm/W |
| 3 | LK-LED 070.0730.0 565.1/DALI AOV-001/003/05.1 | LK-LED 070.0730.0565.1/DALI | 6 | 18 | 650 | 1950 | 108.4 lm/W |
| 5 | 260081.5L 02.202 | DAGALI TABLE LED 280 710lm 3000K opal matt (PMMA) white | 6 | 30 | 711 | 3555 | 118.4 lm/VV |
| 3 | MAXIM - Basic 89908SWOIWP | LED downlight with fan | 18 | 54 | 1650 | 4950 | |
| | | | | 269 | | 43821 | |
| | | | | **269 W** | | **43821 lm** | **114.0 1m/W** |
| | | | | **Ptotal** | | **Ototal** | **Luminous efficacy** |

Electrical schedule

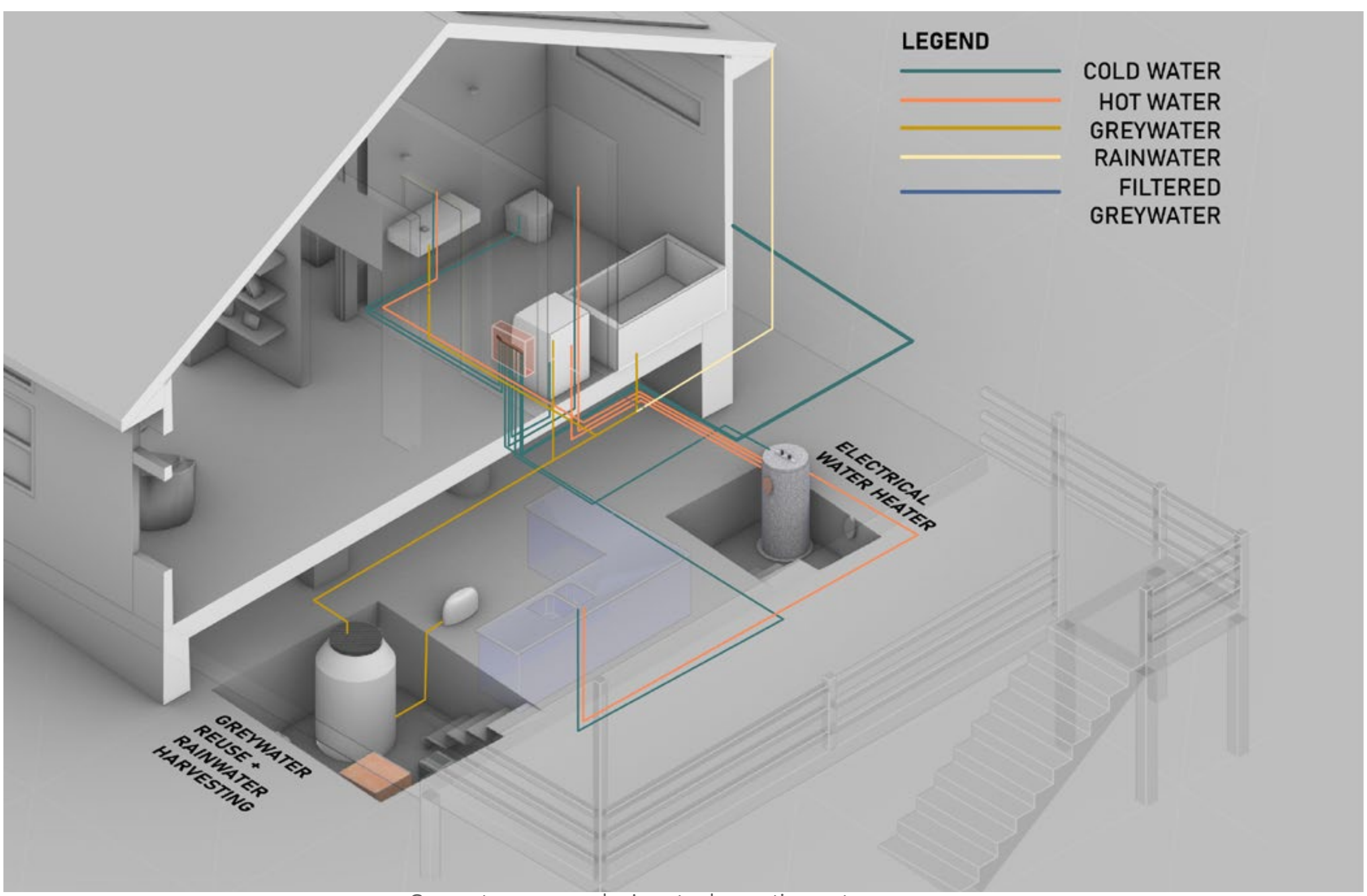


DIALux analysis of indoor lighting

## Grey water reuse, rainwater harvesting and plumbing




Process flowchart for geywater reuse and rainwater harvesting systems




Greywater reuse and rainwater harvesting system

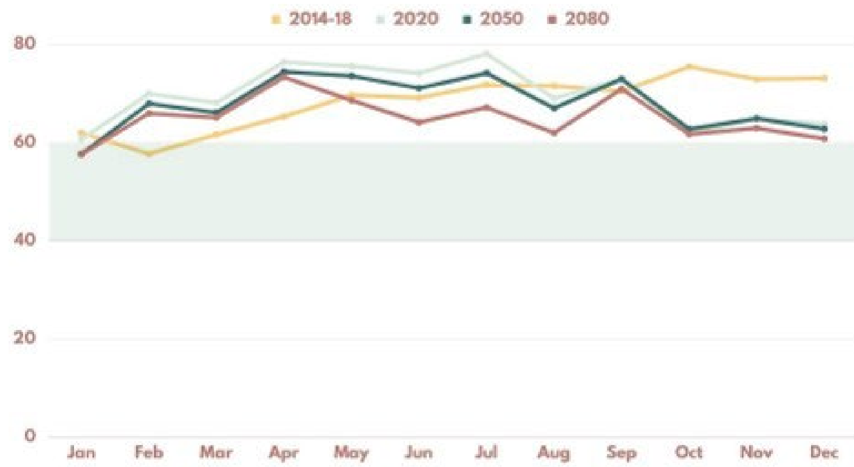
| PLUMBING FIXTURE SCHEDULE | | | | | |
|---|---|---|---|---|---|
| | | PIPE SIZES | | | |
| QTY | FIXTURE | C.W. | H.W. | DRAIN | REMARKS |
| 1 | FLOOR MOUNTED WATER CLOSET | 1" | -- | 3" | 1.28 GPF |
| 1 | KITCHEN SINK - 1 BASIN | 1" | 1" | 2" | 1.5 GPM |
| 1 | SINK - 24" WORK | 1/2" | 1/2" | 1 1/2" | ATCT |
| 1 | MOP SINK | 1/2" | 1/2" | 2 1/2" | |
| 1 | SHOWER- WHITE | 1/2" | 1/2" | 2" | SMOOTH WALL, BARRIER FREE, L-SHAPED GRAB BAR, 3/4 INCH SKIRT, CENTER DRAIN AND GELCOATED SURFACE. ACCEPTABLE MANUFACTURERS: AQUATIC (1363BFSD) SHOWER VALVE: PRESSURE BALANCED MIXING VALVE SHALL BE FLUSH MOUNTED WITH CONCEALED PIPING AT ADA REQUIRED HEIGHT, SINGLE LEVER HANDLE AND INTEGRAL SCREWDRIVER STOPS. SET LIMIT STOPS AT 110°F, 2.5 GPM FLOW CONTROL, WITH COMBINATION SLIDE AND GRAB BAR. ACCEPTABLE MANUFACTURERS: AQUATIC (PART OF ADA PACKAGE), DELTA, AMERICAN STANDARD, SYMMONS, SPEAKMAN, LEONARD, POWERS. SHOWER TRIM: PROVIDE WITH SOAP DISH, BRASS DRAIN AND ADA COMPLIANT SHOWER CURTAIN. PROVIDE ADA SEAT IN LEFT HAND OR RIGHT HAND CONFIGURATION AS INDICATED ON DRAWINGS. |
| 1 | SHOWER MIXING VALVE | 1/2" | 1/2" | 1 1/2" | 1.5 GPM |
| 1 | FLOOR MOUNTED WATER CLOSET - TANK | 1/2" | -- | 3" | |
