ATTACHED HOUSING DIVISION

Project Rest Recover Empower

By Safelink

BY SAFELINK

Rest
Recover
Empower

Kara House

MONASH University

U.S. DEPARTMENT OF ENERGY
SOLAR DECATHLON

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4.1. SETTINGS AND LOCATION

Location: 115-119 Clayton Road, Oakleigh East, 3166, Victoria, Australia

Lot Size: 23411 ft^2 (2175 m^2)

The proposed site for RRE is a rectangular combination of three existing lots (115, 117 and 119 Clayton Road), with the longest side running parallel to the road (174 ft x 134 ft [53.1 m x 41 m]) (**Figure 1**). The lot is east-facing on Clayton Road, a 4-lane major road that runs north to south in Oakleigh East and is bounded by neighboring residential properties, separated by paling fences. The lot is set back 12.30 ft (3.75 m) from the road to include lawn, vegetation, and a sidewalk, which is council-maintained.

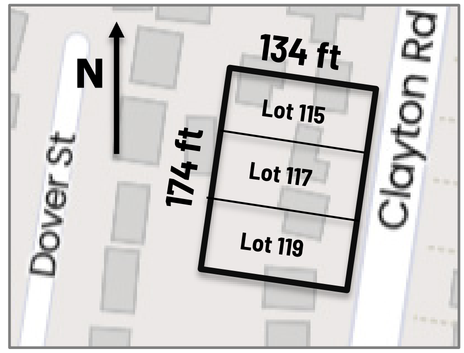


Figure 1. *Selected lot orientation and size.*

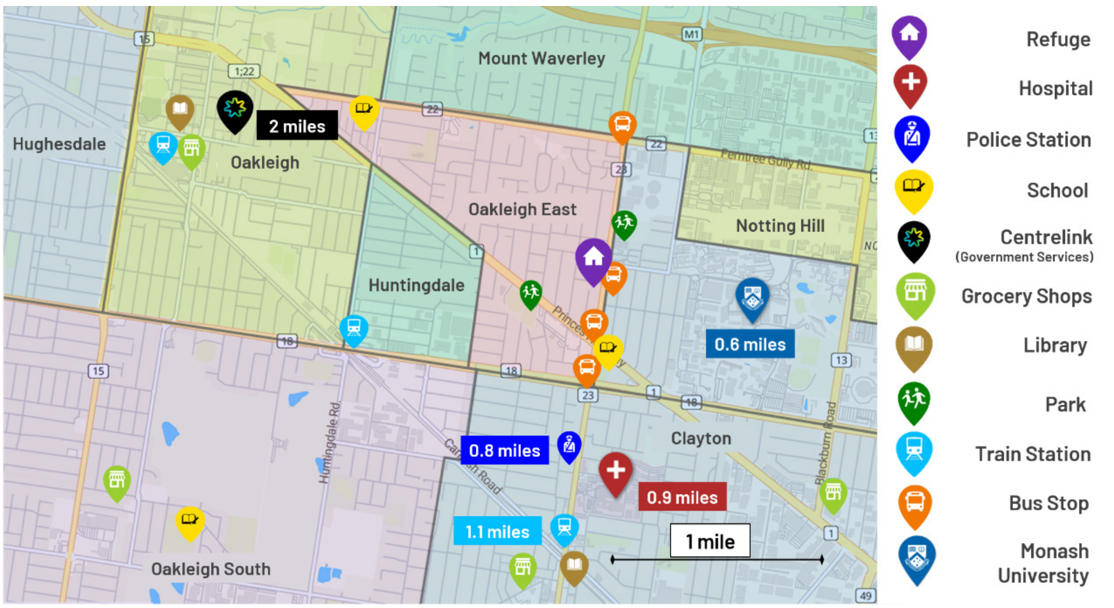


Figure 2*. Map of Oakleigh East and the surrounding suburbs. Key amenities and services in the area are highlighted as per the legend on the right.*

With an area of 0.8 mi^2 (2.1 km^2), Oakleigh East is a suburb of Melbourne, in the state of Victoria, and considered part of the Melbourne Metropolitan Area (population 5.1M). Oakleigh East has a population of approximately 6,500 and is located in the City of Monash, 10 mi (16 km) southeast of downtown Melbourne, the Central Business District (CBD). Along with the neighboring suburbs of Oakleigh, Huntingdale, Clayton and Mount Waverley, this area is mostly residential with some commercial lots including a post office, restaurants, schools, and supermarkets. The average household size in Oakleigh East is 2.7 people, with family appropriate amenities such as hospitals, schools and recreational facilities located within the neighborhood (**Figure 2**). Attached housing building types comprises approximately 20% of all residences in this area, making it a suitable location for RRE.

In Oakleigh East and surrounding suburbs, residents have access to sidewalks on all roads to allow easy pedestrian access to public transport and shopping districts. There are 13 bus routes, operating along all major roads and one train line, easily accessible from the area. Additional train routes are a 10-minute bus ride away from the lot location and allows for reliable transport to and from the Melbourne CBD at a regular daily schedule. Therefore, public transport is abundant, and according to the 2016 census, 17.7% of Oakleigh East's population took public transport to work, compared to about 13.4% in the Melbourne Metropolitan Area.

4.2. TARGET MARKET AND OCCUPANT PROFILE

The Rest Recover Empower (RRE) project aims to provide a purpose-built refuge for women and children experiencing domestic and family violence (DFV). The government-funded attached housing complex will meet the desperate need for dedicated refuge housing in the Victorian community, providing a place of stability and support for families who are forced to escape from dangerous family situations. For RRE, safe, temporary accommodation has been designed in consultation with the Design Partner

(Kara House) to ensure the design supports the clients and their needs. Kara House is a non-profit organization which provides temporary housing for approximately 300 women and 193 children per year to help rebuild their lives after experiencing DFV. With current facilities accommodating only 110 refuge seekers at any given time, there is a seriously underserved group of women and children experiencing DFV in Victoria. In 2017/18 there were 156 unmet requests every day for temporary housing in Australia, with reported cases of DFV in Victoria rising by 15% in 2020 alone. Clearly, there is a significant need for purpose-built DFV refuges, which is further supported by government investments in these facilities following the 2015 Royal Commission into DFV, which concluded that the current shared-accommodation style refuges will need to be rebuilt to better support clients. The RRE project aligns with the Royal Commission findings, as guided through consultation with Kara House.

Figure 3. *(Left) Enclosed communal space, featuring a playground and sensory gardens to aid occupant recovery. This space is one of the passive security measures which fosters safety and security through "community watch". (Right) Render of office space to accommodate on-site staff and to facilitate operation of the refuge.*

The RRE refuge's services provide a safe space, catering to women of all ages and cultural backgrounds, inclusive of women with children, disabilities and those identifying as LGBTQI+. In refuge-style housing, the average length of stay for a given occupant is four weeks, extending up to ten weeks as required. Given the high turnover and fluctuating occupant profile, a flexible '*Occupancy Maximizer Layout*' has been designed to adapt to different family sizes and maintain optimal capacity of the complex. The complex will also include an accessible unit, adhering to local Australian disability standards to provide support to the 5% of clients with a disability.

In order to facilitate client recovery through rehabilitation and therapy programs and to enable operability of the refuge, Kara House has also requested the inclusion of indoor and outdoor multipurpose areas, dedicated office spaces, storage, and a unit for staff to stay on-site.

4.3. LOCAL CLIMATE

Oakleigh East is located within the Metropolitan Melbourne Area, which is considered to have consistent temperature patterns across the suburbs. Oakleigh East is in Australian Climate Zone 6 (US equivalent Zone 3c), with a temperate climate categorized by moderate rainfall and humidity and limited temperature extremes. Oakleigh East has an average daily maximum summer temperature of 78.4°F (25.8°C) and average daily minimum winter temperature of 42.6°F (5.9°C). Melbourne has similar climate characteristics and temperature profiles to that of San Francisco, making it a most suitable comparison for modeling purposes. Australia is located in the Southern Hemisphere, and as such, summer occurs approximately from December - February and winter from June - August.

Melbourne experiences roughly 2700 heating degree days as opposed to 450 cooling degree days annually with a baseline of 65ºF, according to the Australian Bureau of Meteorology. This shows a significantly greater requirement for heating in the plot location. Therefore, high performance rockwool insulation, with an R-value of 3-3.3 per inch, has been selected for all walls, floors, and roofs, along with a high-efficiency heat pump and heat recovery ventilation (HRV) system. Additionally, the significantly higher number of heating degree days led to the selection of a vapor permeable external membrane, and a vapor and air impermeable internal membrane suitable for temperate and cooler climates. This prevents vapor entry into the cross laminated timber framing and insulation batts, while also allowing any vapor within the wall structure to drain out through the air gap.

The annual average rainfall is 29.1 in (738 mm) with total rainfall occurring relatively consistently across summer and winter. However, Melbourne's climate is categorized by less frequent, higher intensity rainfall events, with rainfalls exceeding 0.35 in/hr (8.96 mm/hr) four times per year. As reported by the Australian Bureau of Meteorology, intense, short-duration (less than 1 hour) rainfalls are expected to increase as the climate changes. To ensure resilience during these events, rainwater tanks will be installed to ensure roof runoff is captured and used as much as possible. Additionally, the landscape is designed with permeable

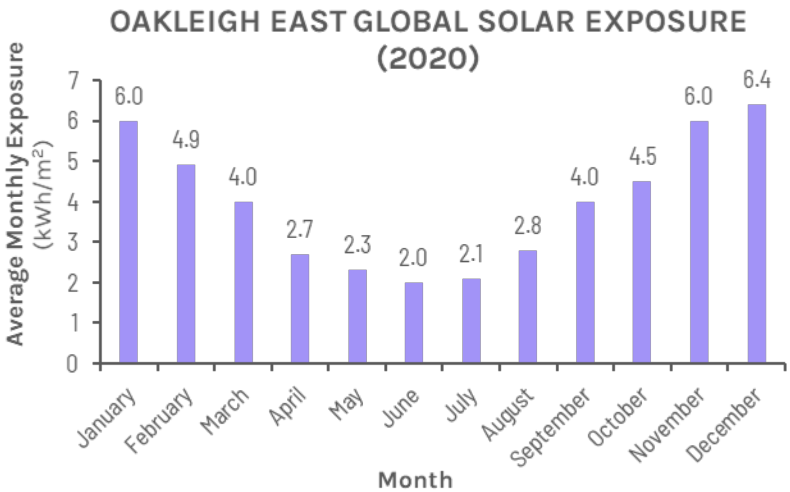


Figure 4. *The 2020 average monthly global solar exposure (kWh/m2) in Oakleigh East*

walkways to promote drainage to the stormwater system. Prevalence of hailstorms have also been considered in the design, inspiring the use of the hail-resistant solar panels (as per Australian standards) and installation of a car park covering.

Australia experiences more solar radiation per square foot than any other country in the world, according to the Australian Government Geoscience Australia. Additionally, the cost of residential solar is 2-3 times cheaper in Australia than in the United States. Therefore, solar is seen as the most reliable residential energy source across Melbourne. In Oakleigh East in 2020, the lowest monthly global solar exposure of 2.0 kWh/m^2 occurred during winter in June (**Figure 4**) which is typically when the greatest energy expenditure for heating is required. Therefore, reducing the overall required heating load, selecting an efficient heating system, and selecting materials with high thermal insulating properties is a priority. Additionally, the solar array will be sized to ensure adequate energy generation during these low solar exposure periods, further supplemented by solar batteries to accommodate for diurnal and seasonal variation. Conversely, in the summer, the solar exposure reaches a high of 6.4 kWh/m^2, which would generate more energy than is required by the complex, thus achieving positive energy production.

Since the complex is located in the Southern Hemisphere, the design has been orientated to optimize northern sun exposure and minimize undesirable heating from direct afternoon western solar exposure. The frequency of heatwaves in Melbourne is expected to increase as a result of climate change; research is predicting that extreme hot days that are currently experienced once every 20 years are expected to occur every 2 to 5 years by the mid-21st century. The design has accounted for this by minimizing windows and maximizing shading on the west side of the complex.

4.4. CODES AND STANDARDS

The design of RRE complies with the guidelines set by the 2019 National Construction Code (NCC) and the local council regulations. The NCC contains three volumes, including the Building Code of Australia (Volumes 1 and 2) and the Plumbing Code of Australia (Volume 3), which provide the minimum necessary requirements for safety and health, amenity and accessibility, and sustainability in the design, construction, performance, and livability of new buildings throughout Australia.

Figure 5. *The accessible unit (right) is designed with a larger layout and greater allowances for those with disabilities or mobility issues, as compared to the standard unit layout (left).*

According to the 2019 NCC, the refuge is classified as a Class 3 residential building containing Sole Occupancy Units and is required to meet fire safety and accessibility standards as set out in Volume 1 of the NCC for multi-residential buildings. Additionally, the accessible unit and all communally accessible areas were designed to the Livable Housing Australia Design Guideline's Platinum Level for occupants with high mobility needs, as requested by the design partner, Kara House.

The City of Monash Council lists this lot as a General Residential Zone Schedule 3 within the Monash planning scheme. The Council codes ensure the building and landscaping respect the neighborhood character and align with the town planning goals. Project RRE has been designed in accordance with all council regulations, so the planning permit application process should be straightforward. All construction and installation standards will be performed to meet the 2019 NCC requirements.

The DOE Zero Energy Ready Home National Program Requirements (Rev. 07) have been met in the design of Project RRE. The conditioned floor area (CFA) of the designed complex (8,332 ft^2 [774 m^2]) is less than the CFA of a model home (11, 800 ft^2 [1096 m^2], assuming 19 bedrooms), so the prescriptive path was taken. Modeling was completed to optimize the design, assuming Climate Zone 3, and ensure that the DOE Zero Energy Home requirements were met. Where necessary, equivalents were made found to meet the Exhibits, for example, ENERGY STAR qualified appliances are not available in Australia, so the Australian equivalent system was used instead.

5. DESIGN GOALS

5.1. PURPOSE-BUILT SPACE

The focus of this project is to create a purpose-built refuge for women and children experiencing DFV, by designing a comfortable and usable space to ensure a supportive occupant experience. According to the requirements set out by the design partner, Kara House, communal areas have been included, such as a multipurpose space (for therapy sessions), study spaces, play areas, a shared kitchen, and outdoor gardens. A flexible unit layout has been designed to maximize the occupant capacity and respond to the high turnover rates. Administration spaces, such as the staff units and office, have been included to aid in the operation of the refuge.

5.2. FLEXIBILITY

A key defining feature of Project RRE is the flexibility it provides the refuge operator in accommodating occupants. The *Occupancy Maximizer Layout* allows a unit to access the upstairs bedroom of an adjacent unit to accommodate for varying family sizes. This solves a key problem with refuges for women experiencing DFV, where there are long waitlists until a suitable size accommodation becomes available. Empowering the refuge operator to make full use of the occupancy space ensures that more women in need are supported and improves the effectiveness of the service. This flexibility has been extended to the operation of the complex, with the refuge operator having control of the unit building systems, including the heating and cooling setpoints, so that the complex's energy usage can be controlled and monitored according to what is best. Additional flexibility with switching between harvested rainwater and town provided tap water allows for adjustments based on reserve levels.

5.3. SECURITY AND PRIVACY

Since this complex is designed to provide crisis accommodation, ensuring the security and privacy of the refuge and the occupants is imperative. Passive security measures include limiting the number of entrances to the complex, creating an inconspicuous exterior which matches surrounding buildings, indoor and outdoor communal spaces, using landscaping to provide privacy, and a police station located 1 mile away. Furthermore, the communal space in the centre of the complex improves safety and security through encouraging community watch and increasing visibility across the site. Active security measures, such as security cameras, are included to ensure occupancy security and provide a feeling of safety.

5.4. EASE OF OPERATIONS

Ensuring the complex is easy to operate at all times for Kara House enables them to use their resources most efficiently. Reducing maintenance and operational tasks, such as streamlining the changeover process, managing occupant access through programmable keycards, and low maintenance native gardens. The building systems have been designed to accommodate occupant comfort and refuge operation in as many occupancy scenarios as possible. Since the refuge will be running continuously over several decades without downtime, the systems must be robust and easily maintainable. Systems are designed for the most extreme conditions; for example, solar panels were sized to generate sufficient power on the lowest sunlight days.

5.5. APPEAL TO STAKEHOLDERS

The complex is designed for Kara House to ensure ease of operation, with low operating costs, minimal maintenance, and high building resilience to ensure longevity since refuges are often kept operational beyond the designed lifetime. In order to meet the high demand for crisis housing, the flexible layout and accessible unit will increase occupancy and accommodate varying occupant requirements. Since the refuge is intended to be government-funded, justifying the upfront costs with the long-term financial and environmental benefits will demonstrate an attainable net-zero standard for Victorian DFV refuges.

6. CONTEST NARRATIVES

6.1. ARCHITECTURE

6.1.1. Conceptual Strategy

Project RRE was designed to meet the need for safe, temporary housing for women and children experiencing DFV in Melbourne. The key focus of the project was to design one of the first purpose-built refuges that provides individualized accommodation spaces for the occupants. Currently, most refuges are shared, dormitory style complexes. Working with Kara House as the design partner, Project RRE is designed to be a flexible space that maximizes occupancy throughout the year, with a focus on self-contained, fully functional individual units. Private and communal garden spaces and shared indoor spaces have been included to facilitate occupant recovery. The site will be managed and operated by a small team of approximately eight staff members. As such, ease-of-operation has been prioritized for occupant changeover and building upkeep. To facilitate this, and at the request of the design partner, dedicated staff spaces were required. Security and privacy were imperative given the delicate situation of the occupants. Passive security has been implemented through the design of the U-shape layout of the complex. In addition to consideration of the intended occupants, Project RRE also focused on using passive design; north-facing solar access was maximized while west-facing windows were scaled down. The aesthetics of the complex were designed to blend the exterior with the surrounding area and create a calming interior space to facilitate occupant recovery and mental wellbeing.

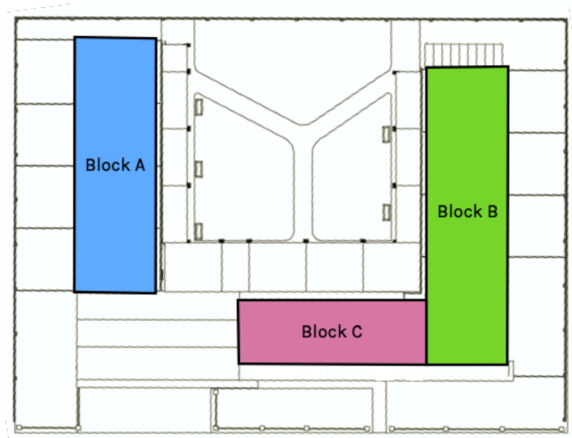


Figure 6. *Site layout showing different*

6.1.2. Site Layout

The complex includes three groups of indoor spaces: Block A (four standard units), Block B (three standard units, one accessible unit) and Block C (ground floor multipurpose space and upstairs staff area) (**Figure 6**).

6.1.3. Unit Layout

A standard 2-story unit consists of a full kitchen, one bathroom including laundry, two bedrooms (one upstairs, one downstairs), a downstairs dining space, and an upstairs living space. Each unit also has access to an upstairs balcony overlooking the communal garden and a downstairs private backyard area with seating and a clothesline (**Figure 7**).



Figure 7. *(Left) Standard unit second story living room, showing window placement to light downstairs areas. (Middle) Standard unit private backyard space, including water tank in green, and retractable clothesline. (Right) Standard unit kitchen and dining area, as seen from the stairs.*

6.1.4. Flexibility

One of the key design features of Project RRE is the flexible unit layout, making the complex more suitable for market requirements. The *Occupancy Maximizer Layout* accommodates for varying family sizes by changing which unit can access the upstairs bedroom. As such, the design aims to ensure that the number of children a woman has is not a barrier to her being able to access crisis accommodation.

Designing of a flexible floorplan required identifying any of the components of a unit that might limit the unit's use to a family of a specific size. Regardless of the number of occupants, each unit has access to one bathroom, a kitchen, and two living areas, which are designed to be fully functional for up to six occupants (one woman, four children and one infant). The *Occupancy Maximizer Layout* provides the opportunity to change the number of bedrooms from the standard two-bedroom unit, decreasing to one bedroom for a single woman (no children or an infant) or increasing to three for a woman with more children (see **Figure 14** in Section *6.3.1 Market Enhancement*).

The *Occupancy Maximizer Layout* works by using the mechanism of a *Hufcor Operable Wall* to change which unit has access to the bedroom entrances. An aluminum frame around the wall section will be connected to three top supported tracks in the ceiling, along which the operable wall can move to restrict bedroom access (**Figure 8**; See animated demonstration here: https://www.monashsolardecathlon.com/attached-housing-2021). When the operable wall is in the standard position (**Figure 8** Middle), both units have access to their respective upstairs bedroom. However, when the operable wall is moved along the tracks in the roof to alternate positions (**Figure 8** Left and Right), one unit loses access to the second bedroom, while the adjacent unit gains access. Once aligned correctly, a manual key operates a deadbolt lock which can lock the wall in each of the three positions. Only Kara House staff are authorized to operate this wall section and the configuration will only be altered during an occupant changeover. The operable wall does not require floor tracks or floor-to-ceiling guides, and it has retractable horizontal pressure seals to ensure a tight seal is achieved along the floor and ceiling for optimal sound control. Additionally, rubber beading and brush door seals along the vertical exposed edge can interlock with cavities in the wall at each allowable door position, enabling it to sit flush with the permanent walls and eliminating the small gap the mechanism will create. To ensure durability, the wall section will have additional internal timber studs to add support even though the wall is not load bearing. The wall section is designed to be as inconspicuous as possible to the occupants of each unit, with a keyhole cover to create a near-continuous surface.

The units remain within the 2019 NNC for all layout possibilities, with fire safety prioritized. As such, the design ensures that all arrangements of upstairs bedrooms result in a distance less than 82 ft (25 m) from the unit exit, which is required. Additional active fire safety measures, such as fire sprinklers, are also included to compensate for additional risk posed by the shared hallway. Since the configuration does not change during occupancy, there are no issues of changed evacuation routes for the occupants in each unit and appropriate signage will be included.

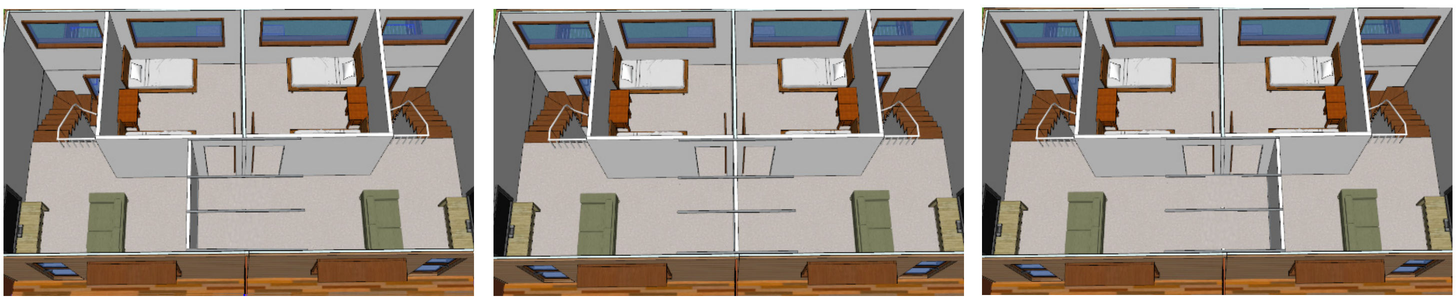


Figure 8. *Operable wall positions. (Left) The unit on the right is able to access the upstairs both bedrooms, while the unit on the left has lost access. (Middle) The standard wall position allowing both units access to their respective bedrooms. (Right) The third position allows the left unit to access both bedrooms.*

6.1.5. Accessibility

Women with disabilities experience higher rates of severe family violence and have fewer pathways to safety. Ten recommendations from the Victorian Government's 2015 Royal Commission into Family Violence addressed people with disabilities, including the requirement for new crisis accommodation to include an accessible unit for both women and children with physical disabilities. In order to prevent accessibility barriers from limiting the availability of crisis accommodation, Project RRE has designed one dedicated accessible unit and ensured all multipurpose spaces are accessible. Each unit is designed in according with the 2019 NCC safety measures, with dual hand railings for the stairs, and balcony railings over 3.2 ft (1 m) high with no horizontal climbing parts between 6-30 in (150-760 mm) above the floor surface. Given that young children will be among the occupants, additional safety measures have been included to prevent falls, such as wall-mounted stair gates, balcony railing coverings, and ensuring that no climbable objects are on the balcony (**Figure 9**).

Figure 9. *(Left) Accessible unit living space, with greater allowances for wheelchair users. (Middle) Balcony railings include safety measures to prevent children from falling. (Right) The staff unit includes a lift for use only by workers requiring wheelchair access.*

The accessible unit is designed to the Platinum Level of the Livable Housing Australia Design Guidelines (similar to Americans with Disabilities Act Standards for Accessible Design). These guidelines foster the mainstream adoption of livable housing principles, particularly in community and government buildings. To adhere to these guidelines, the following considerations were included in the accessible unit: step free entrances to the dwelling; greater clearances and clear spaces in the bedroom, living room and kitchen to allow ease of movement; lever door handles and taps; power points and light switches placed at an easy to reach height and consistent configuration; straight stairs with continuous handrails on both sides; and larger toilets and shower spaces with reinforced walls and grab railings to accommodate wheelchair users.

Alongside the consideration of accessibility for disabled occupants, the design also considers the Australian Government's *Equal Opportunity Act 2010* for the staff space, which enforces a legal requirement for employers to allow people with a disability or injury to work productively and safely. As such, the upstairs staff area is accessible via an elevator, and the bathroom is also designed to the Platinum Level of the Livable Housing Australia Design Guidelines, ensuring the space is inclusive to all staff members (**Figure 9** Right).

6.1.6. Purpose built spaces

In consultation with Kara House, refuge-specific spaces were designed in addition to the residential units in the complex. These spaces consider the unique needs of the occupants by promoting recovery and enabling the provision of additional support activities and services on site to meet the key Design Goal.

The ground floor multipurpose space was designed to incorporate the provision of individual support services with a variety of opportunities for recovery promoting activities in both independent and group settings. The space includes two interview rooms, required by Kara House for individual therapy sessions, case management, and other administrative requirements (**Figure 10**). Additionally, Kara House required a waiting room immediately accessible from the main entrance to the complex, which could also be used to conduct interviews. This layout is intended to maintain the security of the space by preventing the need for prospective occupants to enter shared spaces.

Figure 10. *Dedicated spaces in the multipurpose space. (Left) The 'flexible space' can be used for group activities such as therapy or art classes. (Middle) The play area occupies children while the mothers are using the facilities. (Right) The upstairs office staff space ensures the refuge can operate.*

The largest room in the multipurpose space is the designated 'flexible space', a 422 ft^2 (39.2 m^2) enclosed room designed for organized group activities to promote Project RRE's values of rest, recovery, and occupant empowerment. The flexible space is large enough for a variety of both seated and mobile activities, such as group therapy, skills training, or space for guided play and tutoring for children. Additionally, the multipurpose space includes a computer lab with three computers, providing internet access for women to undertake independent administrative activities. The multipurpose space also includes a small kitchenette and an accessible bathroom, ensuring that all spaces are designed to the Platinum Level of the Livable Housing Australia Design Guidelines.

To ensure operational efficiency of the refuge, dedicated staff facilities are provided on site. In accordance with DFV refuge requirements, an office space that is accessible only by staff has been included above the multipurpose wing of the complex (Block C). Sufficient storage space has been provided for any donations, such as clothing, bedding, and children's supplies, as well as a washing machine, lounge area, and kitchenette for staff use. A supply closet has also been added for the staff washing machines (to wash clothes donations) and for the storage of cleaning supplies. An accessible staff bathroom and a bedroom have been provided to allow staff to stay overnight on a rotational basis to ensure the occupants have 24/7 support and supervision.

6.1.7. Potential to Influence

This refuge has strong potential to influence future Government refuge designs. The 2015 Royal Commission recommended the communal refuge model (shared bedrooms, bathrooms and living spaces), adopted by the 23 current DFV refuges in Victoria, is phased out, with new refuges providing private units to promote safety and inclusiveness. Given this finding, there is a great need for new refuge designs. As the first of its kind, Project RRE provides purpose-built spaces as specified by Kara House, which incorporate energy efficiency and thus make more efficient use of Government funds. The design meets the new refuge requirements and features desired spaces which facilitate client recovery and meet their unique needs.

Additionally, the Victorian Department of Health and Human Services has planned to begin regular reporting on unmet housing demand for people experiencing family violence from 2021, providing greater information into the requirements for the geographic distribution of crisis accommodation facilities over future years. This allows future refuge builds to be planned in response to demand, and the flexibility of Project RRE makes it a great model for replication as the key design features can be applied to any location around Victoria. The design makes use of a standard rectangular block size, meets national building standards, and has replicable unit layouts which operate effectively regardless of their north-south orientation, and could be scaled up or down accordingly. These features can easily inspire future builds with minimal adjustments required to suit the location and refuge occupancy needs. Furthermore, while Project RRE was specifically designed for Kara House, the design contains all necessary features to be operable by any DFV refuge entity.

6.1.8. Site-specific design

The complex has been designed to foster an internal community through the use of the U-shape layout which provides privacy for the central communal garden space. The communal multipurpose area is oriented such that it blocks the rest of the complex from the street view, increasing feelings of safety within the complex. These shared areas encourage community watch and are well-screened from the street, thus passively providing secure connections between internal and external spaces. The building setbacks and window placement have been designed in accordance with the local planning regulations to minimize sightlines into neighboring properties and ensure privacy for occupants without compromising on views. Materials were selected to ensure an inconspicuous facade that blends into the neighborhood surroundings.

6.2. ENGINEERING

6.2.1. Engineering Approach

The key approach of the engineering design was to ease the operation of the refuge for Kara House and thus meet the fourth Design Goal. Passive heating and cooling strategies have been applied to the design to minimize energy loads as a first approach. Where possible, electricity and water usage have been reduced through appliance and fixture selection. The layout of the units was designed so that utilities are centralized to minimize the piping required. Systems and services were placed in areas that enhanced accessibility while also minimizing losses.

All engineering design decisions complied with the regulatory requirements and the codes and standards set out in the 2019 National Construction Code (NCC). Within the NCC, the Building Code of Australia (Volumes 1 and 2) and the Plumbing Code of Australia (Volume 3), provide the minimum necessary requirements for safety and health, amenity and accessibility, and sustainability in the design, construction, performance, and livability of new buildings throughout Australia. All of these codes have been met and exceeded for optimum efficiency where possible. Australian Standard certified products were chosen for all fixtures and fittings.

6.2.2. Building Control Layers

The buildings are supported by raised concrete foundations on concrete footings, with thermal insulation integrated into each slab. Block A will be constructed on one foundation, and Blocks B and C will be constructed together on another foundation. The structure of the building will be established with lightweight framing using cross-laminated timber. This construction approach will be used for the walls, roof, and suspended floor for the second story of the buildings. Batt insulation, suitable for lightweight framing, will be used for both thermal and acoustic protection in different wall sections of the buildings (thermal insulation throughout the building envelope, acoustic insulation between units). Additional control layers will be installed around the framing in both the walls and ceilings, with particleboard panels used to maintain the positioning of non-rigid layers. Refer to Section *6.4.1 Building Control Layers* for a full description of the building control layers.

6.2.3. Lighting System

Window placement has been optimized to maximize natural lighting during daylight hours, minimizing reliance on artificial lighting where possible. North facing windows ensure optimum daylight year-round, with supplemental LED lights used to achieve the minimum illuminance requirement (160 lux) in all spaces (**Figure 11** far left and middle left).

6.2.4. Electrical System

The electrical system is designed in line with the Australian Wiring Rules (AS/NZS 3000:2018 *Electrical installations*) standards for a maximum circuit load of 240V, with units isolated on separate circuits to enable Kara House to shut off power to unnecessary circuits during the down time between occupants. The refrigerator in each unit is on a separate circuit breaker, enabling it to continue running when other appliances are switched off (**Figure 11.** middle right and far right).

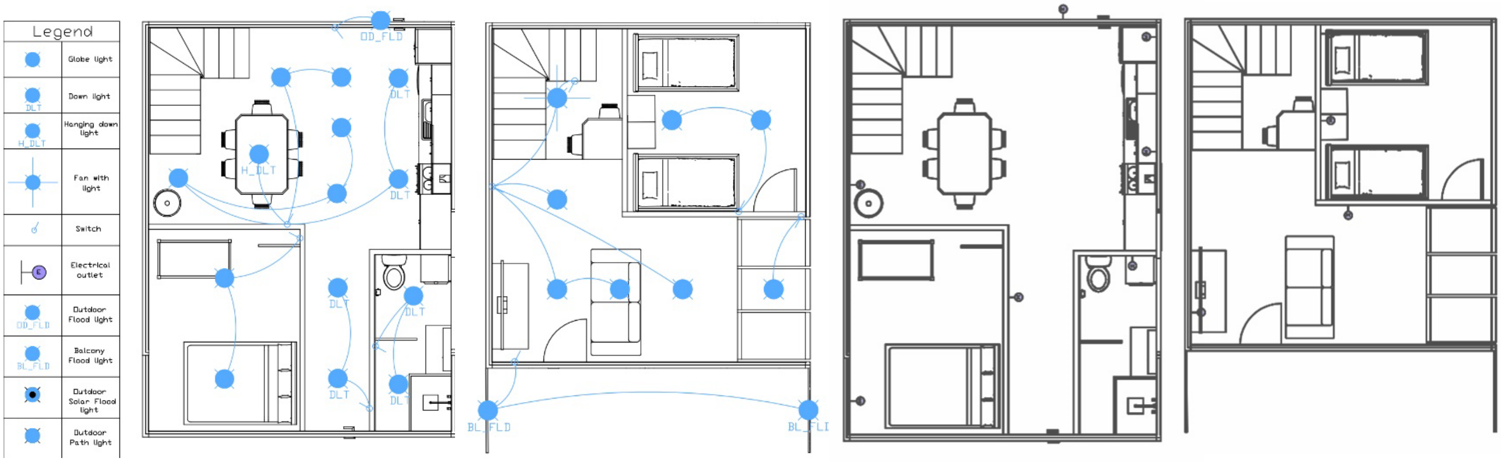


***Figure 11**. LED lighting placement for standard unit: downstairs (far left), upstairs (middle left); Electrical outlet placement for standard unit: downstairs (middle right), upstairs (far right)*

6.2.5. Hot Water System Specifications

Reclaim Energy air source CO_2 heat pumps will be used as the water heating system (**Figure 12**). As a refrigerant, CO_2 has a significantly lower global warming potential than R410A (a commonly used refrigerant) and has no ozone-depleting potential. Under optimal conditions, this CO_2 heat pump achieves a coefficient of performance (COP) of up to 6.02, putting this technology at the top of the market. One air source heat pump and one 83-gal (315 L) hot water tank will be shared between two standard units to minimize heat loss from distributed systems and ensure that sufficient hot water will be available to meet the occupant requirements. The multipurpose and staff space will share the hot water system with the accessibility unit, and the unit next to it, with a single insulated pipe transporting the hot water to the staff shower. A 132-gal (500 L) tank will be used for this connection. Since the staff shower will not be used as regularly, the heat losses are a justifiable compromise to installing a separate hot water system for one shower.

Make: Reclaim Energy
Model: CO_2 Heat Pump
Tank Capacity: 83 gal (315 L) / two units
Average electric input: 3 kWh
COP: Up to 6.02

***Figure 12.** Hot water system*

6.2.6. Plumbing System

The plumbing layout (**Figure 13**) meets the requirements in the Plumbing Codes of Australia (2019 NCC Volume 3). Due to single-entity management of all units in the refuge, individually metered utilities are not required. As such, combined piping systems are used for each water input, making use of water consuming utilities being centralized on the ground floor of the units.

All dishwashers, showers, wash basins, and sinks are connected to the potable water supply. Harvested rainwater will be used for toilet flushing and washing machine use for each unit to offset potable water consumption. Greywater collected from showers is used for irrigation for the communal garden and backyard

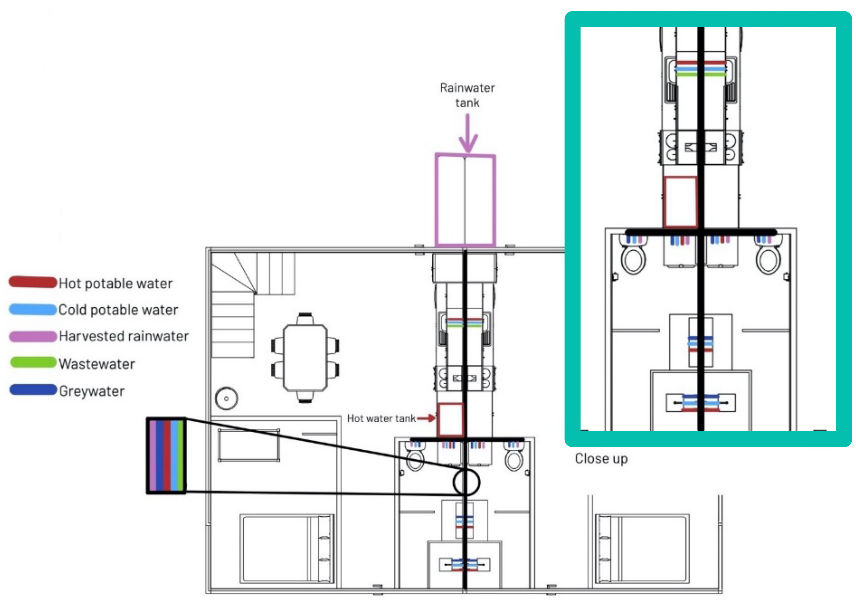


***Figure 13.** Standard unit plumbing layout*

Local guidelines require all new builds to have rainwater tanks to capture onsite runoff to promote drought resilience and protect waterways. One 660-gal (3000 L) rainwater tank collects and stores water for two units and is placed along the unit boundaries to reduce the required fencing. Box gutters are angled to funnel the collected rainwater from the roof of one row of units into the two tanks. The multipurpose space is fitted with two 660 gal tanks, one placed in the front of the refuge to supply water to the toilets in the multipurpose and staff spaces, and another placed on the west side to supply water for irrigation for the communal garden.

Hot water is supplied to the kitchen and bathroom sinks and the showers. These amenities are centralized along the adjoining wall between two units, minimizing losses associated with extended piping. The hot water tanks are placed in close proximity to the hot water services, next to the kitchens of the adjoining units. The selected CO_2 air source heat pump will be scheduled to heat during the afternoon when solar production is greatest to prepare water for use during high periods at night. In the early morning, the solar battery will provide power for the heater to reheat the tank, ensuring hot water is available in the morning. This will allow a single heat pump and one 83-gal (315 L) tank to supply hot water to 2 standard units. The accessible unit's hot water will be supplied by a 132-gal (500 L) tank with a single heat pump, which will also supply the adjacent unit and the communal space.

6.2.7. Water Efficiency

Project RRE's plumbing system is designed to minimize unnecessary consumption of potable water through a combination of onsite water capture, recycling, and water conservation measures. These measures include the selection of low-flow water fixtures, with 1.18 gal/min shower heads installed in all bathrooms, saving 3.22 gal/min compared to standard shower heads in Australia. Alongside water savings, low-flow fixtures also decrease energy consumption from water heating. Home appliances were also selected with water consumption in mind, with washing machine and dishwasher models having water efficiency star ratings of at least four stars (out of a total six stars, where the WELS star rating system ranks appliances according to their water consumption and performance) and an appropriate size for the predicted usage, for example, a smaller 17.7 in (45 cm) dishwasher instead of a standard 23.6 in (60 cm) size, to accommodate for the expected dish capacity for three people assuming daily operation. Landscape design also adopted water conservation strategies, focusing on the selection of native plants suitable for Melbourne's climate.

6.3. MARKET ANALYSIS

6.3.1. Market Enhancement

Existing refuge designs for women experiencing DFV feature dormitory-style, communal spaces which lack the privacy and empowerment of women needed in these situations. The 2015 Royal Commission into DFV concluded that the 23 current Victorian shared-accommodation style refuges will need to be rebuilt to better support clients. Clearly, there is a desperate need for purpose-built DFV refuges. A strong relationship with the Design Partner, Kara House, has resulted in the design of the refuge that exceeds the current market expectations for DFV refuges by providing flexible, safe spaces in a net-zero energy building. Project RRE aligns with the Royal Commission findings, as guided through consultation with Kara House.

All design decisions have been made possible through the strong relationship developed with Kara House. Gaining the insight into what currently works and needs improvement for refuges has been invaluable to ensuring that Project RRE captures what this market currently demands. One of the key areas of focus was providing Kara House with flexibility to operate the refuge at maximum capacity and to accommodate occupants with diverse backgrounds. In 2019, Kara House helped 290 women and 193 children from 46 different linguistic and cultural backgrounds, which Project RRE aims to help further diversify. Single occupancy units with self-contained spaces with a bedroom, bathroom, kitchen, laundry, and living areas were the design factors that limited how many occupants can be accommodated. Each unit is provided access to a private backyard space to meet the planning scheme requirements and aid recovery through green spaces. The spaces were then optimized to accommodate varying family sizes most efficiently. The *Occupant Maximizer Layout* allows adjacent units to have access to an upstairs living and balcony space. Currently, women are placed on waitlists until a suitable size unit becomes available. This means that single units are kept vacant while there is a family with 3 children waiting for a space. Allowing the access of the upstairs bedroom to be transferred between units (in between occupant changeovers), all family sizes can be accepted without removing the upstairs amenity for the other unit. By exploiting all occupiable spaces in the complex, the operational efficiency of the refuge increases as Kara House is able to accept a wider range of families and operate at maximum capacity (**Figure 14**).

The addition of an accessible unit exceeds the expectation of all three key stakeholders: the refuge operator (Kara House), the occupants, and the Government. Having a dedicated space for disabled occupants means that additional shares in the refuge market are met, and more women can be accommodated. It is expected that these spaces will also mitigate sources of discrimination within the refuge, providing a safe place for all. Perhaps more important is the ability of this design to accommodate larger family sizes. It is becoming increasingly common for women with 5-9 children to be requiring accommodation in DFV refuges. Current refuges are typically designed for a maximum of 4 children. Consequently, this demographic is under-served. Project RRE is able to accommodate for this by utilizing the accessible unit as a dual high occupancy unit. By providing the adjacent unit with access to the upstairs bedrooms of the accessible unit, 4 bedrooms and an additional half bathroom can be provided, accommodating these larger family sizes through the use of bunkbeds.

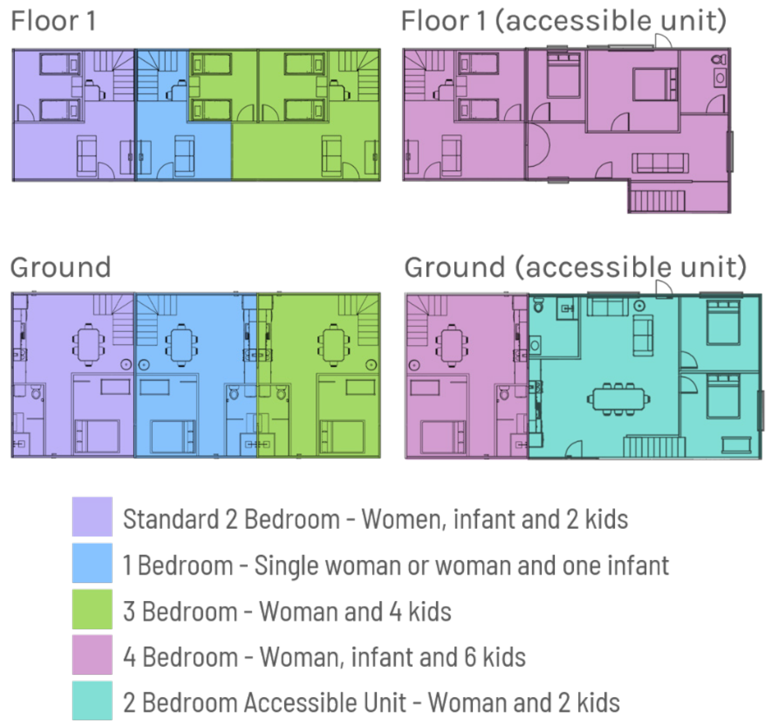


Figure 14. *Expected occupancy scenarios using the flexible layout*

6.3.2. Affordability

As highlighted in the section above, the flexibility of the Project RRE design allows for a high occupancy rate across the year to address the significant number of unmet requests for temporary housing particularly from women. Statistics show that it often takes seven attempts for women to leave an abusive situation, so having safe accommodation available as quickly as possible makes this transition easier. Waitlists for a suitable space can be as long as 2-3 weeks, during which time women are often placed in motels. Because Project RRE provides flexible occupancy of its units, a greater diversity of family sizes can be accommodated, thereby increasing overall occupancy. This increased occupancy will reduce the amount of time families spend on waitlists, decreasing Government funds spend on temporary accommodation at motels. Most importantly, this model improves access to the services victims of DFV receive by placing them in the refuge earlier.

The site is located in Oakleigh East, a suburb in the City of Monash. The City of Monash is one of the safest cities in Victoria. Within the City of Monash, Oakleigh East has the lowest crime rate. Compared with neighboring suburbs, crime in Oakleigh East fell in 2020 to 938 annual incidents compared to an increase seen in adjacent suburbs. Additionally, the lot is located within 1 mile of the local police station, and is in close proximity to public transportation, schools, services, parks, and shopping centers thus decreasing travel related expenses.

Over the lifecycle of the building, Project RRE should provide further cost benefits compared to current refuges. Highly efficient appliances were selected despite higher purchase prices, as they offer energy and therefore, cost savings, over the lifetime. Additional considerations were made to meet the increased safety needs and to match the current high standard of appliances in the current refuges (e.g., induction cooktops were selected for their ease of maintenance and increased safety mechanisms for children, despite being more expensive). Most significant for this complex is the reduced utility costs, decreasing the need for further Government support or fundraising to cover ongoing operation costs. Utility costs for electricity consumption will be drastically reduced by onsite renewable energy generation and battery storage, while rainwater harvesting, and greywater recycling will reduce potable water demand. Furthermore, compared to other refuge designs, significant consideration has been made to reduce the maintenance requirements for the refuge through the use of durable building materials and interiors, and low maintenance native plants such as Lavender Avonview (*Lavandula stoechas*) and Rosemary (*Rosmarinus officinalis*). Building services will require ongoing maintenance however, utilities have been centralized where possible to reduce the servicing requirements. Additional insulation beyond 2019 NCC compliance has been incorporated at an additional upfront cost, but the return on investment in heating and cooling load reduction will be significant. The upfront cost and ongoing maintenance of solar panels is an expense not seen in current refuges, however the payback period for the 86-panel system is only 6.2 years, with a $AUD 69,772 ($USD 53,260) return over a 20-year period.

6.3.3. Construction

The dwellings in Project RRE have been designed in such a way that each unit is identical, with centralized utilities and a modular design. Therefore, this makes the construction process more streamlined and efficient. The construction materials, including

COLORBOND® steel roofing and cross-laminated timber framing, are manufactured locally in Australia to avoid the embodied environmental impact of imported materials. This appeals to the major stakeholders of the complex, being funded by the Victorian Government, as it stimulates and provides jobs for Victorians and contributes to the local economy. Cost-effective materials have been used where possible, such as using rigid Foilboard® insulation for the thermal barrier throughout the building envelope. Ensuring materials are readily and locally available will reduce construction time and having highly trained building tradesmen will ensure high quality construction.

Reduced construction costs were achieved with the design of minimalistic interiors. Minimal built-in storage has been provided as occupants often have few belongings. This reduces the hidden areas that Kara House must clean during changeovers. Cabinetry costs have been further reduced in the kitchen where standalone cooktop ovens and standalone sinks have been used to minimize the waste associated with typical benchtops and to account for the fact that minimal storage and kitchen supplies will be required.

The feasibility of prefabrication construction was investigated for this design. While the replicating nature and modular structure of the units lend the Project to modular construction, it was ultimately deemed infeasible given the lack of development in the Australian market. Given that this refuge design could be used as a template for future refuges, there is the potential for larger scale production and off-site construction of modules. The full configuration of module construction was not completed for this design however there is clearly potential for future buildings of this design. When the Australian prefabrication industry is further developed, this will provide a more efficient construction process with a lower embodied environmental impact, reduced material waste and lowered costs.

6.3.4. Financial Feasibility

A key Design Goal was appealing to stakeholders of the refuge, most notably for the Victorian Government, who would be providing the funding to build this refuge. In order to encourage investment in net-zero buildings, it was important to demonstrate how this can be achieved in a financially feasible manner. Since the consumers of the complex, in this case the occupants escaping DFV, are not financially invested in the complex, this section addresses the other key stakeholders: Kara House and the Victorian Government. Current refuge models operate on the basis that occupants are not charged or charged only a nominal fee and deposit in order to establish some feeling of ownership for their recovery process. However, this fee is not enforced given the often-dire situation of occupants.

There is a desperate need for dedicated refuge housing in Victoria. It is paramount that places of stability and support are provided for families who are forced to escape from dangerous family situations. In 2015 alone, DFV cost Australia $AUD 22 billion ($USD 16.7B). There has been significant government support and recognition of the need to fund DFV refuges, with $AUD 152 million ($USD 114M) committed to the Family Violence Housing Blitz in 2016 to fund refuge housing projects such as Project RRE. Additionally, in 2020, Victoria committed a further $AUD 5.3 billion ($USD 4 billion) to social housing, a portion of which will go towards improving crisis accommodation and increasing support for people fleeing DFV. Project RRE proposes a new refuge standard that maximizes the use of government funds and paves the way to meet Victoria's *Climate Change Act 2017* target of net zero emissions by 2050.