| 1 | FLOOR DRAIN | 1/2" | -- | 4" | FLOOR DRAIN - DUCCO CAST IRON BODY WITH ROUND, POLISHED NICKEL-BRONZE FINISHED STRAINER, HEEL-PROOF GRATE, WITH ADJUSTABLE STRAINER HEAD. PROVIDE WITH TS-1. ACCEPTABLE MANUFACTURERS: JAY R. SMITH (2005) ZURN, WADE, OR JOSAM. |
| 1 | FLOOR DRAIN WITH CLEANOUT | 1/2" | -- | 4" | |
| 1 | SHOWER DRAIN -- | | -- | 2" | |
| 1 | FLUSH MOUNT WALL CLEANOUT -- | | -- | 3" | |
| 1 | CISTERN | 2" | 1-1/2" | 4" | 6000 Gallon Polyethylene Plastic Storage; 102" dia. x 182"H; DURA-CAST PREFERABLE |
| 1 | PRESSURE REGULATING VALVE- LEAD FREE | 1-1/2" | N/A | N/A | PROVIDE WITH PRESSURE AND TEMPERATURE GAUGES AT OUTLET. ACCEPTABLE MANUFACTURERS: WATTS (LF25AUB-Z3), ZURN, BELL AND GOSSETT |
| 1 | REDUCED PRESSURE BACKFLOW PREVENTER | 1-1/2" | N/A | N/A | REDUCED PRESSURE BACKFLOW PREVENTER - BRONZE SEATS AND STAINLESS STEEL TRIM. THE ASSEMBLY SHALL INCLUDE QUARTER TURN SHUT-OFF VALVES, TEST COCKS, AND WYE STRAINER. ACCEPTABLE MANUFACTURERS: WATTS (LF909QT). |
| 4 | TRASH PUMP | 1-1/2" | 1-1/2" | N/A | RECOMEDED USE IN GREYWATER/RAINWATER SYSTEM; ACCEPTABLE MANUFACTURERS: TSURUMI SUBMERSIBLE TRASH PUMP |
| 1 | SAND FILTER | 1-1/2" | 1-1/2" | N/A | ACCEPTABLE MANUFACTURERS: WATERWAY, BLUE WAVE, HAYWARD PRO |

Plumbing schedule

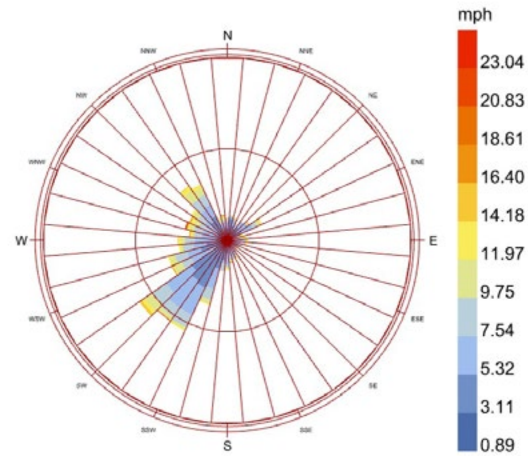
**Cabinetry finishes options**

| | Material | Material specifications |
|---|---|---|
|  | Medium density fiberboard core | **Description:** Formaldehyde-free(NAF) MDF – FSC certified<br><br>**Board:** 100 lb per ¾" panel, 4x6x1/8" (l x w x t), primed finish<br><br>**Application:** Paneling,<br>kitchen and bathroom cabinet(least affected by humidity, temperature changes), AFM Safecoat Durostain sealer |
|  | Maple laminate | **Description:** Urea formaldehyde-free(NAUF) – FSC certified<br><br>**Board:** ½" Laminated board – cabinet face, 5/8" shelving and storage<br><br>**Application:** Cabinets |
|  | Medium density fiberboard veneered panels | **Description:** Formaldehyde-free(NAF) MDF – FSC certified<br><br>**Board:** 109.8 x48.8"x ¾" (l x w x t) 2 sided, prefinished 10% sheen matte finish<br><br>**Application:** Cabinets, AFM Safecoat sealer |