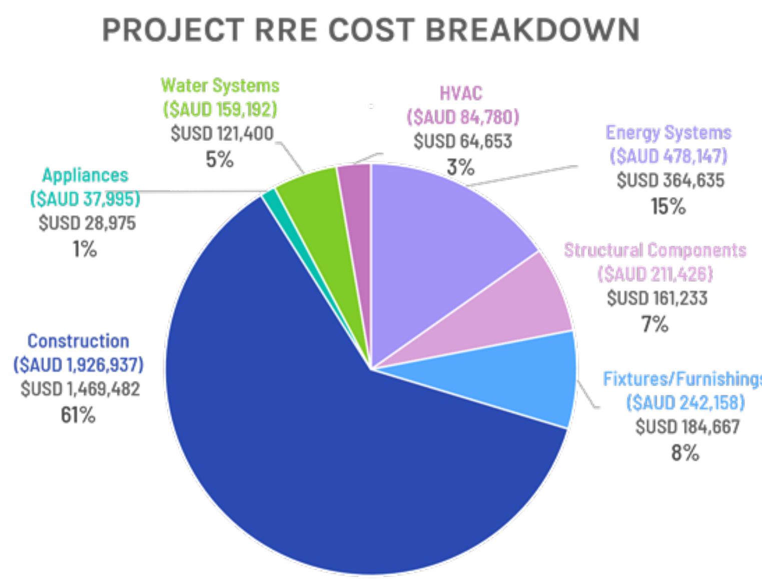


Figure 15. *Total cost breakdown for Project RRE*

The building cost estimate is approximately $AUD 3.14 million ($USD 2.40M) which is well within the $AUD 3.5 million ($USD 2.67M) budget, as advised by Kara House. This estimate was based on the actual budget from the latest refuge build, which was designed in line with the Royal Commission findings and was scaled appropriately to meet the increased size of Project RRE in comparison. The budget excludes the cost of land, and the selected location was approved by Kara House as being characteristic of a traditional refuge location, and thus was deemed acceptable for the Project. The building cost breakdown (**Figure 15**) for the complex does not include the ongoing maintenance and utility costs that will be required of a refuge that is not net-zero. The refuge is designed as temporary accommodation during crisis and once stabilized, the occupants relocate to independent transition houses which are also owned and managed by Kara House. The solar system (15% of the total costs) has been designed so that excess solar generated by Project RRE can be exported to these neighboring transition houses further offsetting the utility costs that Kara House would usually seek government allowances for. Working with Power Ledger, a solar trading company, and the energy provider *AGL Energy*, a Peer-2-Peer virtual power plant will be set up on the *x-Grid Cross Store* system, allowing the transfer of solar between properties connected to the same electricity grid (See section *6.9.3 Grid Interaction*). Therefore, given that the Project RRE building costs are under the given budget and the maintenance and utility costs are drastically reduced, then the project is more affordable than the current refuge designs.

Since the building cost estimate is below the projected cost for a refuge of this size (based on comparable refuge models), it is perhaps easy for stakeholders to suggest reducing costs by eliminating any additional features, such as solar panels. However, it is important to highlight that the building has been designed as a whole and each system is incorporated to achieve optimum operational efficiency overall. Therefore, this design is more financially feasible than current refuges as the additional requirements to meet net-zero do not come at an additional cost. An attractive payback period of 7.2 years has been calculated to demonstrate how the money that the government would have spent in keeping the refuge operational over the long-term has instead been invested upfront and ongoing costs have been almost entirely eliminated. Project RRE is pioneering the way for new refuge designs, and it is the first of its kind in Victoria, so there is limited precedent for comparison.

6.3.5. Operational and Maintenance Cost Estimates

Where possible, the operational and maintenance costs of the refuge have been reduced. Decreasing the energy requirements and offsetting with solar energy generation decreases the reliance on electricity from the national grid. Furthermore, water efficiency has been prioritized and low maintenance and drought tolerant gardens have been designed, which coupled with grey water and harvested rainwater help to limit potable water costs. Durable materials have been prioritized to decrease the long-term maintenance costs. To reduce the maintenance frequency of the exterior, minimal grass spaces have been included, with easy gate access provided between the unit's backyards for when it is required, and limited facade maintenance is needed.

From an operational perspective, costs have been reduced through the unit design to streamline the occupant changeover process. Reducing the storage in the facility to account for the limited supplies that occupants bring to the refuge reduces the number of surfaces the staff have to check for stashed or left items. Easy to clean surfaces such as low-maintenance durable cork flooring and induction cooktops encourage self-maintenance from the occupant. To further reduce maintenance costs, high traffic areas, including unit entryways and hallways within the multipurpose space, will be floored with Comcork tiles. This allows individual floor sections to be replaced on an as need basis, significantly reducing maintenance costs compared to cutting and replacing continuous floor sections. Reducing energy requirements through appliance selection has been considered, with non-powered alternatives encouraged where possible, such as having an outdoor clothesline instead of a dryer, which is common in Australia. Occupancy has been maximized to further alleviate the burden on other governmental resources. This reduces governmental support and the fundraising requirements of Kara House, ensuring the refuge can operate in a more stable manner over the long run. This also allows fundraising to be diverted towards other programs to support occupant recovery instead of operational costs.

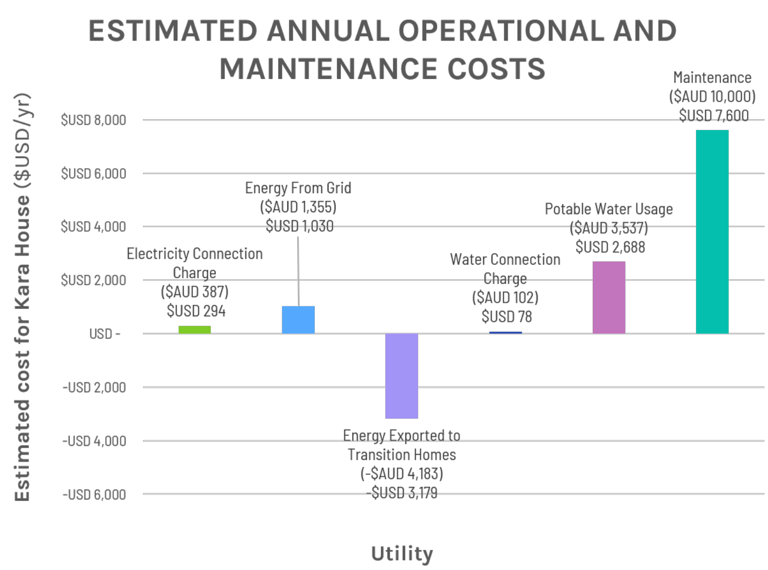


Figure 16. *Annual operational and maintenance costs for Kara House*

The anticipated annual utility and maintenance cost for Kara House is $AUD 11,200 ($USD 8,510). Maintenance and water utility costs are the greatest cost, with additional savings offered from exporting the solar to the transition homes (**Figure 16**). The energy costs were estimated using the Victorian Default Offer which is a daily supply and usage charge (per kilowatt hour) set by the Victorian government to ensure fairness across energy providers.

6.4. DURABILITY AND RESILIENCE

6.4.1. Building Control Layers

Table 1. *Foundation control layer specifications*

Order (outside inwards)	Layer	Thickness (in)	R-Value (ft2·°F·h/BTU)
1	Soil	0	0
2	EPS WafflePod	11.81	5.7
3	Concrete pour	3.94	0
4	Ametalin SilverSark® XHD vapor barrier	0.01	0
5	Comcork	0.18	2.0

Table 2. *Wall control layer specifications*

Order (outside inwards)	Layer	Thickness (in)	R-Value (ft2·°F·h/BTU)
1	Fibre cement cladding	0.39	0
2	Drained cavity	0.98	0
3	Ametalin VapourTech® Wall (vapour permeable)	0.02	0
4	Plywood	0.28	0.3
5	Bradford SoundScreen™ Acoustic glasswool insulation batts and studs	3.54	11.1
6	Rigid Foilboard® insulation	0.79	13.1
7	Ametalin SilverSark® XHD vapour barrier	0.01	0
8	Plasterboard	0.39	0.4

Table 3. *Roof control layer specifications*

Order (outside inwards)	Layer	Thickness (in)	R-Value (ft2·°F·h/BTU)
1	COLORBOND® steel roofing	0.63	0
2	Ametalin Vapour Tech Wall (vapour permeable)	0.02	0
3	Plywood	0.28	0.3
4	Rigid Foilboard insulation	0.79	13.1
5	Plywood	0.28	0.3
6	Bradford SoundScreen™ Acoustic Glasswool insulation batts and studs	10.24	18.1
7	Ceiling joist and attic space	-	-
8	Silver Sark XHD vapour barrier	0.01	0
9	Plywood	0.28	0.3
10	Plasterboard	0.39	0.4

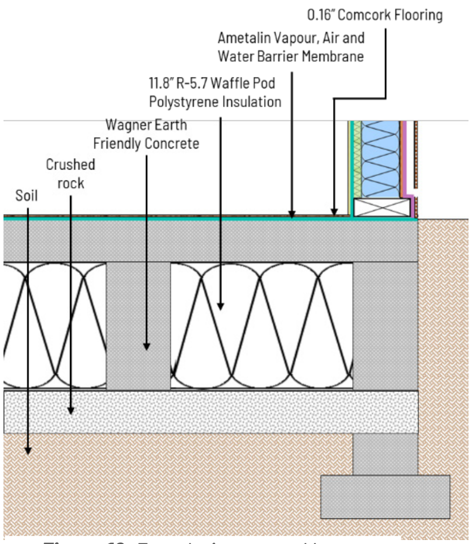


Figure 18. *Foundation control layers*

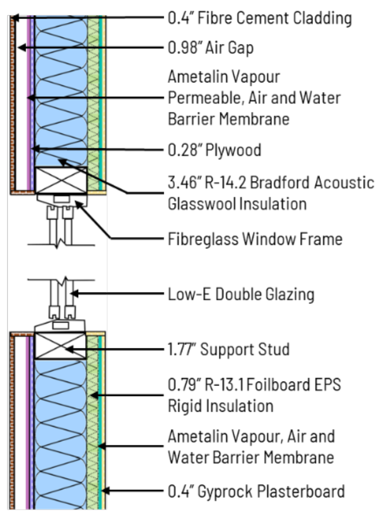


Figure 17. *Wall and window control layers*

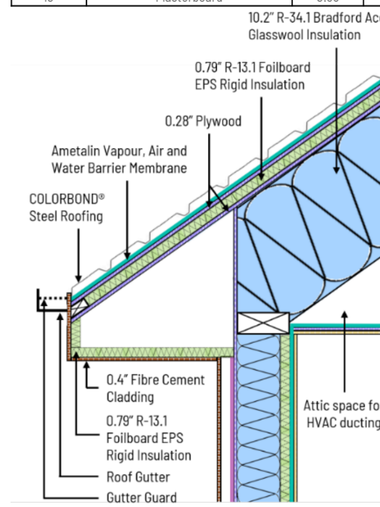


Figure 19. *Roof control layers*

FOUNDATION

A waffle pod slab design was selected for the building foundations (**Figure 18**), meeting structural and thermal insulation requirements while limiting the amount of concrete required. A Melbourne-based company, *Unipod,* produces the expanded polystyrene waffle forms locally, with the foundation form having a total thickness of 15.7 in (400 mm) – 11.8 in (300 mm) of insulation and 3.9 in (100 mm) of concrete. On top of the foundation layer is a vapor-impermeable, airtight membrane, which will be taped to the membrane layer in the wall control layers, creating a continuous barrier against air leakage. The final control layer is the 0.18 in (4.5 mm) thick Comcork flooring, which will be used throughout the complex. This flooring is a highly durable, anti-slip flooring that resists mold and mildew, is easy to clean, and is not susceptible to rot, therefore withstanding the high occupant turnover. The foundation and floor will provide an overall R-value of 7.7 (**Table 1**).

WALLS

The exterior walls have nine control layers (**Figure 17**, **Table 2**). The control layers are designed in consideration of Melbourne's climate, which is characterized as 'heating' with more heating degree days than cooling, and by low-moderate humidity. Following the internal plasterboard, a vapor-impermeable, airtight membrane is used as an air and vapor barrier. This layer will be taped at all joins to create a continuous surface across the envelope, preventing warm air from within the complex from leaking into the wall cavity, where it is at risk of condensing in cooler weather (**Figure 20**). The following layer is the rigid insulation – 0.79 in (20 mm) Foilboard® – selected due to its availability and affordability in Australia and suitable R-value. The foil side will be facing inwards, allowing it to reflect radiant heat back into the interior of the building envelope. The rigid insulation will also form a continuous layer within the building envelope, reducing thermal bridging of the wall studs. The next layer is the thermal insulation layer, with 3.46 in (88 mm) Bradford SoundScreen™ glasswool insulation batts fitted snugly between the 3.54 in (90 mm) timber studs so as to mitigate air flow across the layer as best as possible. The insulation is then protected by a vapor-permeable, weathertightness membrane, which is required by the 2019 NCC to ensure that if any warm air is to escape into the wall cavity it is able to exit, preventing the formation of mold. Finally, the building envelope has a 0.98 in (25 mm) drained cavity to allow airflow, followed by the fiber cement cladding. The combined R-value of all wall layers is 25.9 (**Table 2**, **Figure 17**).

ROOF

The roof control layers are largely a continuum of the wall layers (**Figure 19**, **Table 3**). The plasterboard ceiling will be secured to the ceiling frame, which will then be topped with plywood. The plywood will provide structural support for the vapor-impermeable, airtight membrane, which will be taped to the wall joins to seal off the airtight layer around the entire building envelope. There is then an attic space for the HVAC system, with the building control layers continuing above the ceiling joist. In the frame are a combination of glasswool batts and studs and 0.79 in (20 mm) thick rigid Foilboard® insulation, separated by plywood for support. Another plywood layer above the rigid insulation will support the wind and weathertightness membrane (vapor-permeable), which is sealed by the COLORBOND® steel roofing.

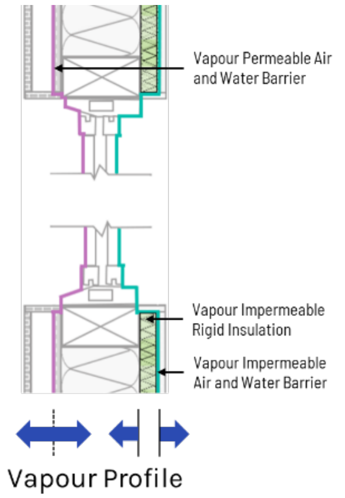


Figure 20. *Vapour profile for wall layer (from exterior on left to interior on right)*

6.4.2. Resilience Risk Mitigation

While Melbourne's mild climate currently presents minimal resilience risks, the increasing impacts of climate change over future years are likely to require greater mitigation of risks associated with weather events. Traditionally, publicly funded refuges in Australia are operational beyond their designed lifespan (40+ years). As such, the design has considered the potential for an increase in extreme weather conditions over the lifespan of the refuge.

While relatively infrequent, hailstorms have caused significant damage in Melbourne. In December 2018, the Insurance Council of Australia reported losses over $AUD 870 million ($USD 612M) after a severe summer storm. Hailstones up to 3.15 in (80 mm) in diameter were reported, with the most significant damage caused to vehicles and roofs. As such, careful consideration was put into the selection of both the roofing materials and the solar panels used in the design. COLORBOND® steel, an Australian-made building material, is used for the roof as it is less susceptible to becoming dislodged from hailstone impacts than traditional roofing tiles. It is also less likely to accumulate hailstones than a tiled roof, decreasing the load on the structural support system of the house in severe storms. COLORBOND® steel roofing is also preferable to concrete or terracotta tiles due to its water-resistant coating, which prevents moisture build up following rain events. COLORBOND® steel roofing was also selected for its simple installation. With its low density and high durability, this material is easier to transport and install than roof tiles, making recovery in the event of storm damage a far simpler process. Additionally, it provides a solid line of defense against ember attack as well as flame resistance, protecting against house fires. Noting the risk of vehicle damage during storm events, the design includes a COLORBOND® steel roof for the car parking spaces.

The installation of the COLORBOND® steel roofing uses fasteners suited for non-cyclonic conditions. *RoofZips* provide screws for fixing the roofing material to timber supports for both cyclonic and non-cyclonic conditions. Currently, cyclones are not a threat for Oakleigh East, however, climate projections suggest that Northern Australia's cyclone-prone atmospheric conditions may migrate to the South from 2070. Therefore, the roof fasteners are able to be upgraded to withstand cyclonic conditions should this present a risk in the future. The timing of expected increases in cyclonic activity coincides with the expected life cycle of the roof material (~50 years).

Panel selection for the rooftop solar system was guided largely by power requirements, as all solar panels commercially available on the Australia market must meet strict hail resistance specifications, withstanding 1.38 in (35 mm) diameter hailstones. The panels will be mounted using a bracket system which exceeds Australian Standards, with high-performance mounting systems that are tested against low-high-low cyclic loading to ensure they are durable in the most extreme storm conditions. As such, they are deemed the most future-proof option, suitable for increased climate variability in the local area alongside the long-expected life of the building.

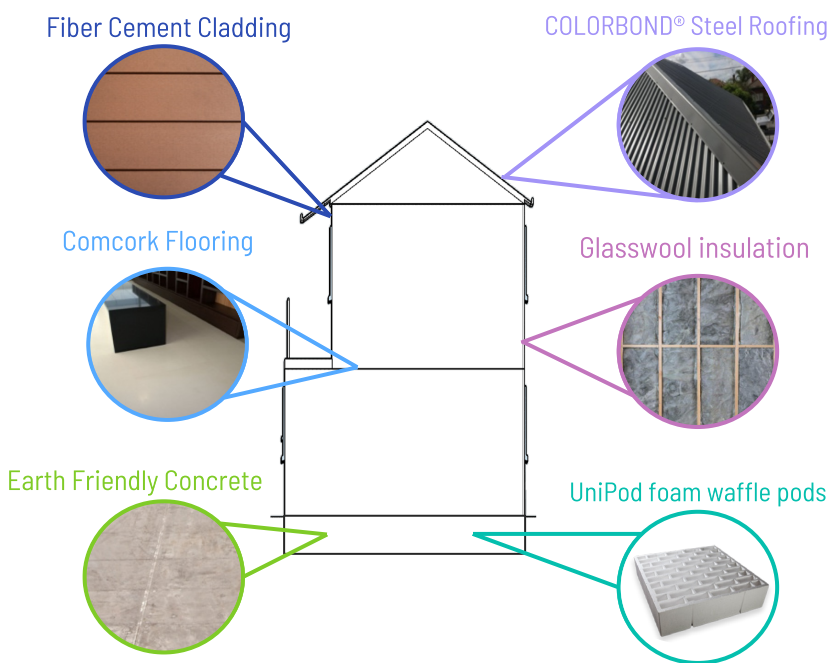


Figure 21. *Materials selection*

There is expected to be an increase in extended periods of extreme heat in eastern Australia in the future due to climate change. In Australia, more people die annually from heat waves than they do from any other disaster. With this refuge designed to house some of the most vulnerable members of society, great care was taken in the design to ensure living spaces will remain comfortable in the event of extreme heat events. The cooling system will provide sufficient cooling at temperatures beyond 115°F (46°C), which combined with internal and external shading, can maintain cool temperatures within the building envelopes.

Taking an integrated approach to resilience, the communal garden space is also designed to withstand heat waves. The landscaping is centered around native plants, which are well adapted to warm, dry Australian summers. The louvred pergola and vegetation within the garden will provide both shade and a natural cooling effect to the immediate outdoor environment. Finally, harvested rainwater will provide resilience against water shortages and restrictions if periods of extended heat coincide with periods of drought, which have previously led to the implementation of statewide water restrictions to ensure Victoria's water supply could meet demand.

6.4.3. Recovery Preparedness

Given Oakleigh East's low risk for natural disasters, recovery preparedness is not a major concern. Storm events are likely to create the most severe weather conditions, which may cause trees to fall down resulting in an electricity blackout. The last major blackout in Victoria was in 2011, when 200,000 homes lost power during a severe storm event. Project RRE's renewable energy systems will provide resilience if this is to occur, since the solar and battery systems are able to run independently from the electricity grid. In addition, the complex is fitted out with emergency controls allowing the external lighting and security system to maintain operation if Kara House deem it to be necessary. Having the non-essential appliances on separate circuits allows Kara House to shut off all non-necessary electricity to conserve battery power in the event of a power failure.

Due to the built-up nature of the area, bushfires are not a direct safety threat and therefore are not considered in the disaster preparedness. House fires, on the other hand, could be an issue. Adequate fire measures including smoke detectors, sufficient escape routes, fire blankets, and a clear fire plan, are included in each space as per Australian 2019 NCC requirements. Additional fire protection is provided in the use of fire-resistant materials, such as the COLORBOND® steel roofing, Comcork flooring, and fiber cement cladding. Glasswool insulation is non-combustible and meets the fire hazard requirements as per Australian 2019 NCC requirements. The strong airtightness of the building envelope helps exclude bushfire smoke fine particulates (PM2.5), whilst F7 filters in the HRV systems are classified as PM2.5 and are able to remove ≥ 50% of the smoke from the incoming air. Whilst not all smoke can be removed by this system, equipping the HRV with a high efficiency particulate air (HEPA) filter would require upgrading to a commercial HRV system to accommodate this. There is the potential to upgrade the filters in the future, and should bushfires continue to increase in frequency in Australia, then a HEPA filter could be installed seasonally. This would result in higher operational costs to account for the greater fan power consumption required for these filters and therefore it is planned that Project RRE would only use F7 filters.

6.4.4. Social Resilience

A final consideration is the social resilience of the refuge. The design has focused on creating a community centralized layout that fosters a culture of respect, not only for the occupants and their neighbors, but for the building itself. Resilience is improved by fostering a 'duty to care', where the occupants are encouraged to take care of their own space by taking cues from the well-maintained garden and other communal spaces. A 'micro-level' of resilience encourages community watch and encourages all occupants to look out for one another. Educational information about net-zero and sustainable house design will be included, such as an explanation about the type of hot water heater, or the solar battery system, to inspire the occupants and provide an opportunity for them to appreciate the innovative solutions featured in the refuge. This empowers the occupants to have a greater understanding of why certain design features have been included, or how the design is supposed to support their recovery. Signage and clear emergency response plans reassure occupants that the refuge will be safe to withstand disasters, adding another layer of comfort and security. Additionally, the increased flexibility of the refuge improves the resilience to changing levels of Government resources.

6.5. EMBODIED ENVIRONMENTAL IMPACT

6.5.1. Life Cycle Assessment

OneClick LCA tool was used to assess the embodied environmental impact (EEI) associated with the manufacturing, distribution and life cycle of the construction materials considered in Project RRE. In general, the LCA estimation process focused on assessing the key features of the design that differentiates it from a standard refuge build. For example, the emissions associated with construction were not estimated, however, Project RRE is expected to have fewer associated emissions than a standard build as less-intensive, lightweight construction will be used. Limitations of OneClick LCA meant that not all materials in the design were available and so the most appropriate substitutes were used where necessary.

The building's lifespan was designed to exceed 50 years, as refuge builds typically do not get renewed. The utilities' life cycle is expected to reach 15 years, provided regular maintenance and servicing takes place. Given the extended nature of the building and the limitations of Government resources, it is assumed that these services will exceed their intended service life.

6.5.2. Material Selection

All materials selected for Project RRE were chosen in consideration of embodied energy and operational energy use, with recycled and renewable materials selected where feasible. Locally manufactured and lightweight materials were also priorities in order to limit embodied emissions from the distribution stage of a material's life cycle.