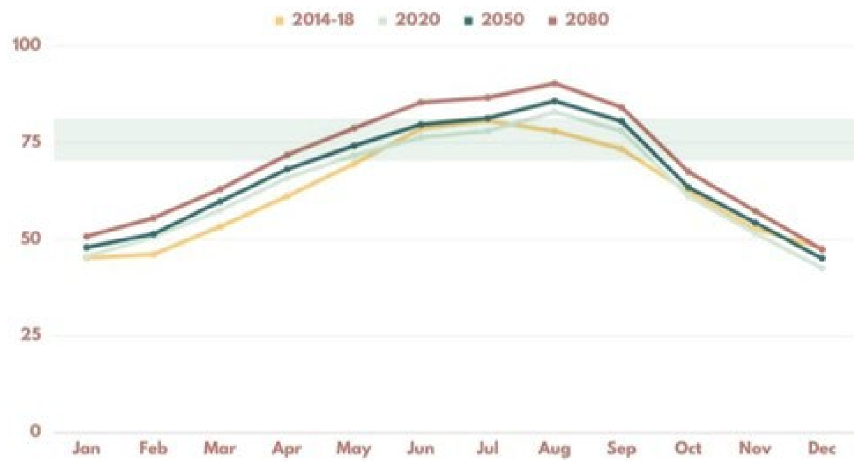
## Climate analysis



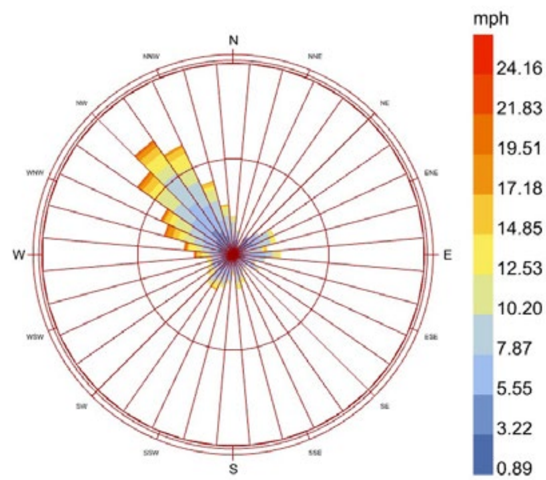
Relative Humidity for year 2014-2080



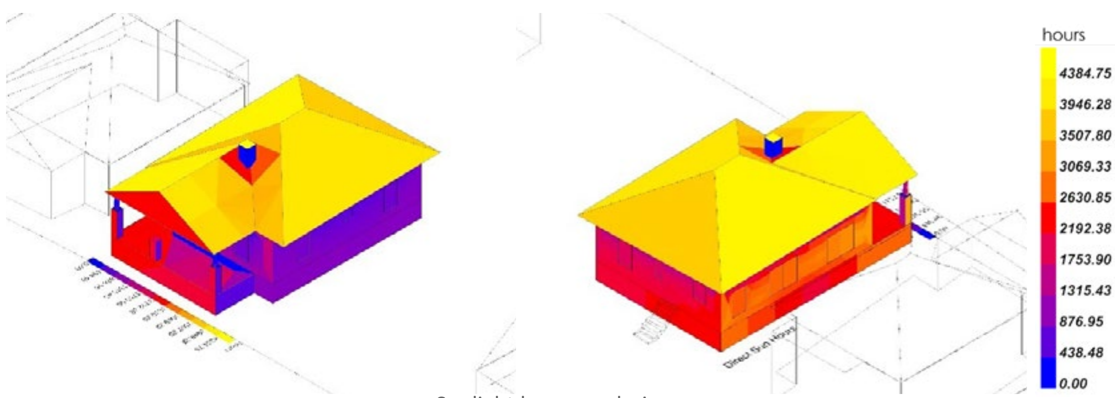
Summer wind direction



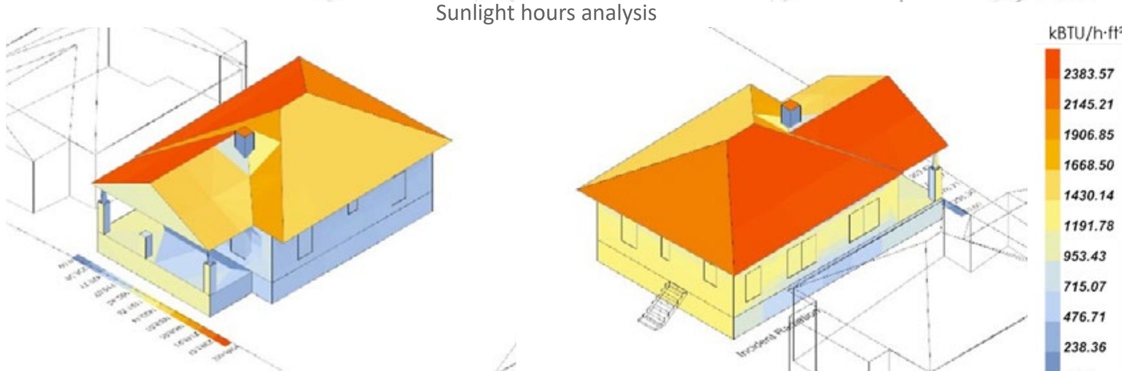
Dry Bulb temperature for year 2014-2080



Winter wind direction

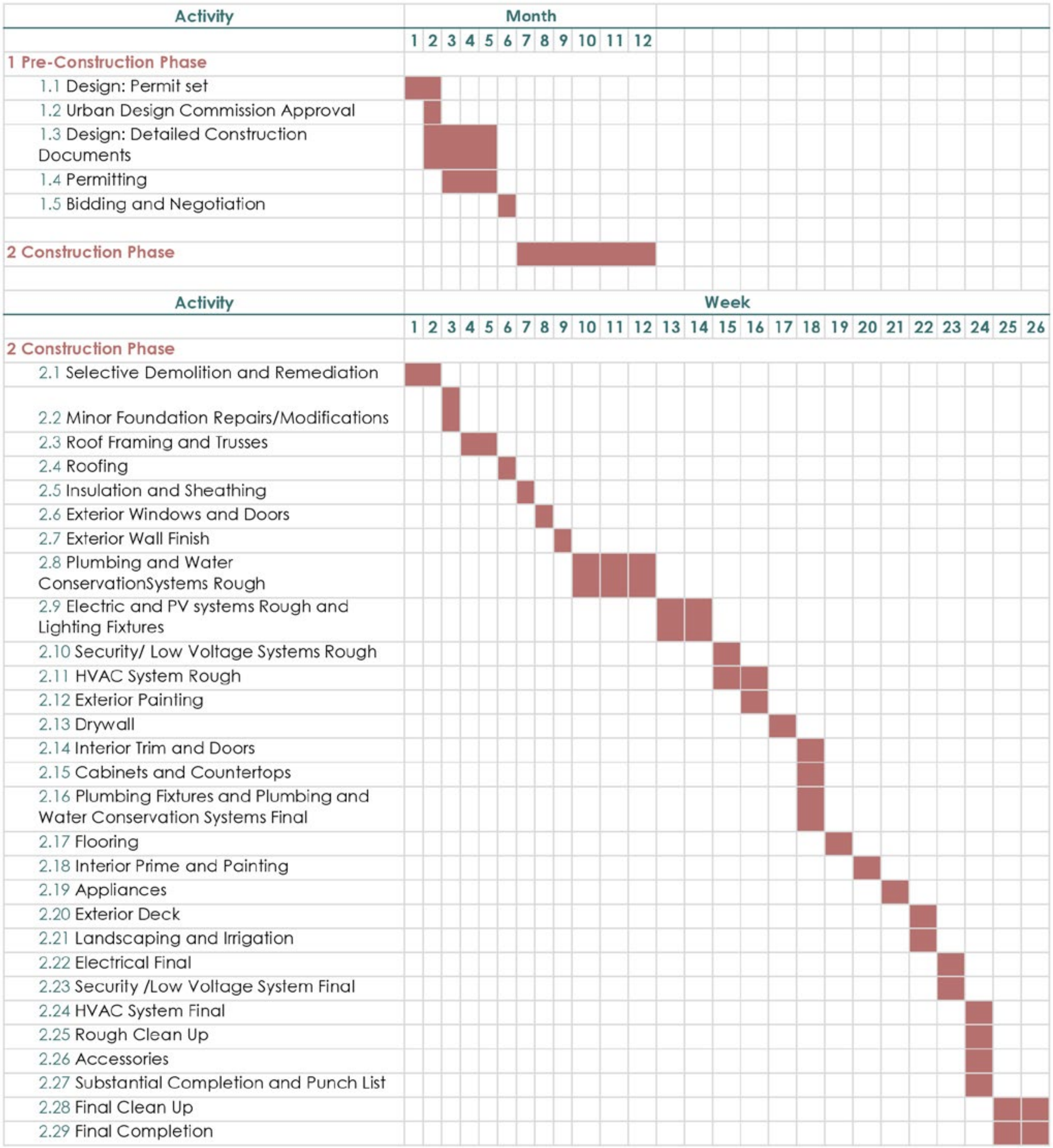


Sunlight hours analysis



Incident solar radiation analysis

**Construction schedule**



## Detailed budget 50-60% AMI

| | | |
|---|---|---|
| **Existing Home Size (sf)** | **946** | |
| | | **$/sf** |
| **Total High Level Budget ($)** | **2,29,680** | **242.79** |
| **Minus Contingency ($)** | -23,280 | |
| **Construction Budget ($)** | **2,06,400** | **218.18** |
| **Minus Atlanta Housing Authority Subsidy** | -10,000 | |
| **Minus Invest Atlanta Subsidy** | -20,000 | |
| **Minus NMTC Subsidy** | -33,000 | |
| **Minus Other WFF Private Subsidy** | -27,000 | |
| **Offering Price to Homeowner (50% AMI)** | **1,16,400** | **123.04** |
| **Offering Price if Contingency is Used (60% AMI)** | **1,39,680** | **147.65** |

**588 James P. Brawley Renovation - Detailed Construction Budget - 50%/60% AMI Scxenario**

**Construction Cost Breakdown**

| | | | | |
|---|---|---|---|---|
| **I. Design and Entitlements** | | **$** | **%** | **$/sf** |
| | A. Building and Permit Fees | 2,379 | 1.04% | 2.52 |
| | B. A&E Fees (6% of Construction Budget) | 12,384 | 5.39% | 13.09 |
| | C. Other | 336 | 0.15% | 0.36 |
| | | **15,100** | **6.57%** | **15.96** |
| **II. Demolition** | | **$** | **%** | **$/sf** |
| | D. Selective Demolition | 4,854 | 2.11% | 5.13 |
| | | **4,854** | **2.11%** | **5.13** |
| **III. Foundation** | | **$** | **%** | **$/sf** |
| | E. Foundation Repairs/Modifications | 4,703 | 2.05% | 4.97 |
| | F. Other | 626 | 0.27% | 0.66 |
| | | **5,329** | **2.32%** | **5.63** |
| **IV. Framing** | | **$** | **%** | **$/sf** |
| | G. Framing (including Roof) | 9,500 | 4.14% | 10.04 |
| | H. Trusses | 2,936 | 1.28% | 3.10 |
| | I. Sheathing | 2,106 | 0.92% | 2.23 |
| | J. General Metal, Steel | 446 | 0.19% | 0.47 |
| | K. Other | 248 | 0.11% | 0.26 |
| | | **15,237** | **6.63%** | **16.11** |
| **V. Exterior Finishes** | | **$** | **%** | **$/sf** |
| | L. Exterior Wall Finish | 10,846 | 4.72% | 11.47 |
| | M. Roofing | 4,657 | 2.03% | 4.92 |
| | N. Windows and Doors | 4,946 | 2.15% | 5.23 |
| | O. Other | 314 | 0.14% | 0.33 |
| | | **20,763** | **9.04%** | **21.95** |

| VI. Major System Rough-Ins | $ | % | $/sf |
|---|---|---|---|
| P. Plumbing (Except Fixtures) | 8,278 | 3.60% | 8.75 |
| Q. Electrical (Except Fixtures) | 6,455 | 2.81% | 6.82 |
| R. HVAC | | | |
| *i. 18 SEER, 11 HPSF, 24,000 Btuh Heat Pump Condenser* | *2,160* | | |
| *ii. Air Handler* | *1,831* | | |
| *iii. Energy Recovery Ventilator (ERV) w/ UVGI and MERV13 Filtration* | *1,153* | | |
| *iv. Smart Thermostat* | *109* | | |
| *v. Kitchen Hood Exhaust Vent* | *296* | | |
| *vi. Bathroom Exhaust Fan* | *93* | | |
| *vii. Supply and Return Grilles* | *140* | | |
| *viii. Piping, Ductwork, and Conduit Allowance* | *4,655* | | |
| *ix. Labor/Installation* | *3,131* | | |
| | 13,568 | 5.91% | 14.34 |
| S. Other | 474 | 0.21% | 0.50 |
| T. Water Conservation Systems (Cistern and Graywater Filtration) | | | |
| *i. 6,000 Gallon Below Grade Poly Cistern* | *5,752* | | |
| *ii. (3) 1/2 HP VFD Shallow Well Jet Pumps* | *866* | | |
| *iii. Multi-Phase Water Filtration System w/ UVGI* | *4,138* | | |
| *iv. Piping, and Conduit Allowance* | *1,552* | | |
| *v. Labor/Installation* | *2,462* | | |
| | 14,770 | 6.43% | 15.61 |
| U. Photovoltaics | | | |
| *i. (15) 400W Monocrystaline PV Panels (6 kW total)* | *5,090* | | |
| *ii. 6 kW Hybrid Inverter* | *1,351* | | |
| *iii. 14.4 kWh Lithium Battery* | *9,880* | | |
| *iv. Cabling and Controls Allowance* | *2,586* | | |
| *v. Less Tax Credits* | *-4,916* | | |
| *vi. Labor/Installation* | *1,891* | | |
| | 15,882 | 6.91% | 16.79 |
| | **59,427** | **25.87%** | **62.82** |