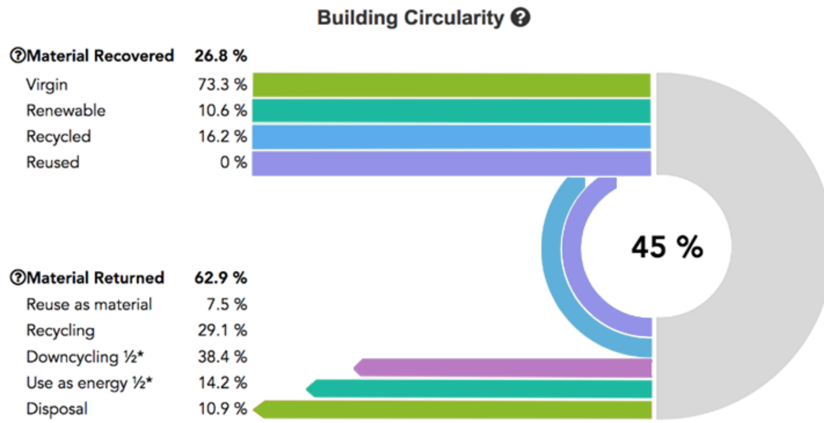


Figure 22. *Project RRE recycled material circularity assessment (from OneClick LCA)*

Concrete is a key contributor to embodied carbon, which is addressed through both reduction and mitigation strategies. The total amount of concrete required for the building foundation was reduced by more than 60% via the installation of the Unipod slab design, with insulation 'pods' reducing the concrete component of the slab to 3.9 in (100 mm), whilst improving the thermal insulating properties of the foundation. The concrete that will be used is Earth Friendly Concrete (EFC) from Australian pioneering geopolymer concrete producer, *Wagner*. Through the use of a geopolymer binder system composed of industrial by-products (fly-ash and furnace slag) in place of ordinary Portland cement, Wagner's EFC is quoted to embody 67% fewer emissions than regular concrete. The reduction in the amount of concrete used and the substitution with EFC resulted in a total reduction in embodied emissions of the foundation slab of more than 65%, in addition to the reduction in energy loss associated with additional insulation (**Figure 23**). The recycled EFC is also manufactured locally, limiting emissions associated with the transport of concrete to the site. Indeed, all construction materials used are readily available locally, including roofing by Australian supplier COLORBOND® steel, and cross-laminated timber framing. Additionally, glasswool insulation batts are made of up to 80% recycled glass, and contain no ozone depleting, irritant, or carcinogenic substances, and Rubber Crumb outdoor ground surfacing is manufactured from 100% recycled tires (**Figure 21**).

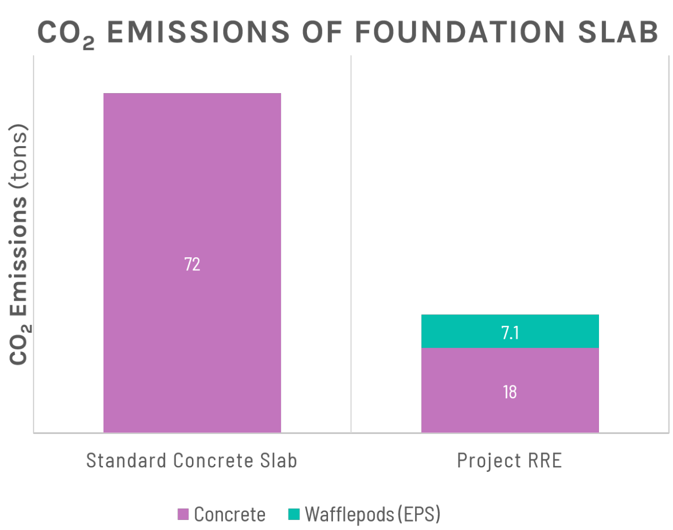


Figure 23. *Carbon emissions for standard concrete slab vs. Project RRE*

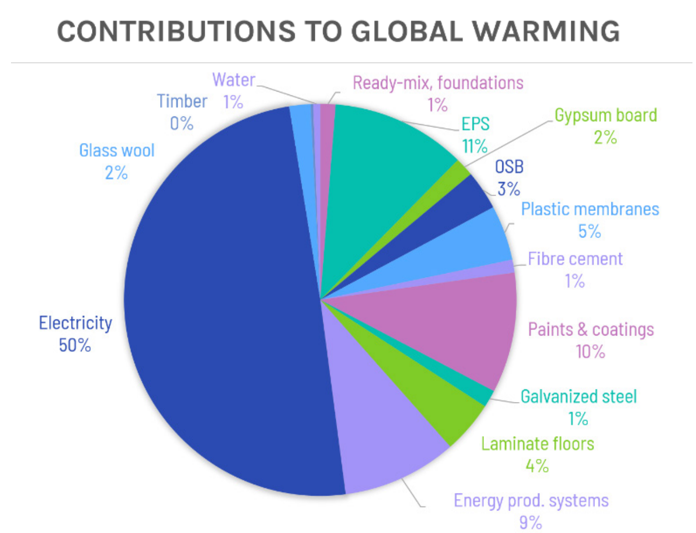


Figure 24. *Global warming contributions of selected building materials*

Renewable materials were also highly prioritized throughout the design (**Figure 24**). The majority of the design's structural components will be constructed from cross laminated timber, rather than steel beams, therefore reducing emissions associated with material production, transport from overseas, and end of life processes. Furthermore, this allowed the use of lightweight construction methods, reducing construction energy requirements through the reduced need for heavy power tools. In addition, a natural playground made almost entirely out of wood was implemented alongside native plants which require no additional irrigation following establishment. This carefully considered landscaping will allow the project to not only minimize plastic usage, but also will enable carbon storage and urban heat reduction. These benefits will extend beyond the building's lifecycle via the planting of trees suited to the local environment which may then be more easily integrated into future developments on the plot.

While the Australian market for prefabricated materials is largely too young to be feasible for a publicly funded project of this scale, recyclable materials were highly prioritized to reduce the environmental impact of building end of life processes (**Figure 22**). Comcork was chosen for the interior flooring, which is a cork-rubber flooring made by an Australian company. It can be completely recycled at the end of the floor's life cycle, compensating for Project RRE's limited design for disassembly possibilities. Throughout the complex, Comcork tiles will be installed, which come in 17x17 in (44x44 cm) squares so that the tiles in high traffic areas (the multipurpose space, and the hallways, kitchen, and living areas in the units) can be replaced with tiles from the corners of the rooms or from the low traffic spaces. This additional flexibility also allows for easy maintenance should damage occur from occupants thus extending the life cycle of the flooring.

Where solar technology is typically also a key contributor to a project's EEI, Project RRE will implement Redflow ZCell flow batteries, which are able to be fully recycled post-use. This is highly attractive compared to standard batteries which rely on virgin rare earth metals. Additionally, refrigerant R32 is used in the Daikin reverse-cycle heating and cooling system which has a 67% lower 'Global Warming Potential' (GWP) than R410A, the most commonly used air-conditioning refrigerant, although both are still considered high-GWP substances. Similarly, CO_2, which has the lowest GWP of all refrigerants and is not considered a high-GWP substance, is used as the refrigerant for the hot water and heating system heat pumps.

6.5.3. Operational Environmental Impacts

A major trade-off between material environmental impact and ongoing environmental benefits was the decision to oversize the solar system. Whilst the additional solar panels increase the project's up-front environmental impact, the resultant reduction in carbon footprint throughout the operational stage of the building's life cycle will far outweigh the impact of each additional solar panel. By oversizing the solar system to not only cover the needs of Project RRE but also supplement energy use in other transitional homes, Kara House's carbon footprint will be significantly reduced. Offsetting these other properties' emissions through solar energy export is especially impactful considering Australia's electricity grid is heavily reliant on coal. With Victoria's current infrastructure, 1 kWh of electricity from the grid produces roughly 2.60 lb. (1.18 kg) of CO_2. Across the year, Project RRE will produce approximately 45,340 kWh of solar energy, equating to 59 tons of offset CO_2. Across the 50+ year lifetime of the refuge, this could amount to over 2,950 tons of CO_2. This is a very important consideration because when compared to other states in Australia, such as Tasmania which produces 0.37 lb. of CO_2 per kWh, the grid in Victoria has particularly high emissions. By rarely having to access the grid and helping to limit other properties' reliance on the grid project RRE will greatly offset the embodied emissions in constructing the refuge.

Originally, Rockwool rigid insulation was chosen as a potential insulation material, to complement the glasswool insulation batts in the building's exterior walls. This material is composed of mostly recycled components, which would present savings in up-front embodied emissions. Unfortunately, it was discovered that Rockwool rigid insulation is not currently available in Australia and the embodied emissions and monetary cost of international transport are contradictory to the design principles. Instead, Foilboard® expanded polystyrene (EPS) insulation panels were selected despite the relatively high embodied carbon associated with EPS. In a similar vein, whilst prefabricated modules and offsite construction would be ideal from an up-front and end-of-life perspective, these methods were ultimately ruled to be unfeasible for Project RRE due to the lack of industry maturity in Australia. Hence, the use of prefabricated and off-site construction technology was largely found to lack the timeliness and reliability required for a government-funded project and as such recycled and renewable raw materials were instead prioritized.

While the installation of rainwater tanks has additional upfront emissions, the benefits of these tanks far outweigh the carbon footprint associated with the tank material. Given the Project RRE is located in a drought-prone region, the water usage these tanks provide is a worthy trade-off. In Victoria, significant water reserves are delegated to the agricultural sector, so water conservation is very important in urban environments. Additionally, these upfront carbon emissions are further offset through the savings that using harvested rainwater and greywater provides. By recycling greywater from showers, bathroom taps and clothes washing machines to use for irrigation and flushing toilets, approximately 1,800 gal less wastewater will be sent to the sanitary sewer system on a weekly basis. Combining this greywater recycling with the use of rainwater lowers potable water demand by approximately 2,192 gal each week. With Victoria's current water systems infrastructure this reduction in wastewater exportation and potable water importation adds up to a reduction of roughly 105 lb. of CO_2 emissions each year per apartment. A total of 1010 lb. of CO_2 each year will be offset due to the water recycling at the complex and roughly 25 tons across the building lifespan of 50 years.

6.6. INTEGRATED PERFORMANCE

6.6.1. Building Envelope

To ensure the optimal performance of the building envelope, a number of design strategies were considered to improve integration and reduce the pressure on engineering systems. The complex is designed such that it has two building envelopes encasing the two building wings (Block A, and Blocks B and C), as opposed to having separate building envelopes for each unit (**Figure 25**). This configuration makes use of the unique nature of the refuge, as Kara House is responsible for utility provision for each unit rather than the occupants themselves, meaning the refuge can be treated as a combined system.

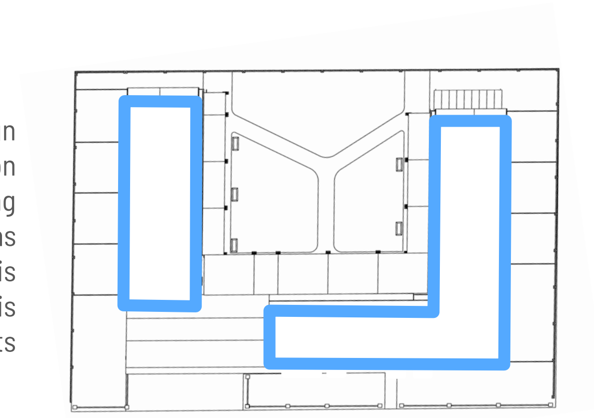


Figure 25. *Building envelopes*

The units are designed to have near-identical climates, allowing them to share subsystems. This reduced the number of penetrations of the building envelope, minimizing thermal bridging. The floor layout of each unit is mirrored along the adjoining walls, allowing for the centralization of utilities between two units, most notably plumbing and exhaust. Therefore, these systems can be combined for each pair of units at their entrance and exit point, essentially halving the number of thermal bridges and air leakage points from subsystems which require management during construction.

6.6.2. Climate

In consideration of Oakleigh East having 2700 heating degree days annually (65°F baseline), a passive approach to heating was prioritized to reduce energy consumption. Window size, quantity, and placement were optimized in consideration of their heating benefits, while also considering the potential for air leakage through discontinuities in the building envelope. Due to the identical unit layout, which is mirrored across Blocks A and B, the layout orientation for each block is reversed and thus, each block has different rooms along the northern facade. The entrance of the units on Block A are north facing, with a south facing rear, which is the opposite of the units in Block B (south facing entrance, north facing rear). Optimal window placement in each room was important to ensure all units are able to receive adequate sun from the north in the winter months to contribute to the passive heating of living spaces. To account for this, it was decided to have two living spaces in each unit, so that the communal garden could be the focal point of the refuge without any unit being deprived of a north facing living space (**Figure 32** & **Figure 33**, in *Section 6.6.6 Lighting system*) These spaces (the kitchen/dining/living open space on the ground floor and the living area on the first floor) are on opposing sides of the units to ensure that regardless of the orientation of a unit, it has one living space receiving north facing sunlight for passive heating. To minimize negative interactions with the building envelope, fiberglass window frames are installed on all windows within the complex, in combination with taping of the airtight membrane around window frames to prevent air leakage. The window sizes were adjusted to suit the orientation of the building, with northern facing windows sized smaller compared to the southern facing windows.

The staircase cavity was recognised as a weak point for maintaining comfortable air temperatures on the ground floor without putting excessive pressure on the HVAC system of each unit. The cavity is designed to be an open space in order to allow the penetration of light and associated heat to reach the ground floor. However, an impact of this decision is the potential loss of ambient heat, as warmer, less dense air rises up the cavity to the second story. While the ventilation system is able to combat this, it was recognized that this heat loss can be partially mitigated by installing a ceiling fan at the top of the stair cavity to push warm air back into the ground floor, reducing pressure on the ventilation system.

A similar integrated approach to passive cooling strategies is required due to Oakleigh East falling within a temperate climate zone with relatively hot summers. With units running parallel to the north-south axis, there are minimal exposed surfaces on the

Figure 28. *Timber louvred pergola covering the accessible pathway*

Figure 26. *External doors*

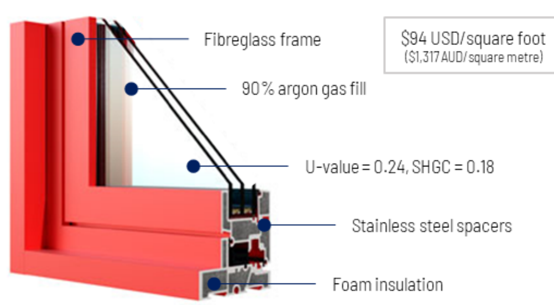


Figure 27. *Cascadia Universal Series window specifications*

western facade, limiting the impact of the hot western afternoon sun in the summer months. The layout of the multipurpose and staff areas is more challenging in this regard since it is oriented east-west. Whilst the multipurpose space is protected by the 16 ft (5 m) timber louvered *Vergola* pergola (**Figure 26**), the staff area is exposed to the western sun. Additionally, all windows have a 1.6 ft (0.5 m) overhang to reduce the cooling loads. Windows are also designed to promote passive cooling through cross ventilation, with strategic window placement on both the north and south facades designed to allow air flow through the units.

6.6.3. Doors and Windows

Passive House International-certified Cascadia Universal Series windows were selected for installation across Project RRE (**Figure 28**). The fiberglass framed windows are double glazed, since triple glazing was determined to be beyond the price range for a Government-funded infrastructure project and hence the cost could not be justified for the benefit it provided to our project. Awning windows with a fiberglass frame and stainless-steel spacer were selected, with bathroom windows frosted for privacy. Although available from a local supplier, these windows are manufactured in Canada, however this trade-off was considered worthwhile to ensure windows of a high quality.

Each of the timber external doors will have a small, double glazed window inset at eye level to allow light into each unit. In the doors leading to the private backyard and the upstairs balcony, two larger windows will be installed into the door to open the living areas to the green spaces (**Figure 27**).

6.6.4. Building subsystems

CONTROL OF BUILDING SUBSYSTEMS

To meet Design Goal 4 (ensuring ease of operation), the subsystems are categorized into three methods of control: automated, centralized, and occupant (**Figure 29**). While in optimal circumstances all systems would be automated, considerations into ease of operation are balanced with the need for flexibility and occupant independence. As such, a hierarchy of controls was established, with the subsystems most necessary for achieving net-zero energy given priority. Automated or centrally controlled components are expected to minimize the risk of user error or sub-optimal energy savings associated with occupant interaction. Where possible, control has been given to Kara House to ensure that resources and utilities are efficiently managed. Appliance timers allow for scheduling based on solar capacity and enable Kara House to switch off appliances that are not in use. While rainwater tanks will be used for toilet flushing and washing machines, an additional tank for Block C will allow Kara House to connect a hose for any cleaning or maintenance requirements.

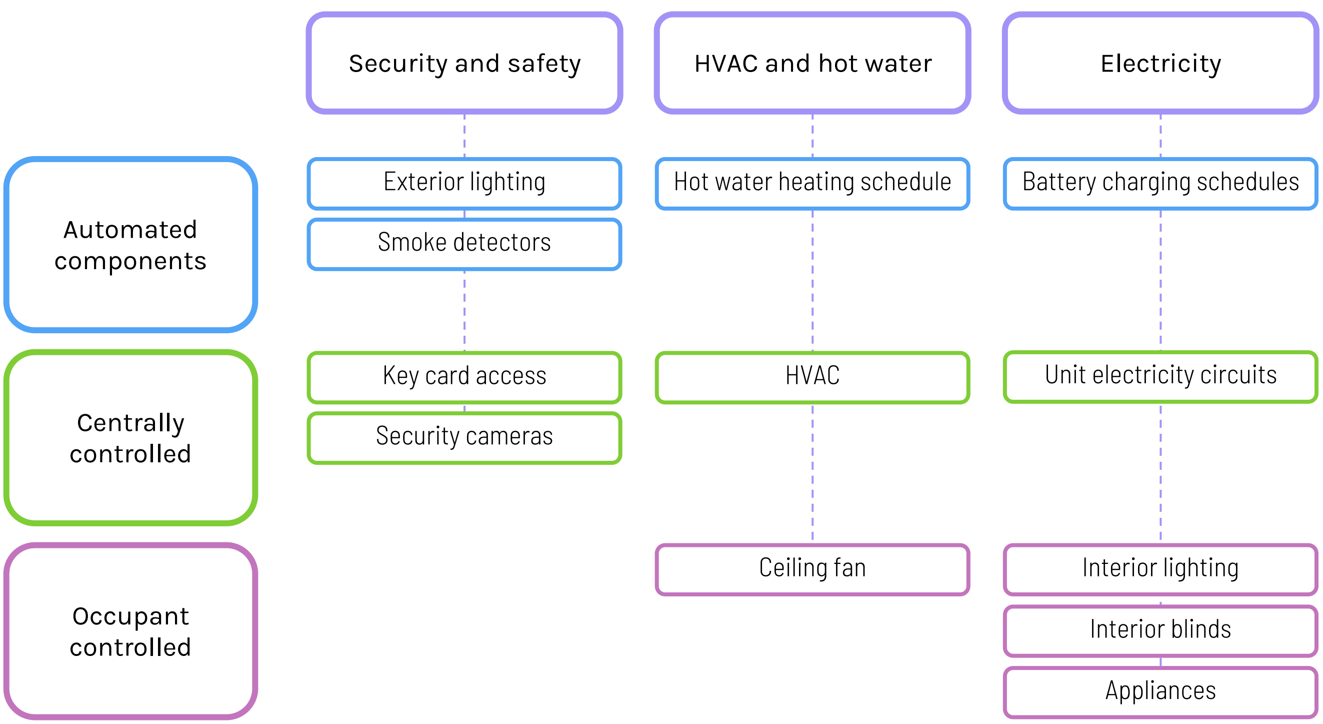


Figure 29*. Control of building subsystems*

SECURITY

To comply with state-funded emergency accommodation requirements, security was a top priority for Kara House. As such, security was integrated into the design at all levels, comprising both passive and active strategies. Each security measure was intended to foster a sense of security for the occupants while effectively reducing and managing the real risks associated with the nature of this type of accommodation.

The complex is designed such that occupants' units are set back from the street, with the multipurpose and staff spaces comprising the majority of the street front. The multipurpose and staff building (Block C) is also designed to act as a buffer between the street and the occupants, with the U-shaped building layout creating a communal space in the center of the complex which is obstructed from street view. Further passive security measures have been adopted to increase perceived security from within this communal space, with Australian Pleached Hornbeam (*Carpinus Betulus*) hedging and fence extenders along the back and side fences to block interactions with neighboring properties.

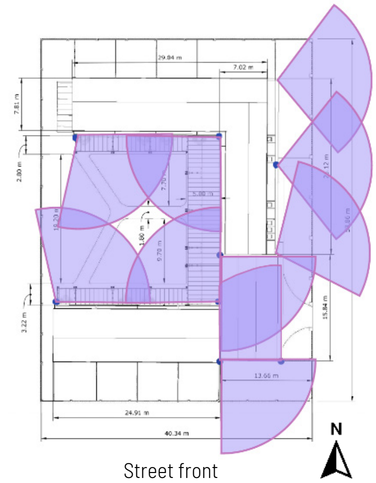


Figure 30. *Security camera coverage*

These design decisions are supplemented by active security measures, most notably the fit out of the complex with security cameras and security lighting. The perimeter of the complex is visible from a security system managed by Kara House (**Figure 30**), consisting of nine security cameras and a surveillance monitor. Sensor lights are also used around the exterior of the complex to recognize movement after dark; however, they are located away from bedroom windows where possible to decrease disturbance to the occupants. It was necessary to ensure that the active security measures integrated into the passive security goal of maintaining an inconspicuous street front so as not to draw attention to the complex by being small in size and hidden in the facade where possible. Automatic, dark-activated, solar exterior lights further bolster security by providing soft lighting above each unit door, within the key spaces of the communal garden, and along the pathways.

A keycard access system is also designed for all access points to the interior areas of the complex. A reprogrammable RFID (Radio Frequency Identification) keycard access system was adopted to provide Kara House full control over all access points. Kara House will be able to activate and deactivate all cards virtually through a keycard encoder and printer as occupants come and go, avoiding unwanted security breaches in cases of lost or stolen cards. Being able to individualize key cards also allows Kara House to limit access to staff areas and to cut access to communal spaces after curfew. Door closers are also installed on the front entrance door to the multipurpose space and the side entrance gate from the carpark, eliminating the risk of them accidentally being left open.

SPACE-CONDITIONING SYSTEM

The building's structural system incorporates several layers of insulation to condition the interior spaces. A combination of rigid and batt insulation, as well as vapor membrane barriers ensure the walls adequately maintain the indoor thermal environment. A heat recovery ventilation system is implemented via ceiling ducts throughout the units to ensure adequate fresh air is provided without losing heat. Window placement maximizes passive heating during winter to supplement the heating conditioning system and allow cross ventilation when required. Centralized heating and cooling systems are controlled by Kara House which ensures that there are minimal disturbances to the building envelope conditions.

6.6.5. Renewable energy systems

The rooftop solar PV system is the sole supply of renewable energy to the complex, and thus has been optimized to provide the best possible performance in all conditions. The solar panels will be installed on all north facing roof surfaces and will be oriented directly north. For maximum sun exposure, the panels will be angled at 32° from the horizontal, providing the greatest benefit in winter when the sun is lower in the north. As the roof is angled 23° from the horizon, this will be achieved with additional framing. While framing comes at an additional cost, lifting the panels further off the roof surface can also contribute to optimize performance as the air gap between the panels and roof is greater, keeping the panels cooler by reducing heat absorption from the steel roof. The battery system is also installed in consideration of temperature, with the batteries stored in an exterior shed on the south side of the building to protect them from rain, sun, and wind.

In order to run the hybrid battery system (See *Section 6.9.2 Renewable Energy Generation*), the system will be installed with AC coupling. Two inverters will be installed to manage energy flows between the solar panels and the units, batteries, and grid. The solar panels will be installed with 230 V microinverters, providing electricity to the units on the priority circuit, with excess energy going to the secondary circuit. The secondary circuit is controlled by the battery inverter, which controls the charging and discharging of the battery, safely switching between battery and grid power to prevent damage to the battery system.

Furthermore, the system is designed to produce the maximum amount of electricity possible, meaning no additional solar panels will be installed in the future. As such, the inverters are sized according to the current system, eliminating efficiency losses from oversizing in preparation for additional installation in the future.

6.6.6. Lighting system

The lighting system prioritizes daylight in an attempt to keep energy consumption as low as possible (**Figure 31**, **Figure 32**, **Figure 33**). To complement natural lighting, the electrical lighting system has been designed in accordance with the interiors. As such, brightness is prioritized in key areas requiring higher levels of illumination, including the kitchen benchtop, dining table and bathroom sink. Downlights are used in these places to provide focused lighting, while light globes are used for general purpose lighting throughout the rest of each unit. All globes and downlights will be LEDs with a color temperature of at least 5000k, providing a comfortable ambience to improve the 'homey-ness' feeling of the units.