| VII. Interior Finishes | $ | % | $/sf |
|---|---|---|---|
| V. Thermal Barriers and Air Sealing | | | |
| *i. Closed Cell Spray Foam Foundation Insulation* | *2,053* | | |
| *ii. Mineral Wool Board Wall Insulation* | *228* | | |
| *iii. Loose Fill Blown In Cellulose Attic Insulation* | *3,963* | | |
| *iv. Air Sealing Package* | *517* | | |
| *v. Labor/Installation* | *968* | | |
| | 7,729 | 3.37% | 8.17 |
| W. Drywall | 1,990 | 0.87% | 2.10 |
| X. Interior Trim, Doors, Mirrors | 4,961 | 2.16% | 5.24 |
| Y. Painting | 3,862 | 1.68% | 4.08 |
| Z. Lighting | 1,143 | 0.50% | 1.21 |
| AA. Cabinets and Countertops | 6,335 | 2.76% | 6.70 |
| AB. Appliances | 3,746 | 1.63% | 3.96 |
| AC. Flooring | 5,613 | 2.44% | 5.93 |
| AD. Plumbing Fixtures | 1,922 | 0.84% | 2.03 |
| AF. Other | 432 | 0.19% | 0.46 |
| | **37,733** | **16.43%** | **39.89** |

| VIII. Final Steps | $ | % | $/sf |
|---|---|---|---|
| AG. Landscaping | 1,522 | 0.66% | 1.61 |
| AH. Outdoor Structures (Rear Deck) | 2,821 | 1.23% | 2.98 |
| AJ. Clean Up | 1,398 | 0.61% | 1.48 |
| AK. Other | 188 | 0.08% | 0.20 |
| | **5,929** | **2.58%** | **6.27** |

| IX. Miscellaneous | $ | % | $/sf |
|---|---|---|---|
| AL. Other | 2,088 | 0.91% | 2.21 |
| | **2,088** | **0.91%** | **2.21** |
| **X. General Contractor Fees** | **$** | **%** | **$/sf** |
| AM. Project Management ($500/wk) | 13,000 | 5.66% | 13.74 |
| AN. Project Administration ($150/wk) | 3,900 | 1.70% | 4.12 |
| AO. General Conditions ($400/mo) | 2,400 | 1.04% | 2.54 |
| AP. Contractor's Profit (10% of Construction Budget) | 20,640 | 8.99% | 21.82 |
| | **39,940** | **17.39%** | **42.22** |
| **XI. Contingency** | **$** | **%** | **$/sf** |
| AQ. Contingency Allowance | 23,280 | 10.14% | 24.61 |
| | **23,280** | **10.14%** | **24.61** |
| **Total** | **2,29,680** | **100.00%** | **242.79** |

**2020 Workforce Owner Housing Maximums**

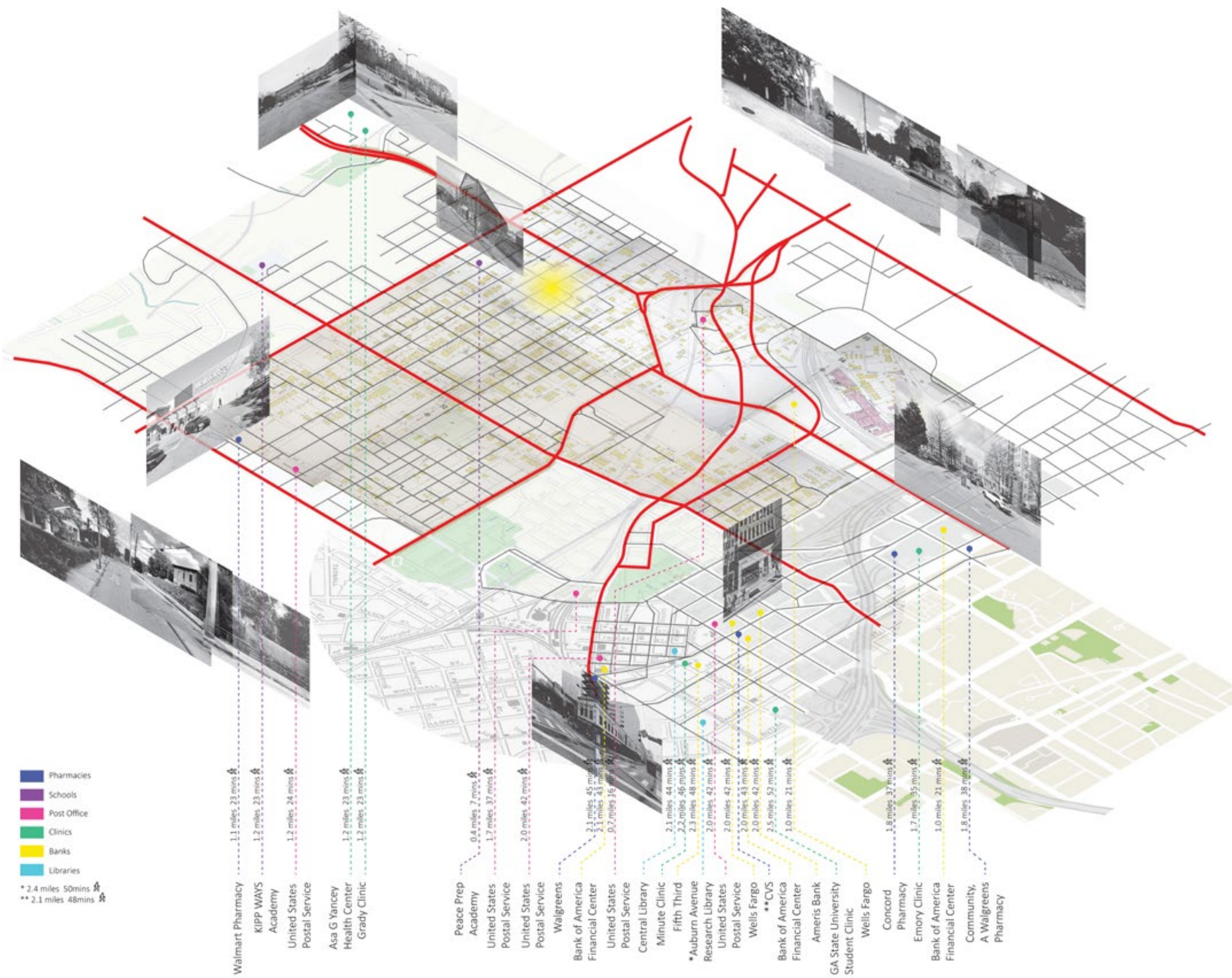
| | Efficiency | 1 Bedroom | 2 Bedroom | 3 Bedroom | 4 Bedroom |
|---|---|---|---|---|---|
| Max Sale Price at 60% AMI | $108,720 | $116,460 | $139,680 | $161,370 | $180,000 |
| Max Sale Price at 80% AMI | $144,960 | $155,280 | $186,240 | $215,160 | $240,000 |
| Max Sale Price at 100% AM | $181,200 | $194,100 | $232,800 | $268,950 | $300,000 |
| Max Sale Price at 120% AM | $217,440 | $232,920 | $279,360 | $322,740 | $360,000 |
| Max Sale Price at 140% AM | $243,180 | $271,740 | $325,920 | $376,530 | $420,000 |