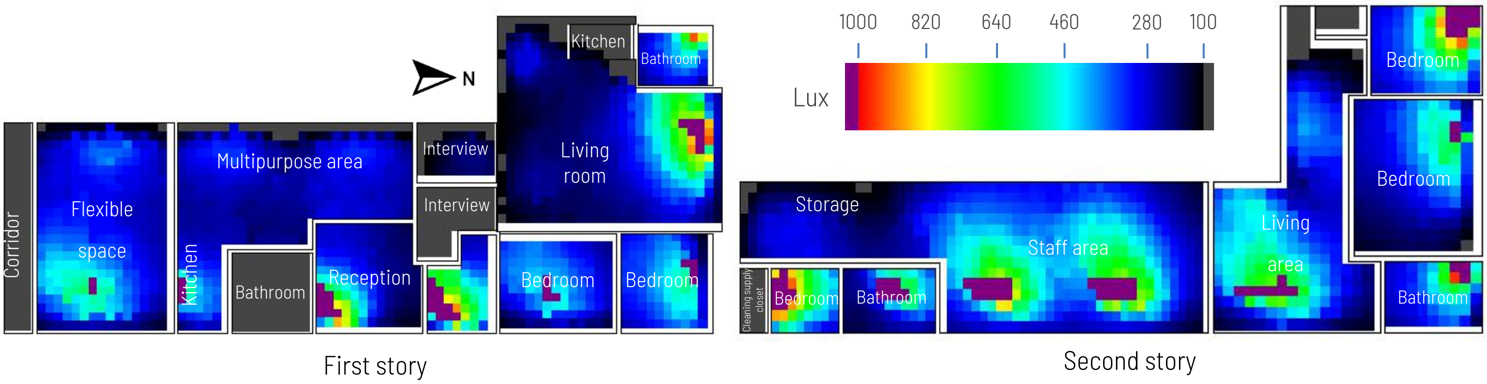


Figure 31. *Block C natural lighting diagram*

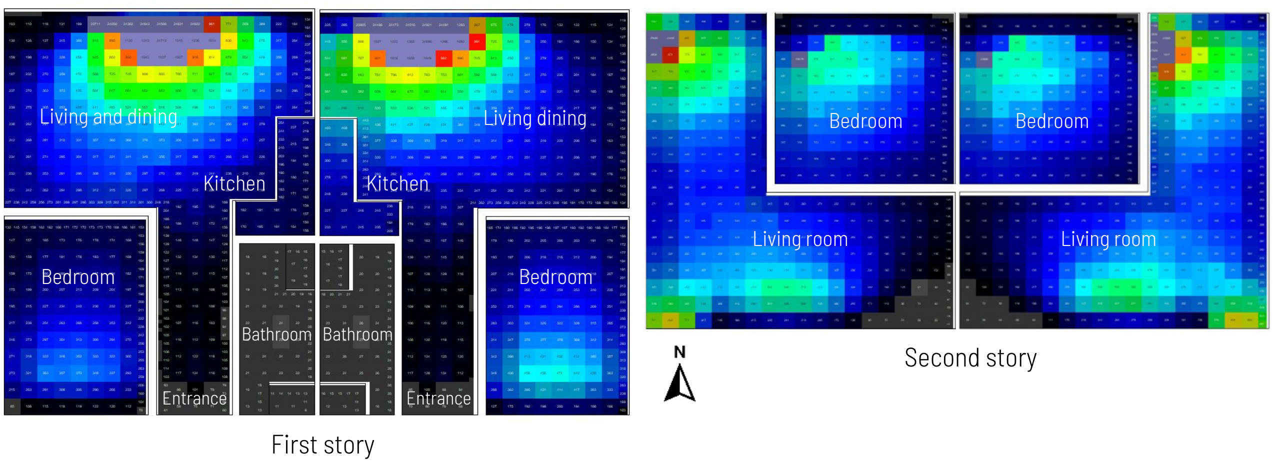


Figure 32. *Block B natural lighting diagram*

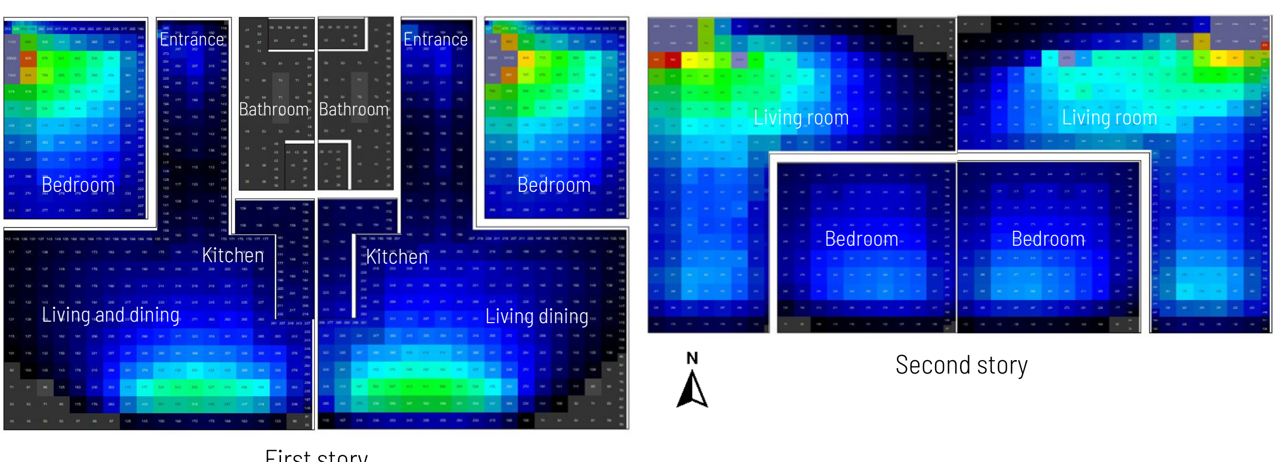


Figure 33. *Block A natural lighting diagram*

6.7. OCCUPANT EXPERIENCE

6.7.1. Green spaces

The communal garden is the central point of the complex and was designed in accordance with the evidence-based crisis shelter guidelines set out by C.C. Marcus and N.A. Sachs in *Therapeutic Landscapes: An Evidence-Based Approach to Designing Healing Gardens and Restorative Outdoor Spaces.* Both the women and children occupants of Project RRE are likely to be suffering health conditions, such as depression, post-traumatic stress disorder, chronic pain, and other injuries as a result of DFV. The Attention Restoration Theory has been implemented to create distinct areas for occupant recovery, providing an escape from the stressors they are experiencing.

Figure 34. *(Left) The standard unit upstairs bedroom has a view of the backyard trees. (Middle) Each unit has a balcony space overlooking the communal garden. (Right) The kitchen window provides an outlook of the backyard green spaces.*

A direct connection to the outdoors has been incorporated in the balcony spaces, private backyards, and visibility of green space from each window in the unit (**Figure 34**). Easily accessed garden spaces are a health-promoting resource and facilitate recovery through the use of sensory gardens, which are designed to provide a feeling of safety and security, separate safe play areas for older and younger children, and areas for different levels of social involvement (**Figure 35**). Specifically, the sensory garden includes calm secluded spaces, informal seating along pathways to promote interaction, larger areas for varying group sizes and visible lines of sight between each seating and play area to promote community watch. The young children's play area is designed to be tactile and encourage movement with a sandpit, hopscotch, tunnel, and slide, alongside spaces for relaxation. Dual-use additions to the garden space were preferred in the design, with an example including wooden beams along the pathways which act as balancing play equipment for children, as well as a way to delineate different garden areas so families can also enjoy spaces independently. A separate space is also designed for older children, which includes a recycled rubber crumb surface with a combined basketball hoop and soccer goal for stress release through exercise, and private swing seats to provide spaces for reflection.

Figure 35. *(Left) Aerial view of communal garden, with the children's play area and sensory garden. (Middle) View of the older children play area from the accessible pathway. (Right) Younger children natural playground area with sandpit and slide/tunnel.*

A secluded sensory garden is designed to engage the senses using fragrant plants such as lavender, as well as texture tables with pebbles or stones (**Figure 36**). Seating on both sides of the wooden divider provides a feeling of privacy, and soft, draping Weeping Peppermint (*Angonis Flexuosa)* trees provide shade while still allowing clear lines of visibility necessary for safety. Color and texture provide focal points and engagement. The garden space is bound by pervious concrete walkways, protected by louvred pergolas to provide shelter and shade. Small, raised vegetable garden beds are located alongside these walkways, providing occupants with a purposeful activity, and encouraging the use of locally grown produce.

Each unit has access to a private balcony regardless of the use of the *Occupancy Maximizer Layout*, which looks out over the community garden. These balconies add an element of luxury to the units, moving away from the traditional 'practicality-first' design of crisis accommodation. The placement of the balconies also acts as a passive safety and security measure, allowing women to watch over their children in the shared access community garden while remaining in their own space. Additionally, the balconies promote visual connections to the landscape, allowing the benefits of the community garden landscaping to be enjoyed from a distance. Individual units also have access to a private backyard with a paved seating area, grass space for private exercise and dense trees along the back fence for privacy.

Figure 36. *(Left) Texture table on the undercover gazebo in the sensory garden. (Middle) Different levels of seating provide occupants with spaces to socialize or sit alone. (Right) Seating in the sensory garden immerse occupants with colors, scents, and textures.*

6.7.2. Appliances

Each unit is designed to be fully self-contained, equipped with a full suite of appliances for the kitchen, bathroom, and laundry (**Figure 37**).

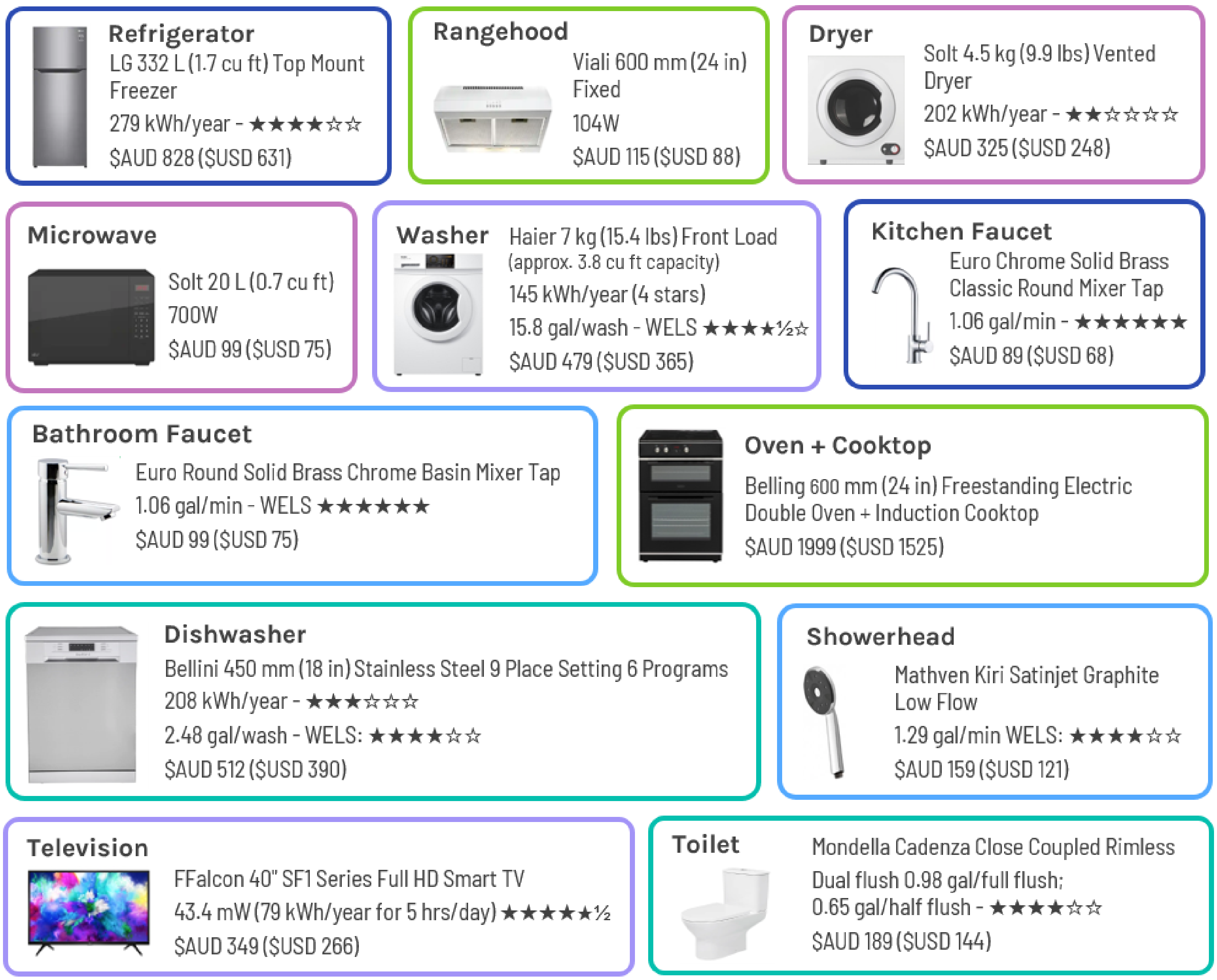


Figure 37. *Appliances and their Energy Star Ratings and Water Efficiency Labelling and Standard (WELS) Ratings*

6.7.3. Building Control

As outlined in *Section 6.6.4 Control of building subsystems*, the building controls are split across three categories: occupant controlled, centrally controlled by Kara House, and automated. The assignment of subsystems within the categories is based on two criteria: complexity of operation, and predictability. If a subsystem is likely to run on a predictable schedule, it has been automated to limit pressure on staff and reduce the likelihood of human-induced error. Conversely, if a subsystem is reactive to unpredictable external conditions such as temperature, occupancy, or sunlight, it is likely to require onsite control. Onsite control is delegated to either Kara House or the occupants according to the complexity of the task (**Table 4**). Considering the short occupancy period (typically limited to six weeks), it is not feasible to require occupants to learn complex operational controls which optimize energy use.

Centralized controls will run from the staff office area, limiting labor and time requirements for Kara House's tasks. To ensure the occupants still experience some level of control over the temperature in their living space, they will be able to run the ceiling fan in their units. As discussed in *Section 6.6.2 (Climate)*, the ceiling fans are also installed for the purpose of preventing heat loss from the ground floor through the stair cavity. It is recognized that this may be counterintuitive to occupants, so a learning board explaining the fan's ideal use will be located next to the switch in a frequently visited area. The occupants have individual control over the appliances in their units, however the dishwashers and washing machines will be on timers, limiting their use to during daylight periods to correlate with maximum solar generation periods. Kara House will have additional control over the appliance circuits; however, this control will only be used during changeover period between occupants.

Table 4. *Control of tasks based on complexity-predictability matrix*

		Complexity of task		
		1 (simple, minimal time)	2	3 (complex, time intensive)
Predictability of task	1 (highly varied operation)	Occupants	Kara House	Kara House
	2	Kara House	Kara House	Kara House
	3 (predictable operation)	Automated	Automated	Automated

6.7.4. Maintenance

A key priority for the complex is to minimize the maintenance required by both Kara House and the occupants. Low maintenance costs are vital to ensuring the economic sustainability of the complex, as occupants are not required to pay rent or bills in refuge housing in Australia. As such, Kara House is responsible for all ongoing costs associated with running and maintaining the complex, with maintenance jobs kept in-house as far as practicable in order to ensure the security of the complex and safety of the occupants. The design implements numerous strategies for minimizing the time, cost, and technical experience required for maintenance tasks (**Figure 38**).

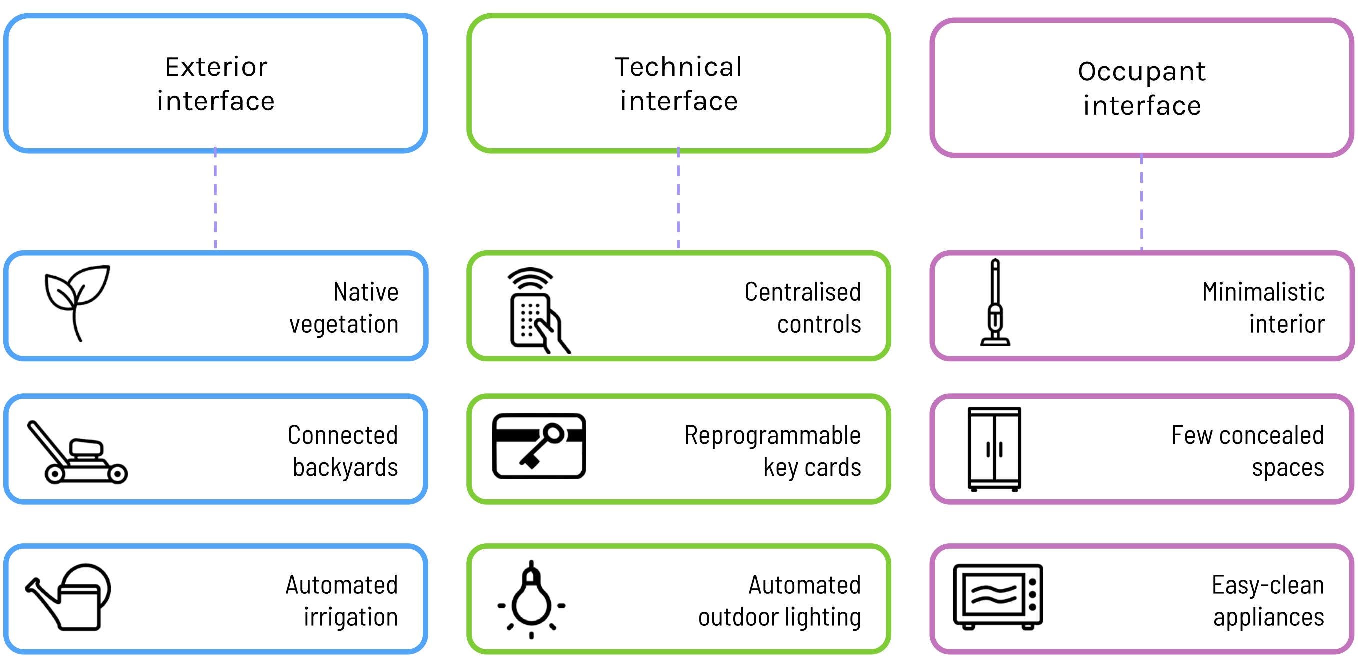


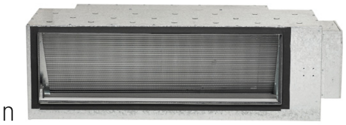
Figure 38. *Strategies to reduce on-site maintenance*

6.8. COMFORT AND ENVIRONMENTAL QUALITY

6.8.1. HVAC System

HEATING AND COOLING

For Project RRE, the annual heating loads are 820 kWh/year, and the cooling loads are 3,434 kWh/year, as modelled using DesignBuilder. To meet these heating and cooling demands of the internal spaces, reverse-cycle, ducted air-source heat pumps will be used. The use of an air source heat pump is the most suitable and efficient option given Oakleigh East's temperate climate conditions.



Make: Daikin
Model: Premium Inverter Ducted reverse cycle
Capacity: 7.1 kW (6.73 Btu/s)
Power supply: 1 phase, 220-240 V, 50Hz
EER/COP: 3.74/4.29
Refrigerant: R32 (66% less GWP than R410A)

Figure 39. *Heat and cooling system*

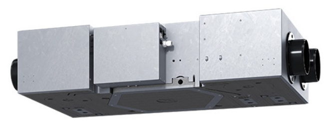
One 7.1 kW Daikin Premium Inverter Ducted reverse cycle Heat Pump system (**Figure 39**) will serve the needs for two units. This will be connected to two fan coil units, one for each story, to distribute conditioned air to two units on each story (**Figure 43**). For the multipurpose space (Block C), a 10 kW heat pump system of the same model will be used to account for the larger space to be conditioned.

This system was sized to meet the design heating and cooling loads of each dwelling. These design loads account for all but 2% of extreme low or high temperature days. On the upstairs level, the same configuration will be installed, so effectively each refuge dwelling will be controlled by two heat pump systems. The air conditioner exceeds the Minimum Energy Performance Standards, and the indoor unit is manufactured to withstand the harsher Australian summer climate. As a balanced system, this ensures that no additional air is added to the space, and indoor heat exchanger technology ensures heat is removed efficiently. The heat pump is set to have a low outlet flow rate to achieve a comfortable temperature. A flow rate of 3.3-9.8 ft/s (1-3 m/s) coming out of the duct ensures that all occupants will feel comfortable even if they are sitting directly under the air conditioning vent.

The Daikin Airbase controller allows Kara House to control the temperature and fan speed to ensure that all spaces within the units are kept at the same comfortable temperature of 72°F (22°C) year-round from an app. Centralizing the HVAC system allows the indoor conditions of all units to be controlled by Kara House. This system suits the structural space-conditioning system as batt insulation is used for all external walls and only acoustic insulation is used in walls between adjoining units. All attached dwellings within the same Block fall within one thermal envelope so unit-specific adjustments are not permitted. A Zone Controller allows zones to be turned on or off which could reduce conditioning needs during occupant turnover when the unit is vacant.

VENTILATION

The ventilation strategies for the units are a combination of mechanical and natural ventilation optimized to achieve a minimum of 0.36 air changes per hour (ACH) with the possibility to go up to 0.77 ach with mechanical ventilation alone. This system exceeds the minimum number of air changes of 0.35 ach, as required by the 2019 NCC. Balanced heat recovery ventilation (HRV) systems are installed as they are the most suitable ventilation system for the lower average humidity in the local climate. While Melbourne has occasional humid days, the average humidity across the year is too low to justify using energy recovery ventilation.



Make: Stiebel Eltron
Model: VCR 180 MC
Air volumetric flow: 29 - 106 cubic ft/min
Power consumption: 105 - 1150 W
Heat recovery: up to 87%

Figure 40. *Heat recovery ventilation system*

The HRV system operates along one floor of two units, so two systems would be required for every two units (**Figure 43**). The selected HRV system is a Stiebel Eltron VCR 180 MC HRV unit (**Figure 40**) which can discreetly and compactly be installed in a ceiling cavity. One of these systems will be installed in the ground floor ceiling cavity to service two adjoining units, while a second system will be installed in the attic to service the upstairs areas of two dwellings. This system is designed for air flow rates of 29-106 ft^3/min (50-180 m^3/h), which is suitable for a standard 2-bedroom unit. The crossflow heat exchanger in the HRV will recover up to 87% of the heat energy from the extracted exhaust air (from bathrooms and kitchens) and use it to heat the incoming fresh air supply (unit-wide). For the multipurpose space (Block C), three of these HRV systems (two downstairs and one upstairs) were used to achieve 0.8 ACH.

For spot ventilation, a rangehood exhaust will be installed above the kitchen stovetop, and an additional exhaust vent for the HRV system will also be positioned in the kitchen. In the bathrooms, an exhaust vent for the HRV system will be installed to control moisture as per 2019 NCC requirements. Additionally, optimized window placements allow for cross-ventilation for natural air flow to compensate for the significant air tightness of the building.

DUCT SIZING AND VENT PLACEMENT

It was decided to have separate ducting for the air conditioning and the ventilation system as a combined system would require significantly oversized duct which were unfeasible given the limited ceiling cavity for the first floor of the units. The ducts directly interfacing with the internals of the house have been sized to ensure a comfortable low air flow rate for the air conditioning is achieved (3.3-9.8 ft/s [1-3 m/s]). The maximum duct size is 12.4 in (315 mm) for the main duct, with each duct and vent sized according to the air exchange requirements, with the smallest duct of 2.48 in (63 mm) placed in the bathroom (**Figure 43**). Vents into each room will be placed in the ceiling cavity or the attic cavity for the first and second floor conditioning, respectively. This means that no ducting or piping is required to be installed within the walls, so the batt insulation layer is not disrupted.