| **Wealth Creation - 60% AMI** | | |
|---|---|---|
| Market Value of Home Today | 2,99,880 | * Based On Comparables Listed On Zillow Near English Avenue |
| Current Home Escalation Rate | 4.80% | * Per Harvard University Joint Center for Housing Studies, Atlanta Market, February of 2020 (pre-pandemic) |
| Market Value After 6 Year Hold | 3,79,100 | |
| Equity Created | 2,39,420 | |
| **Equity To Homeowner (25%)** | **59,855** | |
| Home Price to Next Homeowner | 1,99,535 | |
| Annual Utility Savings | 1,367 | |
| Annual Escalation Rate | 3.10% | * Match Annual Inflation Rate |
| **Value Over 6 Year Hold** | **8,867** | |
| Annual Property Tax | 3,209 | * Based on 1.07% of Market Value Per Zillow |
| Percentage of Land in Assessment | 45.00% | * Rough average of assessments on same block. |
| Annual Prop. Tax Savings | 1,444 | |
| **Value Over 6 Year Hold** | **8,664** | |
| Annual Maintenance Savings | 946 | * Budget $1/sf |
| Average Annual Inflation Rate | 3.10% | * Average Annual Inflation Rate Over Last 20 Years |
| **Value Over 6 Year Hold** | **6,135** | |
| | **83,521** | |

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Homeowner Equity Share | | | | | | 59,855 | |
| Utility Savings | 1,367 | 1,410 | 1,454 | 1,499 | 1,545 | 1,593 | |
| Property Tax Savings | 1,444 | 1,444 | 1,444 | 1,444 | 1,444 | 1,444 | |
| Maintenance Savings | 946 | 975 | 1,006 | 1,037 | 1,069 | 1,102 | |
| | | | | | | | **Total** |
| | 3,757 | 3,829 | 3,903 | 3,979 | 4,058 | 63,994 | 83,521 |

**NPV 3.1% 71,096 In today's dollars at average annual inflation rate of the past 20 years.**

**Context of English Avenue**



## Appendix C - Energy performance summary

**HERS certificate before PV installation**

# Home Energy Rating Certificate

Projected Report

Rating Date:
Registry ID:
Ekotrope ID: 123nRNav

**HERS® Index Score:**

**44**

Your home's HERS score is a relative performance score. The lower the number, the more energy efficient the home. To learn more, visit www.hersindex.com

**Annual Savings**

**$883**

*Relative to an average U.S. home

**Home:**
588 James P Brawley
Atlanta, GA 30318

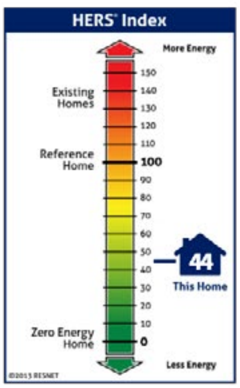
**Builder:**

### Your Home's Estimated Energy Use:

| | Use [MBtu] | Annual Cost |
|---|---|---|
| Heating | 5.6 | $132 |
| Cooling | 1.8 | $41 |
| Hot Water | 5.6 | $130 |
| Lights/Appliances | 12.9 | $303 |
| Service Charges | | $0 |
| Generation (e.g. Solar) | 0.0 | $0 |
| **Total:** | **25.9** | **$607** |

### This home meets or exceeds the criteria of the following:

2015 International Energy Conservation Code




**Home Feature Summary:**

| | |
|---|---|
| Home Type: | Single family detached |
| Model: | N/A |
| Community: | N/A |
| Conditioned Floor Area: | 946 ft² |
| Number of Bedrooms: | 2 |
| Primary Heating System: | Air Source Heat Pump • Electric • 9 HSPF |
| Primary Cooling System: | Air Source Heat Pump • Electric • 18 SEER |
| Primary Water Heating: | Solar Water Heater • Electric • 1.34 Energy Factor |
| House Tightness: | 1 ACH50 |
| Ventilation: | 100 CFM • 81 Watts |
| Duct Leakage to Outside: | 0 CFM @ 25Pa (0 / 100 ft²) |
| Above Grade Walls: | R-18 |
| Ceiling: | Attic, R-57 |
| Window Type: | U-Value: 0.27, SHGC: 0.21 |
| Foundation Walls: | R-6 |
| Framed Floor: | N/A |

### Rating Completed by:

**Energy Rater:** Samantha Morton
RESNET ID:

**Rating Company:** Georgia Tech - English Avenue Yellow Jackets

**Rating Provider:**

Samantha Morton, Certified Energy Rater
Date: 4/4/22 at 2:44 PM

ekotrope

Ekotrope RATER - Version:4.0.1.2869
The Energy Rating Disclosure for this home is available from the Approved Rating Provider.
This report does not constitute any warranty or guarantee.

### IECC 2015 Fuel Summary Comparison

**Property**
588 James P Brawley
Atlanta, GA 30318

**Organization**
Georgia Tech - English Avenu
Samantha Morton

**Inspection Status**
Results are projected

Solar Decathlon Final
Final House Design w/o PV

**Builder**

| Annual Energy Cost [$/yr] | 2015 IECC | Rated Home | Savings | % Saved |
|---|---|---|---|---|
| Electric | $898 | $890 | $8 | 0.9% |

| Annual End-Use Cost [$/yr] | 2015 IECC | Rated Home | Savings | % Saved |
|---|---|---|---|---|
| Heating | $212 | $178 | $34 | 16% |
| Cooling | $76 | $78 | -$2 | -2.6% |
| Water Heating | $235 | $235 | $0 | 0% |
| Lights & Appliances | $375 | $399 | -$24 | -6.4% |
| Onsite Generation | -$0 | -$0 | $0 | 0% |
| Service Charges | $0 | $0 | $0 | 0% |
| Total | $898 | $890 | $8 | 0.9% |

| Annual End-Use Consumption | 2015 IECC | Rated Home | Savings | % Saved |
|---|---|---|---|---|
| Heating [Electric kWh] | 2,013.8 | 1,691.5 | 322.3 | 16% |
| Cooling [Electric kWh] | 722.2 | 740.0 | -17.8 | -2.5% |
| Hot Water [Electric kWh] | 2,228.1 | 2,228.1 | 0.0 | 0% |
| Lights & Appliances [Electric kWh] | 3,561.3 | 3,790.1 | -228.8 | -6.4% |
| Total [Electric kWh] | 8,525.4 | 8,449.7 | 75.8 | 0.9% |
| Total Onsite Generation kWh | 0.0 | 0.0 | 0.0 | 0% |

| Peak Electric Consumption | 2015 IECC | Rated Home | Savings | % Saved |
|---|---|---|---|---|
| Peak Winter kW | 1.81 | 1.73 | 0.08 | 4.5% |
| Peak Summer kW | 1.16 | 1.17 | -0.01 | -0.6% |

| Utility Rates | |
|---|---|
| Electricity | Georgia Power |
| Natural Gas | Dereg. |