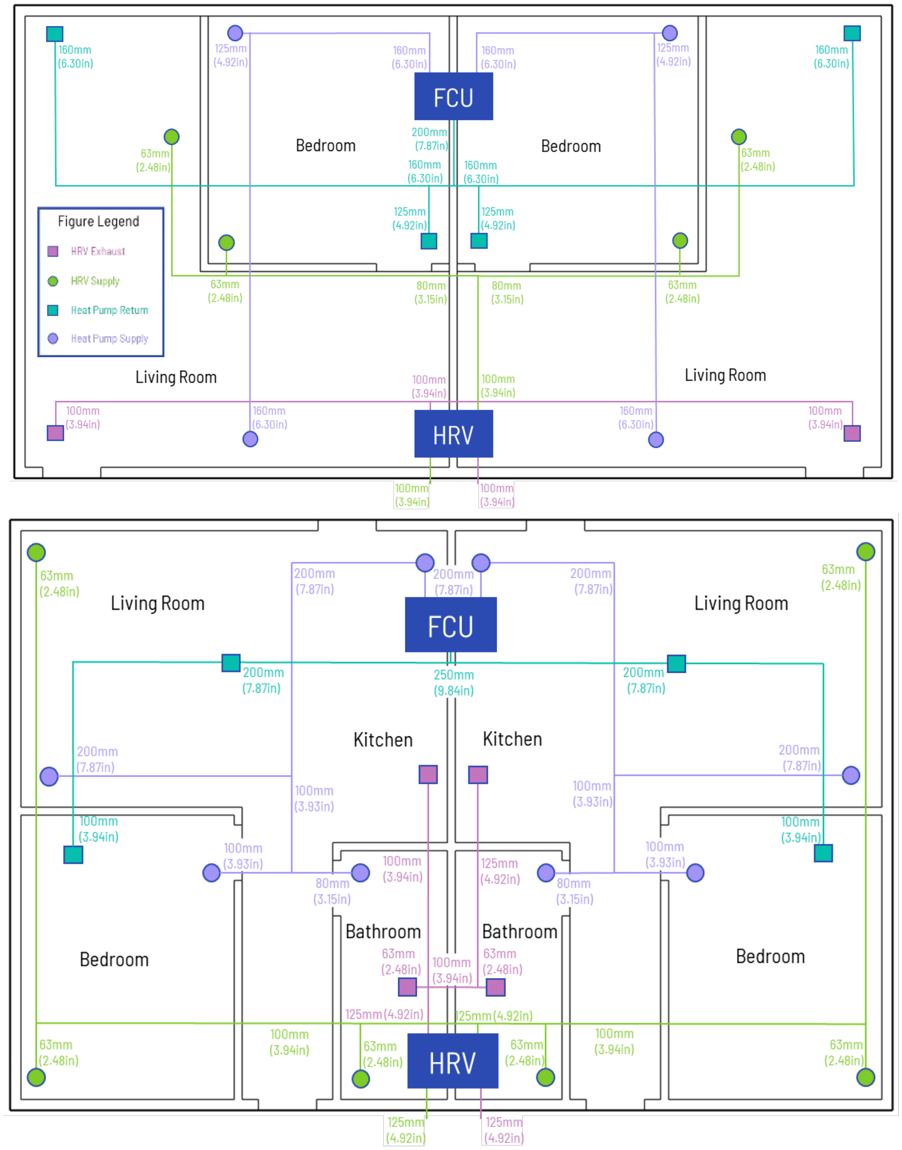


Figure 43. *Duct sizing and vent placement for the downstairs (bottom) and upstairs (top) of two standard units. Ducting is in the ceiling cavity and attic space. One HRV and one fan coil unit heating/cooling system is shared across each story of the two units*

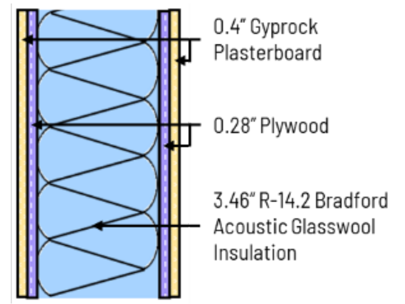


Figure 42. *Interior wall section control layers*

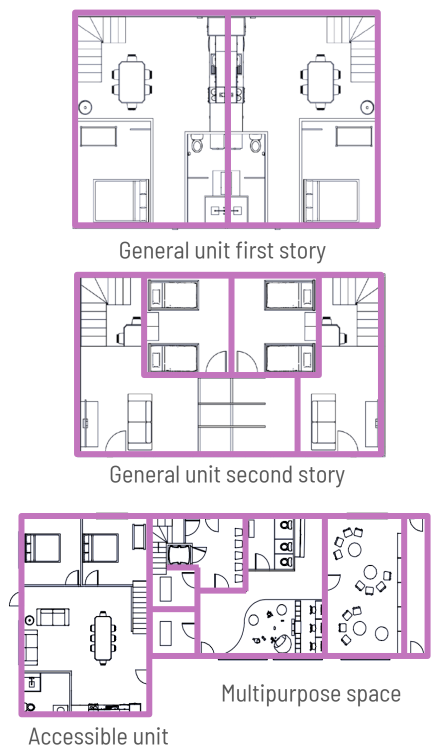


Figure 41. *Acoustic insulation throughout the buildings*

6.8.2. Source Control

In order to maintain high air quality inside each unit, a filter can be placed at the heat exchanger outlet of the HRV system, so only one filter is required per system. A Stiebel Eltron Grade F7 (as per the EN779) air filter with a rating of ePM1 ≥50% (as per the ISO 16890) will be used on the HRV system to remove particles ≥1 μm. While a high efficiency particulate air (HEPA) filter would be most ideal to filter bushfire smoke, they are not compatible with this residential HRV system, are more expensive, and require far greater fan power consumption. Given that there is currently no known safe threshold for particulate exposure, the F7 filter is more than sufficient for removing the majority of the expected air pollutants. These filters can easily be changed during occupant changeover periods every six months or as required. Furthermore, the HRV air filter and the glasswool insulation are all approved by the National Asthma Council Australia Sensitive Choice® program so are suitable for asthma and allergy sufferers.

The use of a vapor impermeable membrane barrier ensures that no moisture is able to infiltrate the building envelope, but an outer vapor permeable membrane layer prevents moisture from building up within the wall cavity. The glasswool insulation fibers are not classified as an irritant or as carcinogenic so will not be introducing any harmful chemicals during construction or removal. All construction and installation practices will meet the requirements of the 2019 NCC to ensure that all materials are appropriately handled.

6.8.3. Acoustic Considerations

The major acoustic consideration for the refuge is minimizing noise between the units, and between rooms in the multipurpose space to allow privacy for occupants. Given the experiences most occupants have been through before coming to the refuge, Kara House also noted the importance of quality therapy spaces for the provision of their onsite recovery services and the need to minimize exterior noise for occupant wellbeing. Therefore, interior wall layers in the multipurpose space, the internal walls between each unit, the roof, and the internal floor between the two stories were designed with acoustic insulation to ensure the creation of peaceful spaces which provide a feeling of privacy (**Figure 41**) High density Bradford SoundScreen™ glasswool insulation batts have a thickness of 3.46 in (88 mm) and an R-value of 11.1 $ft^2 \cdot °F \cdot h/BTU$ was used as insulation across the complex to reduce sound transfer by up to 75%. With plywood on either side of the insulation (**Figure 42**), the whole wall has a Weighted Sound Reduction Index (R_W) of 42 (meaning that it decreases sound pressure level by 42 dB) and is able to absorb almost all sound with a frequency above 125 Hz. Further soundproofing occurs in the selected double-glazed windows, which have an R_W of 33 to minimize the sound leakage through them.

Additionally, the low fan speed of both the HRV, and heating and cooling ducts ensures that minimal noise is produced by the HVAC system. For the HRV system, a sound power level of 33 dB is achieved which is as loud as someone whispering 5 ft away, while a maximum of 50 dBA is expected for the heating and cooling system, which is about the same level of sound that comes from a household refrigerator.

6.9. ENERGY PERFORMANCE

6.9.1. Energy Modeling

DesignBuilder was used to help the team better understand the integration of design and energy performance (**Table 6**). The software allowed the building layers and material selection to be modelled based on an Australian climate. Window placement, insulation thickness, and HVAC systems were all optimized using the simulation's energy analysis. REM/Rate was then used to perform the final energy performance calculations based on the optimized model and achieve the Zero Energy Ready Home certification. Additional modeling for the lighting was performed using DIALux, and the solar photovoltaic (PV) system was sized using *Solar Choice Solar and Battery Calculator.*

For accuracy and simplicity, two representative models were evaluated using REM/Rate: a single unit; and the multipurpose and accessible unit. The HERS Index was generated both without PV and with PV (**Table 5**), however the PV estimations are likely to be different since the centralised system and the solar batteries could not be modelled.

Table 6. *Overall site energy performance results for the first and the final model*

	First Iteration Model	Final Optimized Model
Total site energy consumption (kWh/year)	47,435	37, 623
Energy produced on site (PV) (kWh/year)	-	31, 633 (84%)
Net site energy (kWh/year)	47,435	5, 990
Heating loads (kWh/year)	1,400	820
Cooling loads (kWh/year)	7,800	3,434

Table 5. *HERS Index for two REM/Rate models*

	Single Unit	Multipurpose Space
HERS Index (without PV)	48	49
HERS Index (with PV)	-2	-22

To determine the overall energy performance of Project RRE, the site was modelled as two building types in Design Builder: one model contained two standard units, and the other contained the multipurpose/office space and the accessible unit. The DesignBuilder energy modeling was an iterative process. DesignBuilder default templates were used to create a base model which could be built off, with changes made to various aspects of the model specifications, including ventilation values (natural and mechanical), window placement, insulation thickness, power loads (lighting, appliances, heating, and cooling), time use in different rooms of each unit, and PV generation. Once changes were made, the simulation was run to assess the change in energy loads. This process of adjusting specifications and simulating the results was iterated to achieve the number of solar panels required to achieve net zero across Project RRE without a battery storage system. The solar PV was then removed from the model and the PV sizing was done manually based on the energy consumption loads from the DesignBuilder model. Once finalized, the DesignBuilder model was imported into REM/Rate, which was used to perform the final energy performance calculations, generate the HERS index, and generate the DOE Zero Energy Home certification.

Due to inaccurate modeling of battery storage on DesignBuilder, the total onsite renewable energy system (generation and storage) was modeled using Solar Choice, an Australian solar comparison platform. The DesignBuilder simulation estimated that 86 solar panels (31.8 kWh) were the minimum number required to achieve net zero across the Project without a battery storage system. This allowed specific inputs to be modeled, including estimated diurnal usage patterns and Australian energy pricing, creating a more accurate output for the battery storage system. The estimated solar array sizing was then compared against PV Watts and OneClick LCA tool to ensure accuracy in the design of the solar PV and battery storage system.

6.9.2. Renewable Energy Generation

The complex will have onsite energy production from rooftop solar photovoltaics, making use of Melbourne's sunny climate and the large availability of north-oriented roof space. Solar batteries will be used to store excess solar energy produced during daylight hours, reducing reliance on electricity from the grid at night and on cloudy days, as well as providing resilience in the event of blackouts.

SYSTEM COMPONENTS

The *Seraphim SolarBright* solar panels have an efficiency of 19.8% and are designed to provide maximum solar output even under shady conditions. The panel is split into two separate halves, allowing one half of the panel to continue to run at full output if there is shading over the other half. The *Seraphim* panels feature monocrystalline half-cell technology, improving performance by decreasing resistive losses. Furthermore, smaller cell sizes reduce the mechanical stress on each cell, making the panels more robust against cracking.

Redflow ZCell zinc-bromine flow batteries allow for full depth discharge on a daily basis, making them suitable for the high demand on the centralized energy system during peak periods. Unlike lithium-ion batteries, they are able to be fully discharged without any damage to the battery itself, so the battery system does not have to be oversized to compensate for minimum storage requirements. This helps to ensure the longevity of the system, extending the expected lifespan of the system beyond ten years. The liquid in the battery is also a fire retardant making it safer than regular batteries.

Make: SolarBright
Model: Seraphim SRP-370-SMB
Wattage: 370 W
Cell design: 166 half-cell panels
Dimensions: 69.9 in (L) x 41.4 in (W) x 1.4 in (D)

Figure 44. *Solar panel specifications*

Make: Redflow
Model: ZCell Residential
Energy storage: 10 kWh, 48 V
Electrical charge: 208 Ah
Battery type: zinc-bromine flow
Dimensions: 45.7 in (L) x 40.4 in (W) x 19.1 in (D)

Figure 45. *Solar battery specifications*

Figure 46. *Detailed render showing solar batteries (outlined in green on left) and the solar panel array (right)*

SIZING

As the units do not require individual metering under the premise of a short-term refuge facility, all solar panels will be connected to a centralized energy system with shared energy storage through the batteries. This method dampens the impact of peak loads due to variation in use across the units, allowing faster demand response times.

The solar array was sized based on solar and battery calculation results (using *Solar Choice*). Because DesignBuilder is not able to model batteries, the minimum array size it provided was used as a starting point for total renewable system (generation and storage) sizing. Given energy consumption loading and patterns, it was found that 4 batteries (4x10 kWh) will be the optimum number to ensure they have a chance to discharge. In comparison, while 5 batteries were able to store more of the energy produced by the solar system, they were only discharging to 43% overnight, wasting energy overall. The solar array was then optimized for 4 batteries, which was found to be a 65-panel system considering energy consumption loading and patterns.

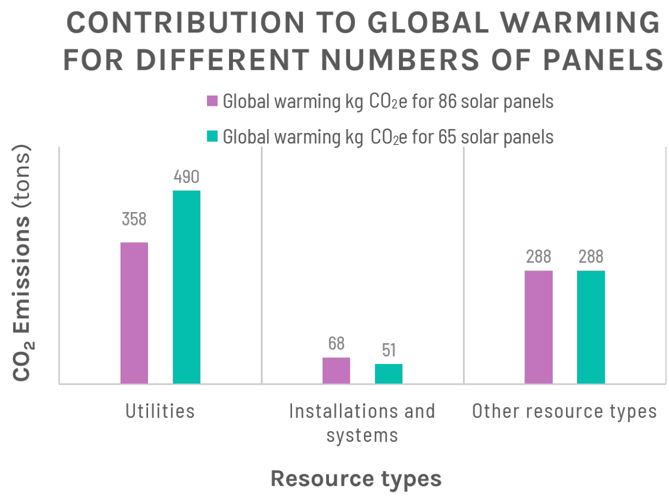


Figure 47. *Embodied emissions associated with potential solar array size*

A 65-panel array (24 kW) will result in 22% of energy consumption being provided from the grid, whereas an 86-panel array (31.8 kW) will have a 16% grid contribution. This is particularly problematic, given that 80% of the Victorian electricity grid is produced from non-renewable energy sources, relying heavily on coal-fired power stations, which produce 2.60 lb. (1.18 kg) CO^2 per kWh. Given that OneClick LCA showed that the majority of the emissions from the Project will be associated with electricity consumption (**Figure 24** in *Section 6.5.1 Life Cycle Assessment*), this was seen as an opportunity to further reduce the Project's carbon footprint. Using a solar array with 86 panels resulted in a 14% overall reduction in CO^2 emissions for the complex compared to the 65-panel array, despite the increase in embodied emissions related to the increase in materials (**Figure 47**). While oversizing the solar system puts the complex beyond net zero (net negative) in energy production, this will drastically reduce the reliance on and consumption of grid electricity. The number of days where no grid electricity is required increases from 32 days for the 65-panel array, to 73 days for the 86-panel array, consequently reducing the Project's carbon emissions and increasing resilience. Additionally, the oversized system accounts for variability in the usage patterns of the occupants. Unpredictable loads, such as an occupant requiring a mobility scooter that needs to be charged, as well as behavior patterns which could increase utility usage, could significantly increase the appliance usage for the complex. The greater solar array provides greater flexibility which increases Kara House's resilience and ability to accommodate all occupant's needs.

In months with higher solar exposure, it is anticipated that all excess energy will be exported to Kara House's transition homes (See *Section 6.9.3 Grid Interaction*), with associated cost savings predicted to offset both the costs of the solar system and the grid energy costs which may be required during non-sunny periods. The payback period for Kara House is over 2 years shorter for the 86-panel array (6.2 years) as opposed to the 65-panel array (7.4 years), despite the higher upfront cost. As a result, decrease in the operational utility costs of the transition homes because the larger solar array can export more power. Over a 20-year period, the larger panel array is predicted to further save $AUD 69,772 ($USD 53,260) (assuming 3% annual inflation rate) than the smaller array, with Kara House saving a further $AUD 2,867 ($USD 2,188) in utility costs in the first year alone through exporting solar to the transition homes. This further benefits Kara House beyond financial gain, as the positive energy balance complements their organizational goal of reducing their carbon footprint and striving for environmental excellence.

6.9.3. Grid Interaction

While the solar system is designed to ensure fallback on electrical input from the grid is minimal, large quantities of on-site harnessed solar energy are expected to be exported to the grid. This interaction will take place through a 'virtual power plant' (VPP) initiative under local energy provider *AGL Energy* and solar trading company *Power Ledger*. The VPP initiative is a Peer-2-Peer (P2P) system which uses Blockchain technology on the x-Grid Cross Store network to allow the transfer of solar between properties connected to the same electricity grid. This VPP allows Kara House to export excess solar produced to its own transition homes once the Project RRE batteries are fully charged, as opposed to on-selling back to the grid. On-site energy consumption for Project RRE will always be prioritized over exportation, ensuring there is sufficient solar energy stored in the battery system, even during winter when there will be considerably less excess solar. This system further offsets Kara House's carbon footprint and reduces operational costs for their other services, thus justifying the larger solar system implemented for Project RRE (**Figure 48**).

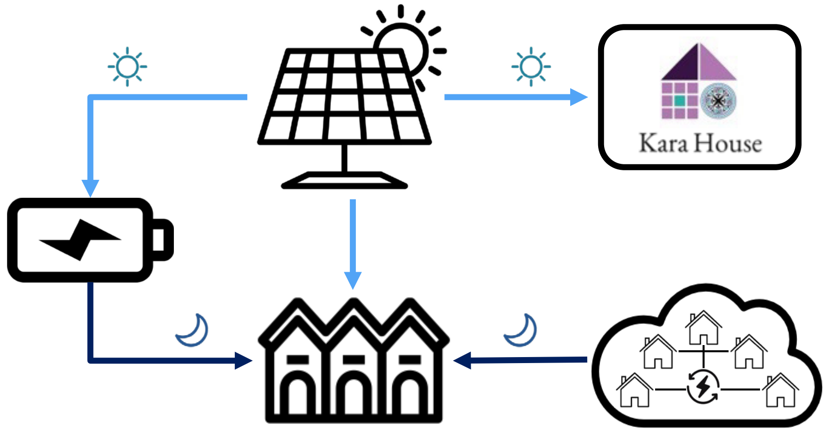


Figure 48. *Grid and renewable system integration*

6.9.4. Appliance Loads

In Australia, appliances must be registered under regulatory requirements to enforce minimum energy efficiency standards. Appliances are given an Energy Rating Label from the Australian Government with a star rating awarded from one to six stars based on the electrical efficiency of a model relative to others of the same size (with six stars being the most efficient). The energy labelling process also provides an estimated running cost over a 10-year period based on standard domestic use and average electricity prices. This estimation was used to determine the most suitable appliances, with a higher Energy Rating Label prioritized over cost for the fridges and washing machines, as these appliances have the greatest energy consumption. In comparison, cost was a greater influence for lower use appliances, with all appliances selected still having an Energy Rating Label of at least three stars (which is the equivalent of being ENERGY STAR Certified). Furthermore, appliances were sized in consideration of likely usage patterns as outlined by Kara House in order to avoid oversizing and thus, unnecessary energy consumption. Based on these decisions, each unit has an average daily appliance load of 6.96 kWh and total annual load of 2,542 kWh.

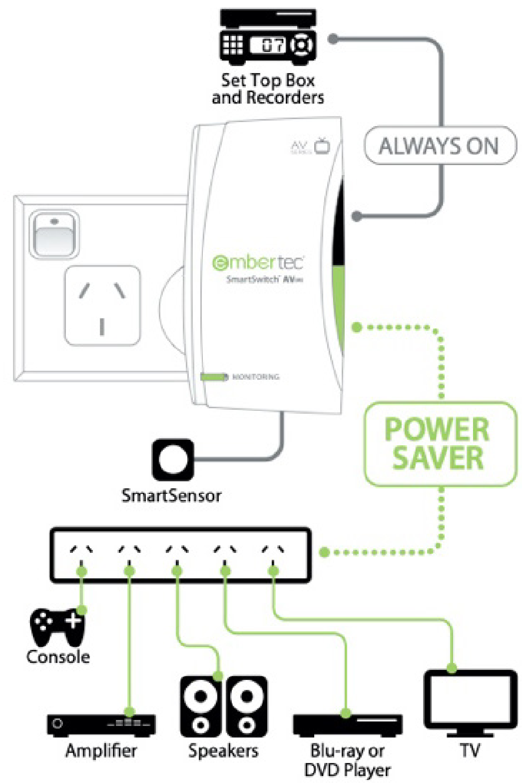


Figure 49. *Embertec SmartSwitch™ wall plugs (from company website)*

To optimize the appliance loads in consideration of the refuge's solar PV system, some appliances will be installed with timer settings. This will restrict the acceptable running times for large appliances (washing machines and dishwashers) to a period which correlates with the maximum solar exposure (between the hours of 10am and 4pm). Furthermore, this will decrease pressure on the battery system and further reduce the consumption of energy from the electricity grid. In addition, TVs will be fitted with Embertec SmartSwitch™ smart plugs (**Figure 49**), which shut off power after each hour if the user is not actively watching through a 'power saver' mode. Similarly, wall-plugs are fitted with shut-off timer systems, which recognize low current and shut off power when appliances are in sleep mode, reducing plug loads to zero.

The high turnover of occupants results in a downtime period when the units may be empty, which emphasizes the need to limit unnecessary energy consumption through sleep modes and idling of appliances. As the average period of zero occupancy is between 1-3 days, the refrigerators must continue to be powered, yet all other appliances are able to be shut off. To achieve this, the refrigerator in each unit is installed on a separate circuit breaker to all other appliances and wall plugs, thus allowing Kara House to cut all electricity to a unit from a standard fuse board whilst keeping the refrigerator on.

Figure 50. *Compact Lift Elegance Plus elevator*

As outlined previously, a compact residential elevator has been included in the staff office space to provide access for staff requiring wheelchair access. Different to a typical elevator, the Compact Lift Elegance Plus elevator (**Figure 50**) plugs into a standard 10-amp domestic power socket and uses less energy than that required to boil a kettle when operating. It will be installed in the stairwell void and is equipped with safety sensors and a backup battery for operation during power outages. This elevator will only be operated minimally by staff members who require wheelchair access and will not be used otherwise to reduce the energy impact.

APPENDIX A. DESIGN RENDERINGS

PROJECT RRE FULL SITE VIEW

PURPOSE-BUILT SPACES

Figure 51. *(Top Left) View of unit bathroom taken from the shower. Each unit has a combined bathroom, toilet, and laundry, with shower and ironing board. (Top Right) Accessible unit kitchen. The kitchen and dining room are designed to be very open. (Bottom Left) Balconies on the second story of each unit provide an additional semi-private outdoor space. (Bottom Right) Individual seating area out the front of each unit along the shared accessible pathway*

COMMUNAL THERAPEUTIC GARDENS FOR OCCUPANT RECOVERY

Figure 52. *(Top Left) Private seating in the sensory garden, used for therapeutic benefits and to provide a space of solitude. (Top Right) Sensory garden windchimes. The sensory garden aims to stimulate all senses including sight, smell, touch, and sound. (Bottom Left) A natural playground for younger children. (Bottom Right) Combined basketball hoop and soccer goal for older children*

DEDICATED MULTIPURPOSE AND ACCESSIBLE SPACE

Figure 53. *(Top Left) Indoor play area for children can also have tables added for group study. (Top Right) The flexible space can be adjusted for a range of activities, such as group therapy or art classes. (Bottom Left) Computers to provide access to the internet and entertainment. (Bottom Right) Accessible unit kitchen view taken from the front entrance. The accessible unit has extra space around furniture to ensure enough clearance for wheelchair use.*

***Figure 54**. View from the Block A solar panel array, showing sensory garden and communal areas*

APPENDIX B. CONSTRUCTION DOCUMENTS

B.1 SITE PLAN

1. Block A – 4 standard units
2. Block B – 3 standard units
3. Block B – accessible unit
4. Block C – multipurpose space + staff area
5. Covered carparking space
6. Main entrance (reception)
7. Corridor
8. Accessible pathway
9. Communal garden – teen area
10. Communal garden – kids play area
11. Communal garden – sensory garden
12. Garbage and recycling bins
13. Private backyard space
14. Battery storage

***Figure 55**. Project RRE site layout*

B.2 REPRESENTATIVE FLOOR PLAN(S) WITH DIMENSIONS

Figure 57. *Standard unit second story floor plan with dimensions (Measurements in metres)*

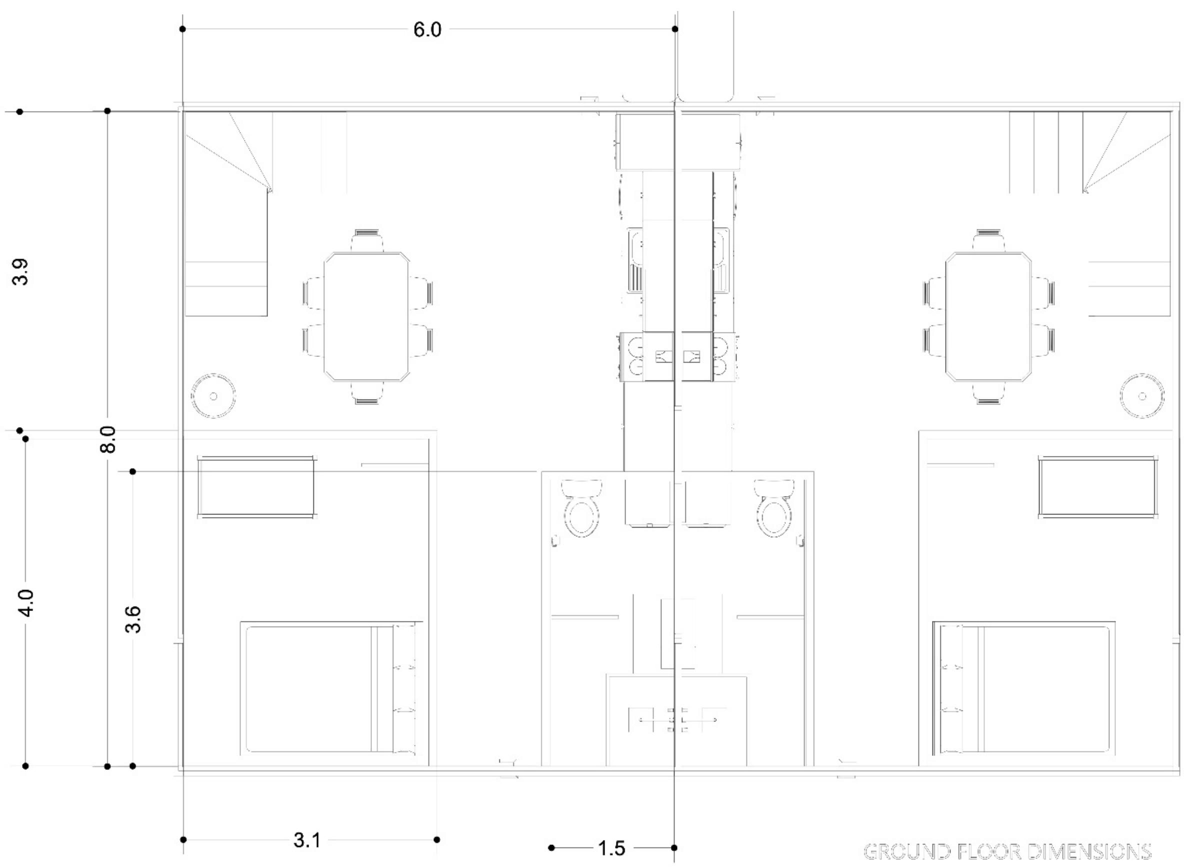


Figure 56. *Standard unit first story floor plan with dimensions (Measurements in metres)*