**HERS certificate after PV installation**

# Home Energy Rating Certificate

Projected Report

Rating Date:
Registry ID:
Ekotrope ID: 123nRNav

## HERS® Index Score:

**-1**

Your home's HERS score is a relative performance score. The lower the number, the more energy efficient the home. To learn more, visit www.hersindex.com

## Annual Savings

**$1,490**

*Relative to an average U.S. home

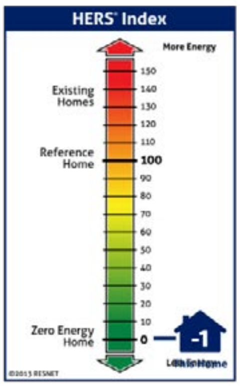
**Home:**
588 James P Brawley
Atlanta, GA 30318
**Builder:**

## Your Home's Estimated Energy Use:

| | Use [MBtu] | Annual Cost |
|---|---|---|
| Heating | 5.6 | $132 |
| Cooling | 1.8 | $41 |
| Hot Water | 5.6 | $130 |
| Lights/Appliances | 12.9 | $303 |
| Service Charges | | $0 |
| Generation (e.g. Solar) | 26.6 | -$607 |
| **Total:** | **25.9** | **$0** |

## This home meets or exceeds the criteria of the following:

2015 International Energy Conservation Code

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| Model: | N/A |
| Community: | N/A |
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| House Tightness: | 1 ACH50 |
| Ventilation: | 100 CFM • 81 Watts |
| Duct Leakage to Outside: | 0 CFM @ 25Pa (0 / 100 ft²) |
| Above Grade Walls: | R-18 |
| Ceiling: | Attic, R-57 |
| Window Type: | U-Value: 0.27, SHGC: 0.21 |
| Foundation Walls: | R-6 |
| Framed Floor: | N/A |

## Rating Completed by:

**Energy Rater:** Samantha Morton
RESNET ID:

**Rating Company:** Georgia Tech - English Avenue Yellow Jackets

**Rating Provider:**

Samantha Morton, Certified Energy Rater
Date: 4/4/22 at 2:52 PM

**ekotrope**

Ekotrope RATER - Version:4.0.1.2869
The Energy Rating Disclosure for this home is available from the Approved Rating Provider.
This report does not constitute any warranty or guarantee.

# 588 James P Brawley

**Atlanta, GA 30318**

**Builder:**

**This report is based on a proposed design and does not confirm field enforcement of design elements.**

## THIS HOME IS CERTIFIED TO MEET THE 2015 INTERNATIONAL ENERGY CONSERVATION CODE

### Building Features

| | | | |
|---|---|---|---|
| **Ceiling** | Attic, R-57 | **Duct** | Supply R-6.0, Return R-6.0 |
| **Above Grade Walls** | R-18 | **Duct Leakage to Outside** | 0 CFM @ 25Pa (0 / 100 ft²) |
| **Foundation Walls** | R-6 | **Total Duct Leakage** | Untested |
| **Framed Floor** | N/A | **Heating** | Air Source Heat Pump • Electric • 9 HSPF |
| **Slab** | N/A | **Cooling** | Air Source Heat Pump • Electric • 18 SEER |
| **Infiltration** | 1 ACH50 | **Water Heating** | Solar Water Heater • Electric • 1.34 Energy Factor |
| **Window** | U-Value: 0.27, SHGC: 0.21 | | |

As a 3rd party extension of the code jurisdiction utilizing these reports, I certify that this energy code compliance document has been created in accordance with the requirements of Chapter 4 of the adopted International Energy Conservation Code based on FULTON County. If rating is Projected, I certify that the building design described herein is consistent with the building plans, specifications, and other calculations submitted with the permit application. If rating is Confirmed, I certify that the address referenced above has been inspected/tested and that the mandatory provisions of the IECC have been installed to meet or exceed the intent of the IECC or will be verified as such by another party.

Name: Samantha Morton
Signature:
Organization: Georgia Tech - English Avenue Yellow Jackets
Date: 4/4/22 at 2:52 PM

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2015 IECC compliance results calculated using Ekotrope RATER's energy and code compliance algorithm.
Ekotrope RATER is a RESNET Accredited HERS Rating Tool. All results are based on data entered by Ekotrope users.
Ekotrope disclaims all liability for the information shown on this report.

**EUI performance summary**

| | Occupancy Schedule | | Occupancy Schedule | | Equipment Schedule | | Lighting Schedule | |
|---|---|---|---|---|---|---|---|---|
| | Living | | Bedroom | | Entire house | | Living | Bedrooms |
| **Hours** | Weekend | Weekday | Weekend | Weekday | Weekend | Weekday | All Days | All Days |
| **0** | 0.6 | 0.5 | 1 | 1 | 0.24 | 0.24 | 0.06 | 0.06 |
| **1** | 0.6 | 0.5 | 1 | 1 | 0.24 | 0.24 | 0.06 | 0.06 |
| **2** | 0.6 | 0.5 | 1 | 1 | 0.24 | 0.24 | 0.06 | 0.06 |
| **3** | 0.6 | 0.5 | 1 | 1 | 0.24 | 0.24 | 0.06 | 0.06 |
| **4** | 0.6 | 0.5 | 1 | 1 | 0.24 | 0.24 | 0.19 | 0.19 |
| **5** | 0.6 | 0.5 | 1 | 1 | 0.24 | 0.24 | 0.39 | 0.39 |
| **6** | 0.7 | 0.75 | 1 | 1 | 0.24 | 0.24 | 0.44 | 0.44 |
| **7** | 0.85 | 0.75 | 1 | 1 | 0.32 | 0.33 | 0.39 | 0.39 |
| **8** | 1 | 0.9 | 0.9 | 0.8 | 0.32 | 0.32 | 0.17 | 0.17 |
| **9** | 1 | 1 | 0.6 | 0.25 | 0.35 | 0.32 | 0.12 | 0.12 |
| **10** | 0.9 | 0.9 | 0.25 | 0.15 | 0.35 | 0.32 | 0.12 | 0.12 |
| **11** | 0.7 | 0.25 | 0.25 | 0.1 | 0.4 | 0.32 | 0.12 | 0.12 |
| **12** | 0.65 | 0.25 | 0.25 | 0.1 | 0.4 | 0.32 | 0.12 | 0.12 |
| **13** | 0.65 | 0.25 | 0.51 | 0.1 | 0.4 | 0.32 | 0.12 | 0.12 |
| **14** | 0.65 | 0.25 | 0.5 | 0.1 | 0.4 | 0.32 | 0.2 | 0.2 |
| **15** | 0.65 | 0.25 | 0.25 | 0.1 | 0.4 | 0.32 | 0.12 | 0.12 |
| **16** | 0.65 | 0.25 | 0.25 | 0.1 | 0.4 | 0.32 | 0.44 | 0.36 |
| **17** | 0.8 | 0.25 | 0.26 | 0.1 | 1 | 0.94 | 0.61 | 0.4 |
| **18** | 0.8 | 0.6 | 0.26 | 0.35 | 1 | 0.92 | 0.82 | 0.61 |
| **19** | 0.8 | 1 | 0.5 | 0.7 | 1 | 0.89 | 0.98 | 0.84 |
| **20** | 0.8 | 1 | 0.7 | 0.85 | 1 | 0.89 | 1 | 1 |
| **21** | 0.8 | 1 | 0.7 | 0.85 | 1 | 0.89 | 0.69 | 0.85 |
| **22** | 0.7 | 0.7 | 1 | 1 | 0.98 | 0.89 | 0.38 | 0.45 |
| **23** | 0.6 | 0.5 | 1 | 1 | 0.23 | 0.23 | 0.16 | 0.16 |