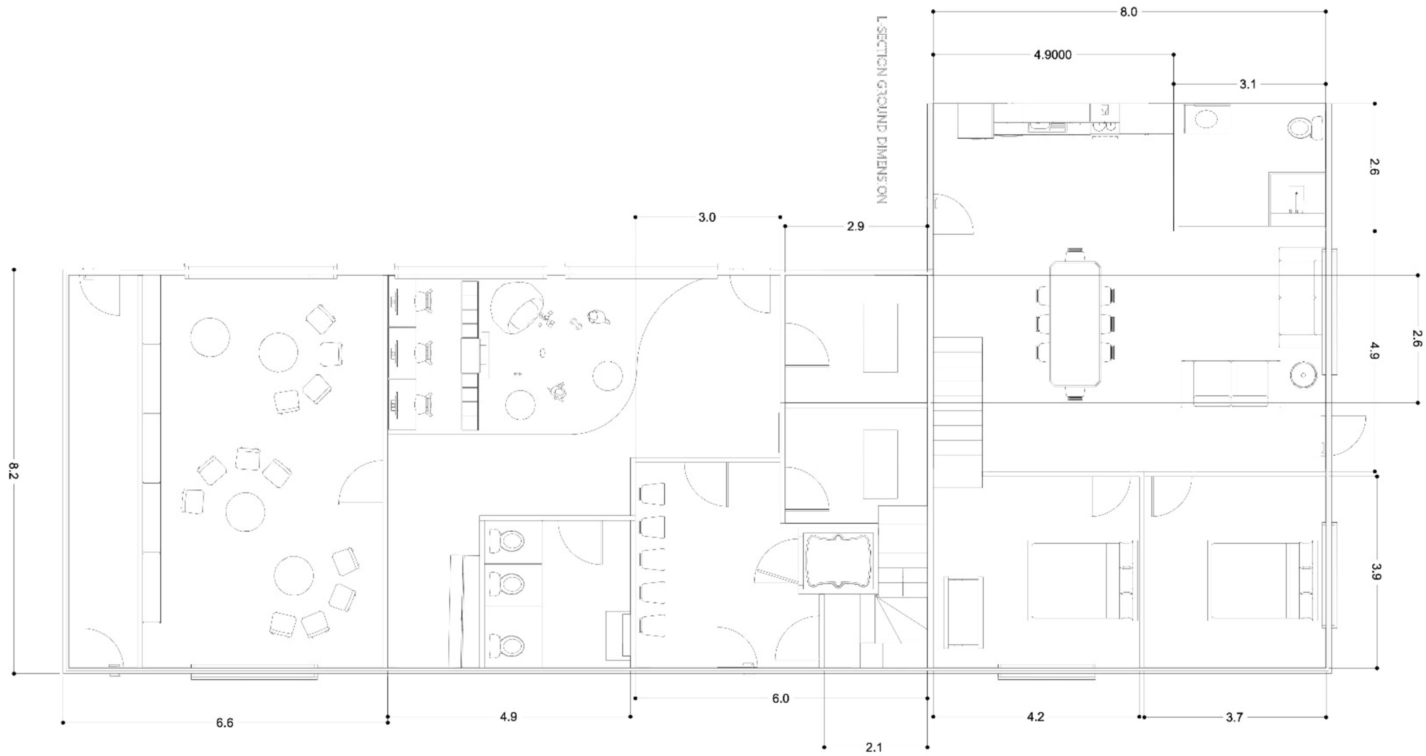


Figure 58. *Multipurpose Area (right) and Accessible Unit (left) first story floor plan with dimensions (Measurements in metres)*

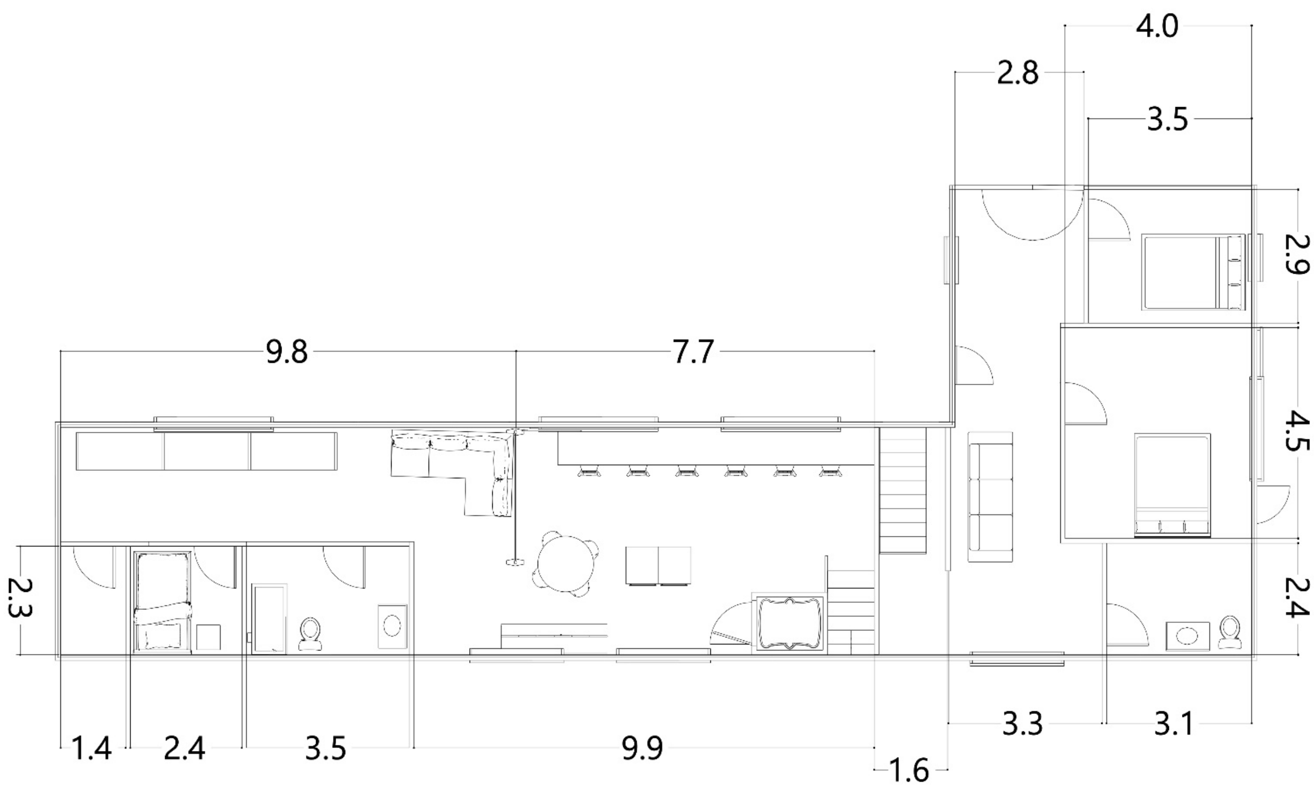


Figure 59. *Multipurpose Area (right) and Accessible Unit (left) second story floor plan with dimensions (Measurements in metres)*

B.3 BUILDING ELEVATIONS

Figure 60. *Project RRE front building elevation (West facing)*

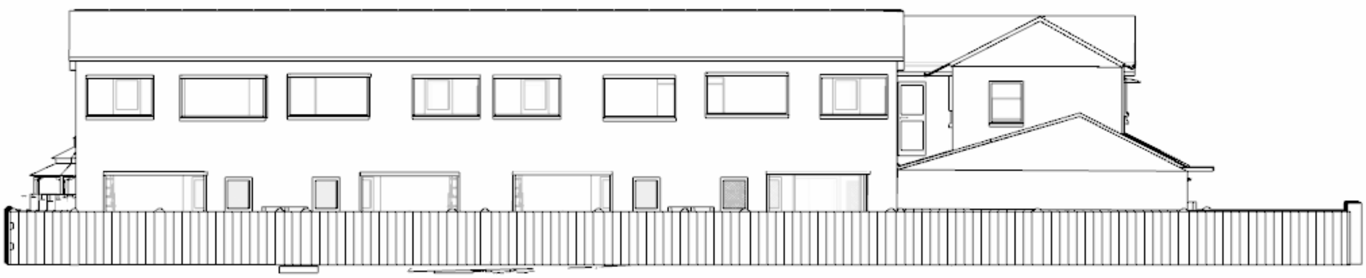


Figure 62. *Project RRE side building elevation (South facing)*

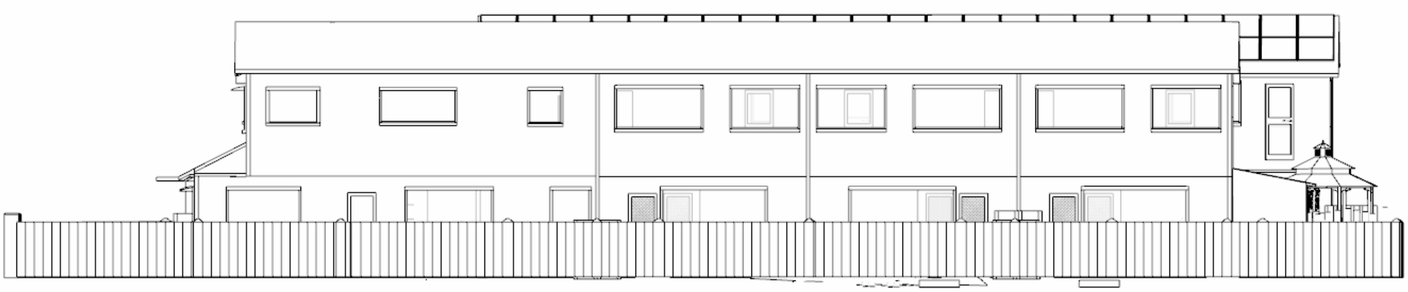


Figure 61. *Project RRE side building elevation (North facing)*

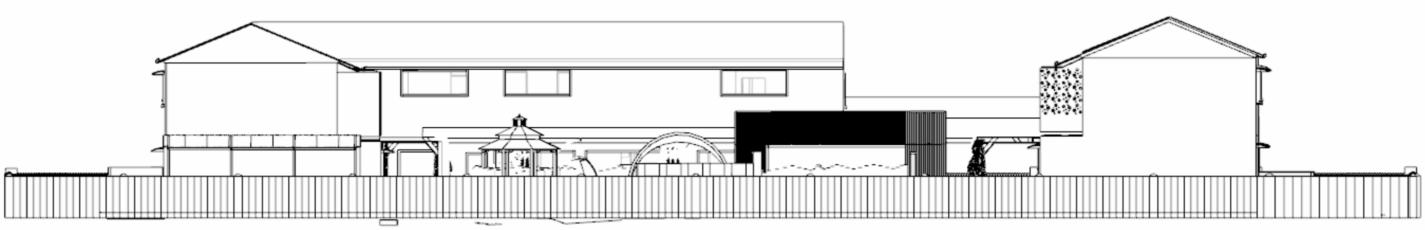


Figure 63. *Project RRE rear building elevation (East facing)*

B.4 BUILDING SECTIONS

Refer to *Section 6.4.1 Building Control Layers* for full diagrams of building science control layers.

B.5 INTERIOR DETAILS

Figure 64. *Accessible unit first story rendered floor plan (Left) and second story rendered floor plan (Right)*

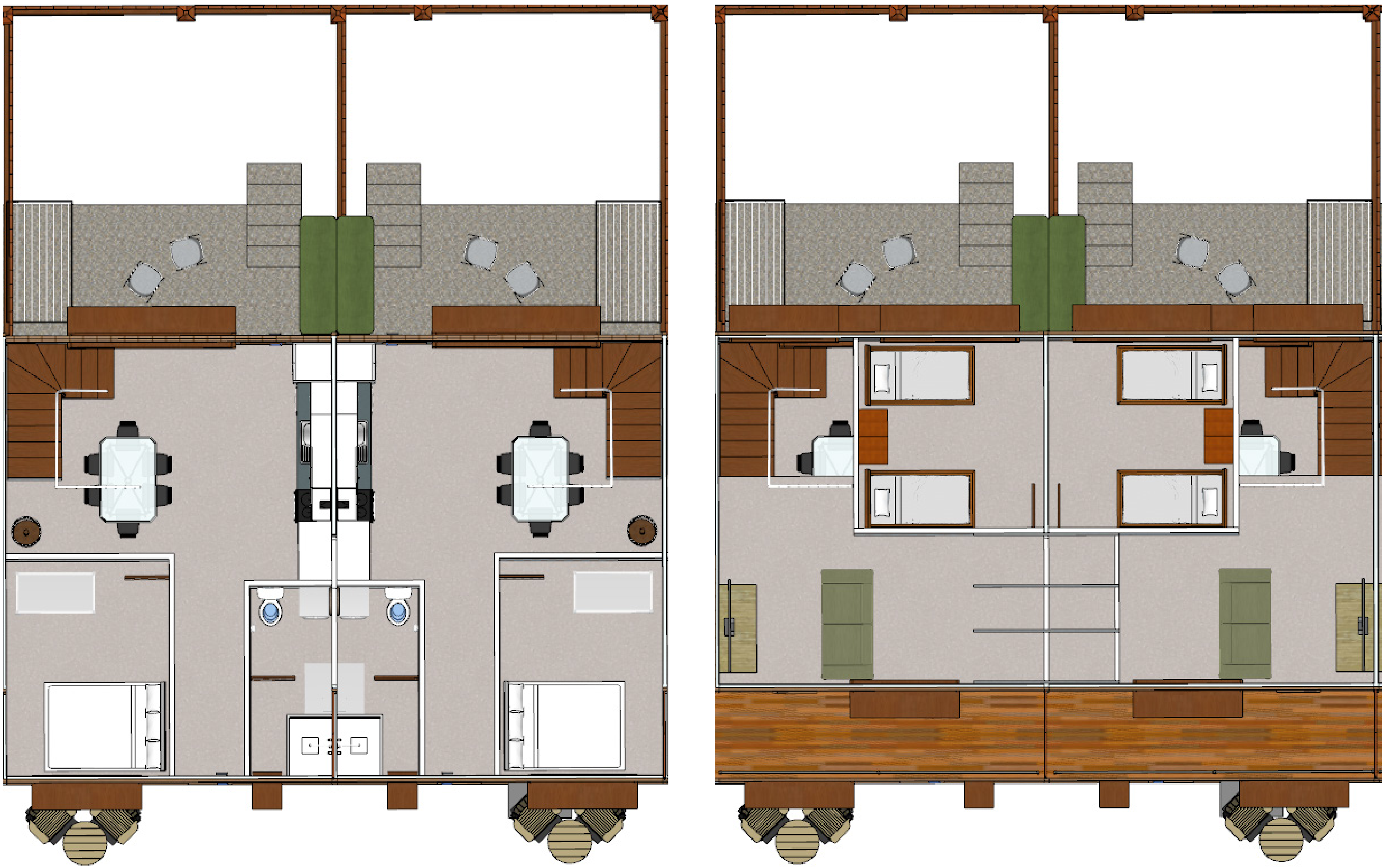
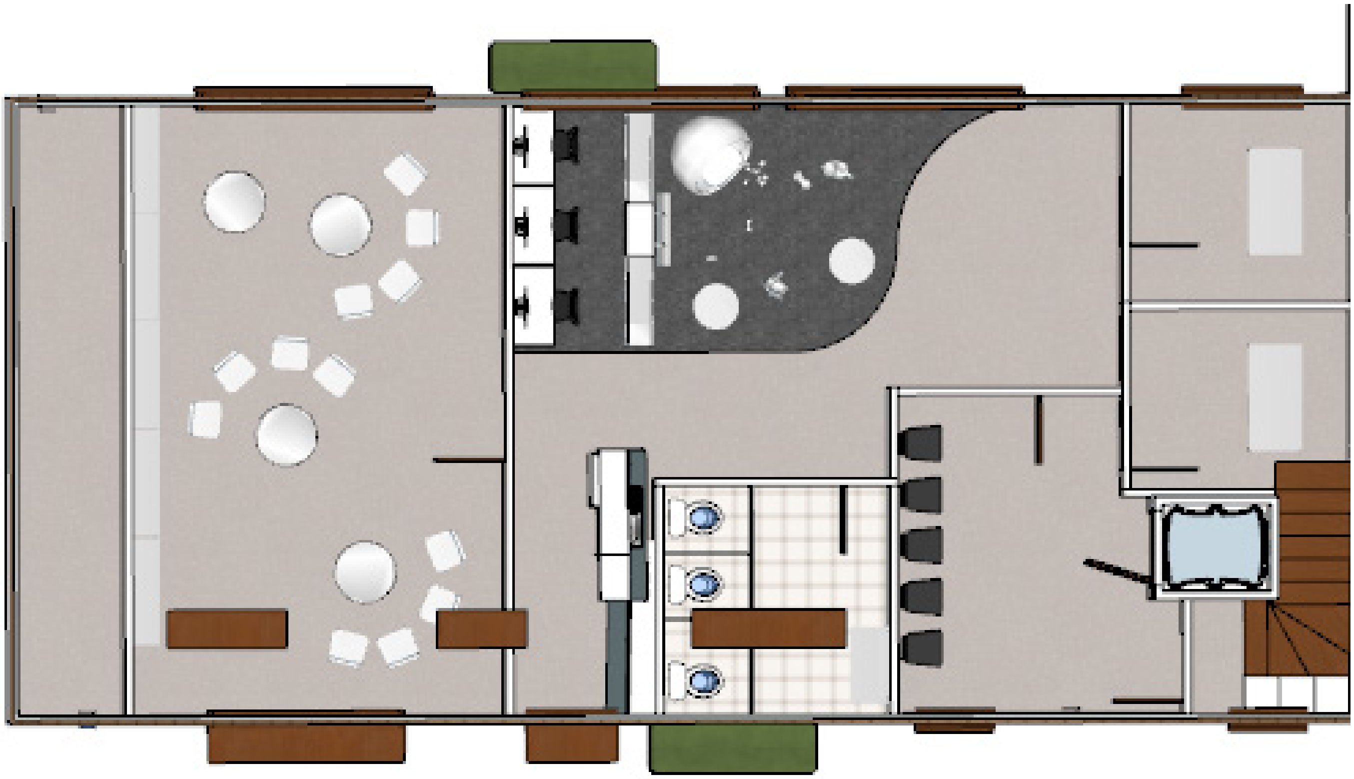


Figure 65. *Standard unit first story rendered floor plan (Left) and second story rendered floor plan (Right)*



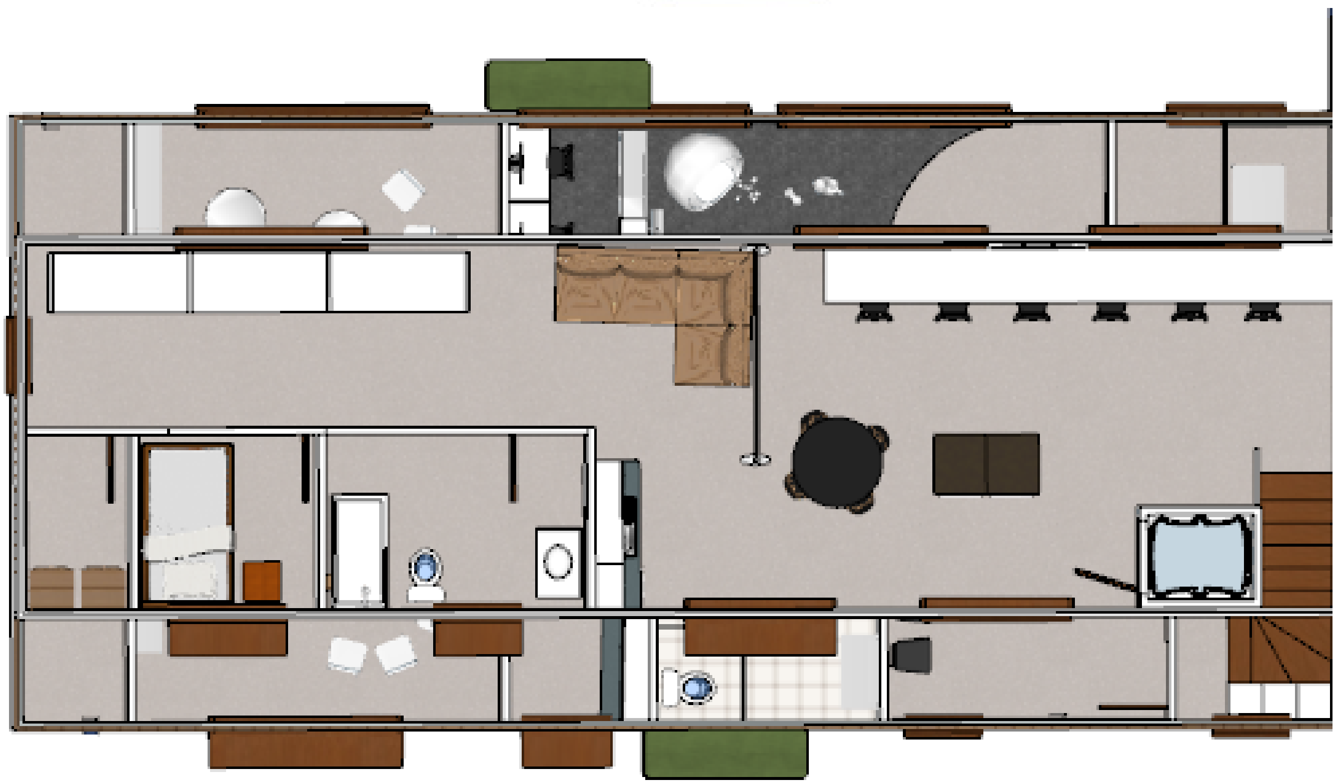


Figure 66. *Multipurpose space first story rendered floor plan (Top) Staff space second story rendered floor plan (Bottom)*

B.6 CONSTRUCTION DETAILS

The building science control layers for the wall, floor, roof, and window details can be found in *Section 6.4.1 Building Control Layers.* The door and window details can be found in *Section 6.6.3 Doors and Windows*