- Lighting Power Density considering LED lights in the entire house is **0.46 W/Sft**.
- The Plug Load density by considering all affordable and energy-efficient equipment is **0.62W/Sft**
- The air changes per hour is **1.00**
- As we are proposing a mini-split ducted ERV compatible heat pump system, we considered PSZ HP systems with economizer- Differential enthalpy and DCV. The Latent Heat recovery is 0.75, and the sensible heat recovery is 0.81.
- For HVAC Sizing, the peak cooling load for a summer design day is - 6019 Btu/hr
- The Peak heating load for winter design day is -3985 Btu/hr
- The setpoints are as follows:

| Roof Assembly | SI | IP |
|---|---|---|
| **R Value** | 0.57 | 3.22 |
| **U Value** | 1.37 | 0.24 |
| **Layers From Exterior to Interior** | **Construction** | **Thickness In Meters** |
| **High Reflective Shingles** | New | 0.02 |
| **Roof Decking** | New | 0.016 |
| **Roof Rafters** | Existing | 0.05 |

| Floor Assembly | SI | IP |
|---|---|---|
| **R Value** | 0.127 | 0.72 |
| **U Value** | 3.43 | 0.6 |
| **Layers From Exterior to Interior** | **Construction** | **Thickness In Meters** |
| **Wooden Boards Osb** | New | 0.016 |
| **Floor Joists** | New | 0.05 |

| Ceiling Assembly | SI | IP |
|---|---|---|
| R Value | 10 | 56.8 |
| U Value | 0.098 | 0.017 |
| Layers From Exterior to Interior | Construction | Thickness In Meters |
| Loose-Fill Cellulose Insulation | New | 0.38 |
| Zip Sheathing | New | 0.016 |
| Ceiling Joists | Existing | 0.05 |
| Plaster And Lath | Existing | 0.015 |
| Low VOC Paint | New | 0.01 |

| Wall Assembly | SI | IP |
|---|---|---|
| R Value | 4.5 | 25.8 |
| U Value | 0.21 | 0.037 |
| Layers From Exterior to Interior | Construction | Thickness In Meters |
| Paint | New | 0.02 |
| Wood Siding Osb | Existing | 0.016 |
| Air Gap | | 0.0127 |
| Mineral Wool Board | New | 0.025 |
| Zip Sheathing | New | 0.016 |
| Cavity Cellulose Insulation | New | 0.089 |
| Std Wood 4 Inch | Existing | |
| Plaster And Lath | Existing | 0.015 |
| Low Voc Paint | New | 0.01 |

| Type | U (IP) | VLT | SHGC |
|---|---|---|---|
| Double paned, Low-e window 1" | 0.27 | 0.49 | 0.21 |
| Wooden Door | 0.17 | | |

| Requested Location: | Atlanta |
|---|---|
| Location: | Lat, Lon: 33.73, -84.38 |
| Lat (deg N): | 33.73 |
| Long (deg W): | 84.38 |
| Elev (m): | 300.4 |
| DC System Size (kW): | 6 |
| Module Type: | Standard |
| Array Type: | Fixed (roof mount) |
| Array Tilt (deg): | 29 |

| Array Azimuth (deg): | 180 |
|---|---|
| System Losses: | 15 |
| Invert Efficiency: | 96 |
| DC to AC Size Ratio: | 1.2 |
| Average Cost of Electricity Purchased from Utility ($/kWh): | 0.116 |
| Capacity Factor (%) | 16.6 |

| | Indoor | | Outdoor | |
|---|---|---|---|---|
| Set Points | Min in C/ F | Max in C/ F | Min in C/ F | Max in C / F |
| Natural Ventilation | 19 / 66.2 | 25 / 77 | 17 / 62.6 | 30 / 86 |
| HVAC | 18 / 64.4 | 26/ 78.8 | | |

- The site EUI is 12.096 kBtu/sf, and the source EUI is 40.25 kBtu/sf.
- The total energy consumed Annually for a gross area of 1991 sf is 24,070 KBtu.
- We produce 29,785 kBtu of energy on-site and achieve a Net positive house, no off-site renewable energy is used
- The EUI of the house after including PV is – 2.9 kBtu/sf

| Month | AC System Output (kWh) | AC System Output (kBtu) | Solar Radiation (kWh/m^2/day) | Plane of Array Irradiance (W/m^2) | DC array Output (kWh) | Value ($) |
|---|---|---|---|---|---|---|
| 1 | 614.4 | 2096.4 | 4.2 | 130.6 | 641.8 | 71.3 |
| 2 | 598.0 | 2040.6 | 4.6 | 128.1 | 624.9 | 69.4 |
| 3 | 758.5 | 2587.9 | 5.3 | 165.2 | 792.6 | 88.0 |
| 4 | 812.2 | 2771.4 | 6.0 | 180.2 | 848.3 | 94.2 |
| 5 | 848.9 | 2896.7 | 6.2 | 191.7 | 886.1 | 98.5 |
| 6 | 802.7 | 2739.1 | 6.2 | 186.2 | 838.3 | 93.1 |
| 7 | 786.5 | 2683.7 | 5.8 | 180.8 | 821.7 | 91.2 |
| 8 | 784.9 | 2678.2 | 5.9 | 183.6 | 819.4 | 91.1 |
| 9 | 755.8 | 2579.0 | 5.8 | 173.1 | 788.9 | 87.7 |
| 10 | 763.6 | 2605.5 | 5.5 | 171.1 | 796.7 | 88.6 |
| 11 | 644.9 | 2200.4 | 4.7 | 139.8 | 673.0 | 74.8 |
| 12 | 558.8 | 1906.7 | 3.8 | 117.9 | 583.2 | 64.8 |
| Total | 8729.3 | 29785.6 | 64.0 | 1948.5 | 9114.9 | 1012.6 |

Design Partner

Industrial Partner