B.7 MECHANICAL PLANS AND SCHEDULES

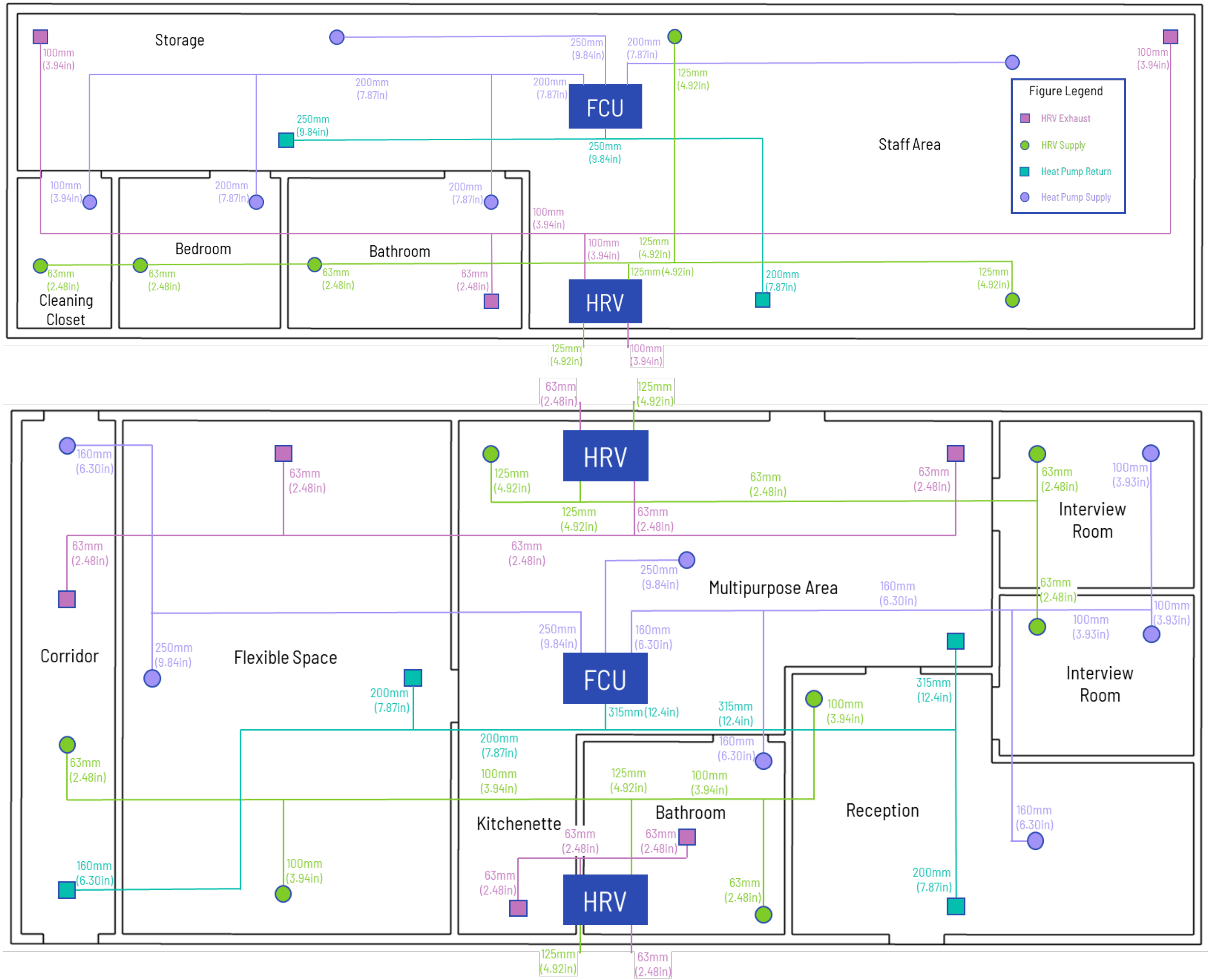


Figure 67. *Duct sizing and vent placement for the multipurpose space downstairs (bottom) and staff office upstairs (top). Ducting is in the ceiling cavity and attic space. One HRV and one fan coil unit heating/cooling system is shared across each story of the two units*

B.8 PLUMBING PLANS AND SCHEDULES

Refer to *Section 6.2.6* ***Plumbing System*** and *Section 6.2.5* ***Hot Water System Specifications***

B.9 ELECTRICAL AND LIGHTING PLANS AND SCHEDULES

Figure 68. *Lighting layout for the multipurpose and accessible unit first story (top) and the staff area and accessible unit second story (bottom)*

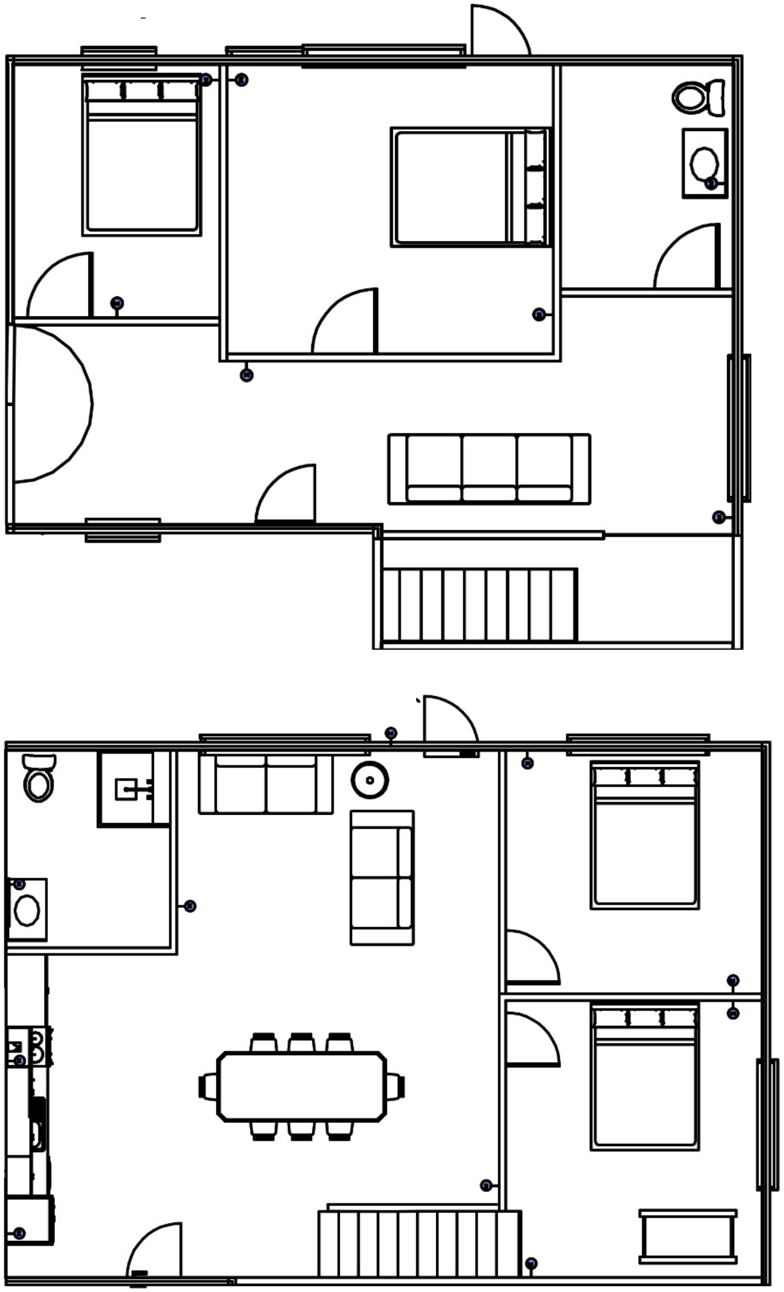


Figure 69*. Accessible unit downstairs (bottom) and upstairs (top) electrical outlet layout*

Legend

	Globe light
DLT	Down light
H_DLT	Hanging down light
	Fan with light
	Switch
E	Electrical outlet
OD_FLD	Outdoor Flood light
BL_FLD	Balcony Flood light
	Outdoor Solar Flood light
	Outdoor Path light

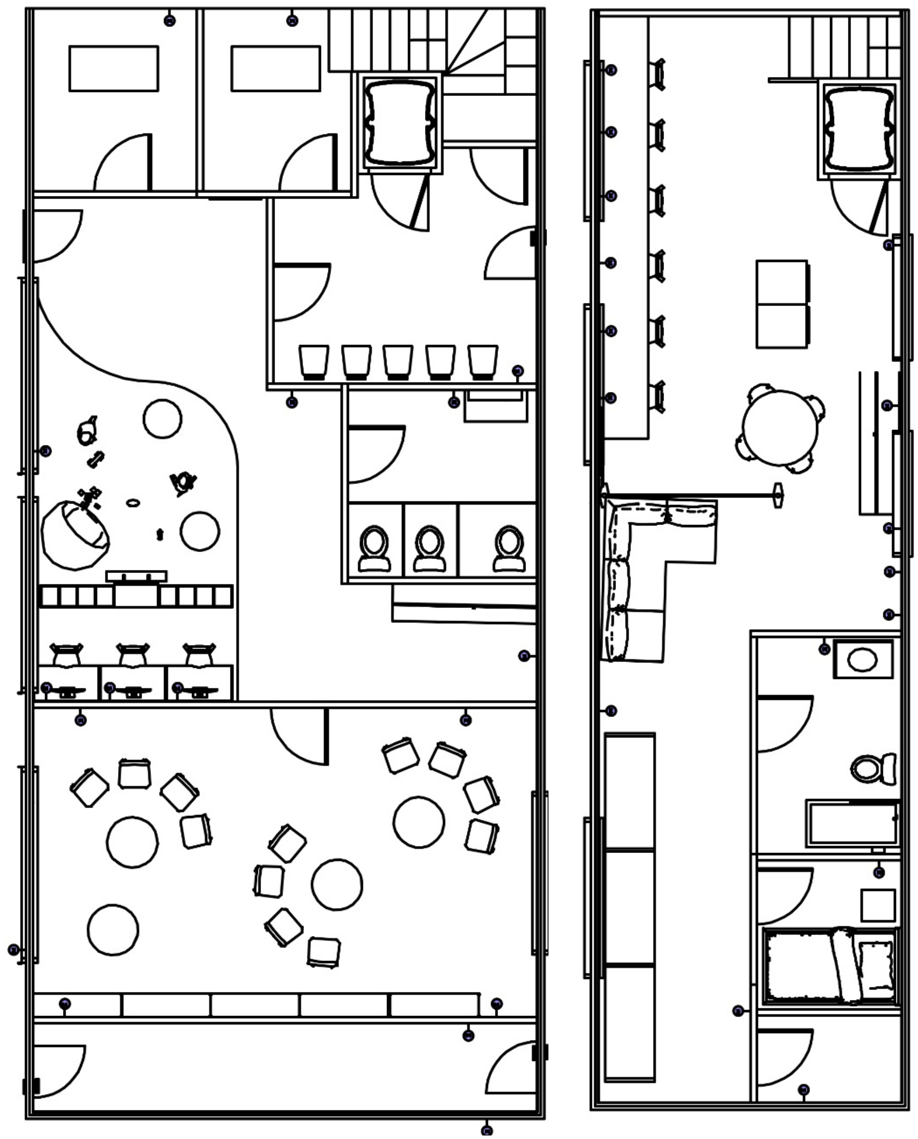


Figure 70. *Multipurpose space (left) and staff area (right) electrical outlet layout*

APPENDIX C. ENERGY PERFORMANCE SUMMARY

The DOE Zero Energy Ready Home National Program Requirements (Rev. 07) have been met in the design of Project RRE. Since Project RRE is a residential complex, the conditioned floor area (CFA) for the whole site was calculated to be 8,332 ft^2 [774 m^2], assuming 19 bedrooms. This is lower than the CFA of a model home of this size (11, 800 ft^2 [1096 m^2]), allowing the prescriptive path to be taken. Therefore, the house size adjustment factor not required. The designs considered Exhibits 1 and 2 and met all requirements (Figure xx). For accuracy and simplicity, REM/Rate was used to evaluate two representative models: a single unit (Model 1); and the multipurpose and accessible unit (Model 2).

The HERS index for a single unit (Model 1) is 48 without PV, and -2 with PV. For the multipurpose and accessible unit (Model 2), the HERS index is 49 without PV and -22 with PV. This difference in HERS indices between the two models can be attributed to the higher number of solar panels on the multipurpose area roof space, which will be powering the units across the whole site. The systems were oversized to provide flexibility given the varying occupant situations and to allow for solar energy to be exported to other Kara House properties. We expect that the HERS index for the whole site would be somewhere in between these two indices. The HERS index without PV is almost the same for both models. Additionally, the solar batteries were not included in these models

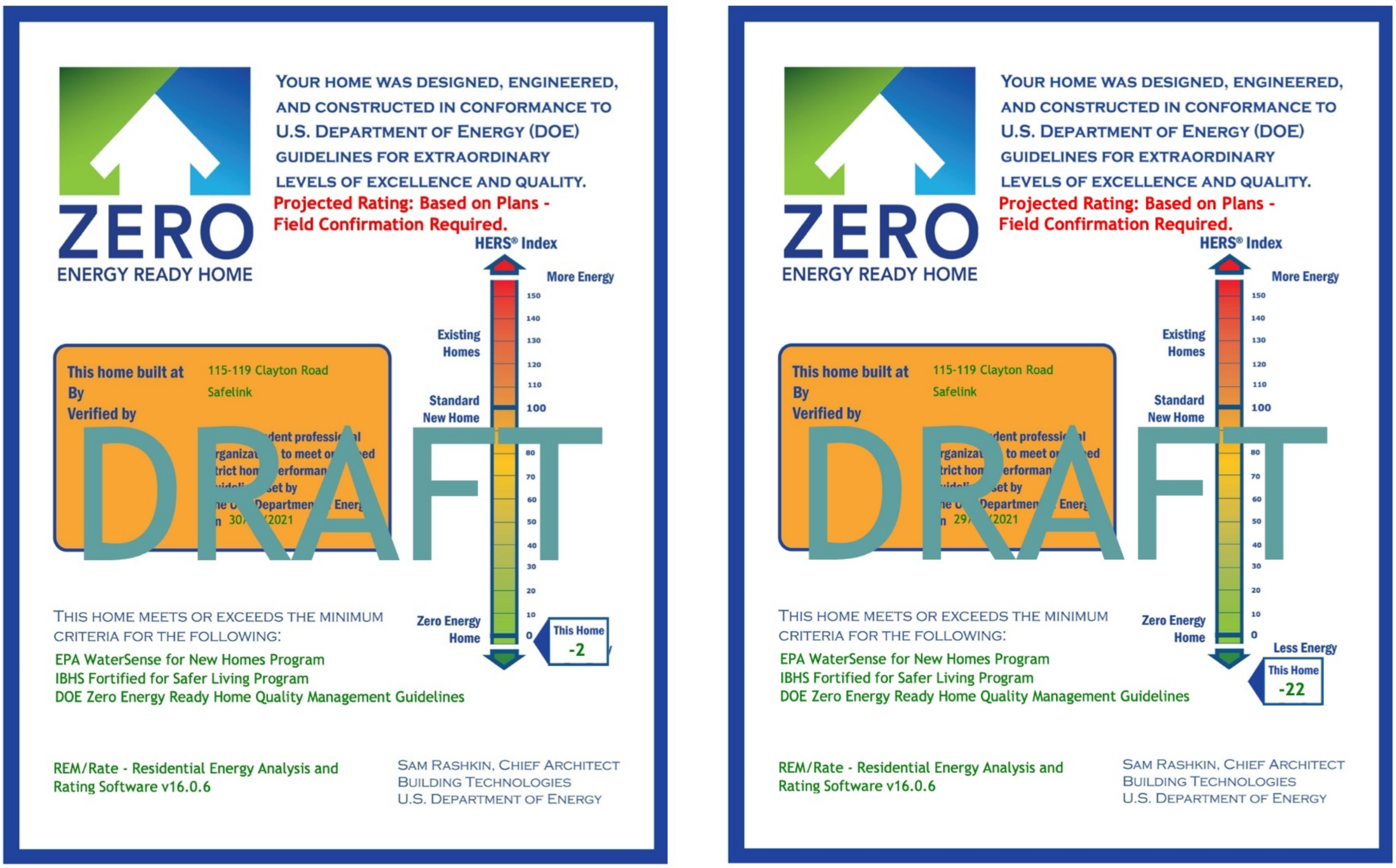


Figure 71. *Zero Energy Ready Home Certificate for Model 1 (single unit) (Left) and Model 2 (multipurpose space and accessible unit) (Right)*

DOE Zero Energy Ready Home

Projected Rating: Based on Plans - Field Confirmation Required.

Energy Performance	
House Type	DOE Zero Energy Ready Home Builder Partner ID#
Townhouse, inside unit	18185
Year built	Square footage of Conditioned Space including Basement
2021	970.0
Number of Bedrooms	Square footage of Conditioned Space without Basement
2	970.0
Site address (if not available, list the site Lot #)	Registered Builder
115-119 Clayton Road	
Oakleigh East, VIC, Australia	Certified Rater
,	
HERS Index without On-site Generation	Date of Rating
48	
HERS Index with On-site Generation	Rating Software
-2	REM/Rate - v16.0.6
HERS Index of the Target Home using size adjustment factor	Estimated annual energy costs($)
64	44
Estimated annual energy use	Estimated annual energy savings
Electric: -205 kWh	Electric: 8904 kWh
Energy cost rates	Estimated annual emissions reductions
Electric: 0.08 $/kWh	CO2: 2.5 tons / SO2: 1.3 lbs / NOx: 1.8 lbs

DRAFT

DOE Zero Energy Ready Home Certification

As the certified Rater for this house, I certify this house meets/complies with all mandatory requirments of the DOE Zero Energy Ready home guidelines, including the following:

X	Compliance with all ENERGY STAR Qualified Homes Version 3.1 requirements and checklists
X	Compliance with Mandatory Fenestration Requirements
X	Compliance with Mandatory Insulation Requirements
X	Compliance with Mandatory Duct Location Requirements
X	Compliance with Mandatory Appliance Requirements
X	Compliance with Mandatory Lighting Requirements
X	Compliance with Mandatory Fan Efficiency Requirements
X	Compliance with Mandatory EPA Indoor airPLUS
X	Compliance with Mandatory Water Efficieny Requirements
X	Compliance with Mandatory Renewable Energy Ready Solar Electric Requirements
	This home was qualified via sampling in lieu of testing, in accordance with allowable sampling provisions as stated in the DOE Zero Energy Ready Home National Program Requirements

Optional Compliance for Builder Recognition

I further certify that the following also apply to this house:

YES	NO	DON'T	Optional Home Builder Commitments for Recognition

*Certification under the DOE Zero Energy Ready Home permits limited exceptions to full compliance with Indoor airPLUS. Builders seeking the Indoor airPLUS label must achieve full compliance with the Indoor airPLUS Verification Checklist.

REM/Rate - Residential Energy Analysis and Rating Software v16.0.6

This information does not constitute any warranty of energy costs or savings.

© 1985-2021 NORESCO, Boulder, Colorado.

DOE Zero Energy Ready Home

Projected Rating: Based on Plans - Field Confirmation Required.

		KNOW	
X			Certified under the EPA WaterSense for New Homes Program
X			Certified under the IBHS Fortified for Safer Living Program
X			Followed the DOE Zero Energy Ready Home Quality Management Guidelines
X			The buyer of this home signed a waiver giving DOE Zero Energy Ready Home access to utility bill data for one year

*Certification under the DOE Zero Energy Ready Home permits limited exceptions to full compliance with Indoor airPLUS. Builders seeking the Indoor airPLUS label must achieve full compliance with the Indoor airPLUS Verification Checklist.

DOE Zero Energy Ready Home

Projected Rating: Based on Plans - Field Confirmation Required.

Energy Performance	
House Type	DOE Zero Energy Ready Home Builder Partner ID#
Townhouse, end unit	18185
Year built	Square footage of Conditioned Space including Basement
2021	4114
Number of Bedrooms	Square footage of Conditioned Space without Basement
5	4114
Site address (if not available, list the site Lot #)	Registered Builder
115-119 Clayton Road	
Oakleigh East, VIC, Australia	Certified Rater
,	
HERS Index without On-site Generation	Date of Rating
49	
HERS Index with On-site Generation	Rating Software
-22	REM/Rate - v16.0.6
HERS Index of the Target Home using size adjustment factor	Estimated annual energy costs($)
64	45
Estimated annual energy use	Estimated annual energy savings
Electric: -176 kWh	Electric: 32238 kWh
Energy cost rates	Estimated annual emissions reductions
Electric: 0.08 $/kWh	CO2: 4.5 tons / SO2: 2.6 lbs / NOx: 2.8 lbs

DRAFT

DOE Zero Energy Ready Home Certification

As the certified Rater for this house, I certify this house meets/complies with all mandatory requirments of the DOE Zero Energy Ready home guidelines, including the following:

X	Compliance with all ENERGY STAR Qualified Homes Version 3.1 requirements and checklists
X	Compliance with Mandatory Fenestration Requirements
X	Compliance with Mandatory Insulation Requirements
X	Compliance with Mandatory Duct Location Requirements
X	Compliance with Mandatory Appliance Requirements
X	Compliance with Mandatory Lighting Requirements
X	Compliance with Mandatory Fan Efficiency Requirements
X	Compliance with Mandatory EPA Indoor airPLUS
X	Compliance with Mandatory Water Efficieny Requirements
X	Compliance with Mandatory Renewable Energy Ready Solar Electric Requirements
	This home was qualified via sampling in lieu of testing, in accordance with allowable sampling provisions as stated in the DOE Zero Energy Ready Home National Program Requirements

Optional Compliance for Builder Recognition

I further certify that the following also apply to this house:

YES	NO	DON'T	Optional Home Builder Commitments for Recognition

*Certification under the DOE Zero Energy Ready Home permits limited exceptions to full compliance with Indoor airPLUS. Builders seeking the Indoor airPLUS label must achieve full compliance with the Indoor airPLUS Verification Checklist.

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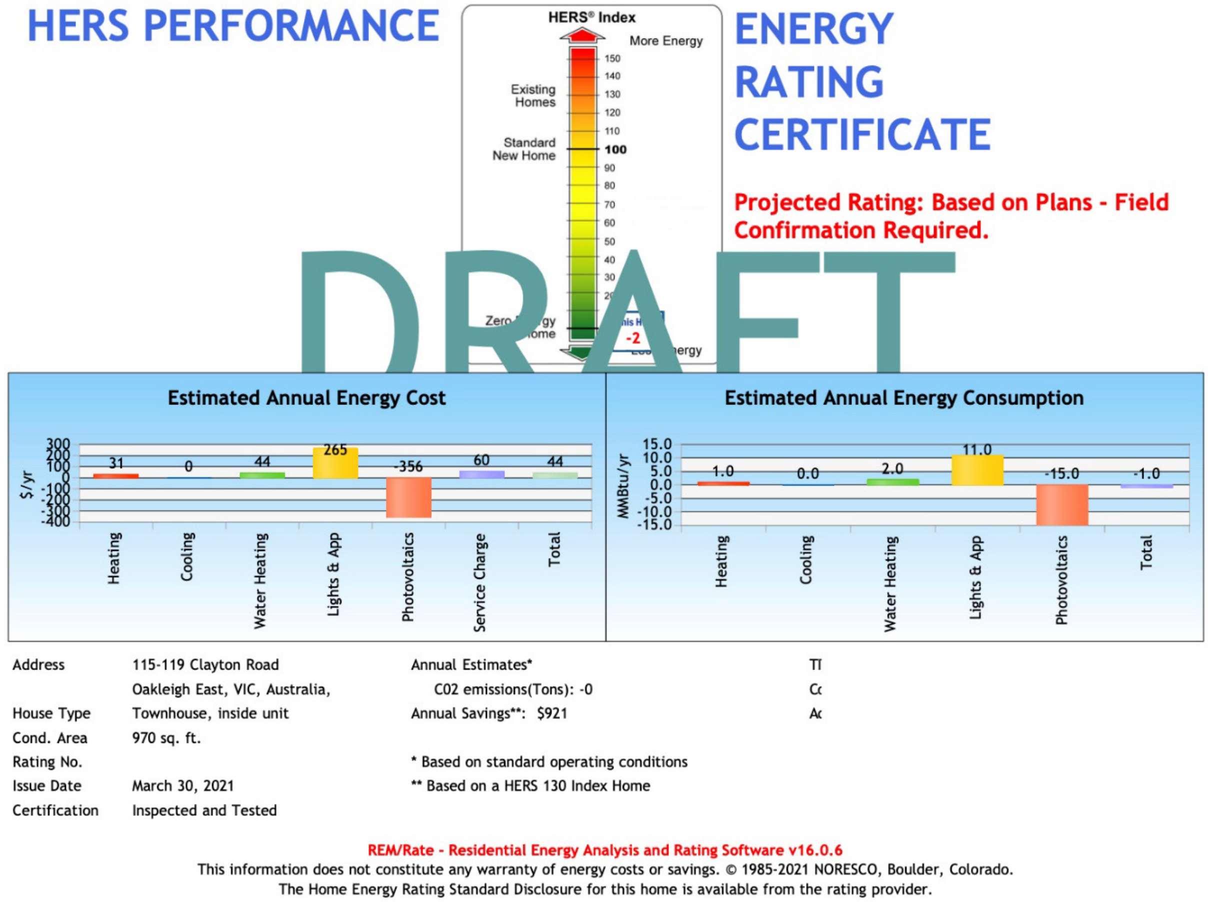
DOE Zero Energy Ready Home

Projected Rating: Based on Plans - Field Confirmation Required.

		KNOW	
X			Certified under the EPA WaterSense for New Homes Program
X			Certified under the IBHS Fortified for Safer Living Program
X			Followed the DOE Zero Energy Ready Home Quality Management Guidelines
X			The buyer of this home signed a waiver giving DOE Zero Energy Ready Home access to utility bill data for one year

*Certification under the DOE Zero Energy Ready Home permits limited exceptions to full compliance with Indoor airPLUS. Builders seeking the Indoor airPLUS label must achieve full compliance with the Indoor airPLUS Verification Checklist.

Figure 72. *Zero Energy Ready Home Certificate for Model 1 (single unit) (Left) and Model 2 (multipurpose space and accessible unit) (Right)*



HERS PERFORMANCE

ENERGY RATING CERTIFICATE

Projected Rating: Based on Plans - Field Confirmation Required.

Address	115-119 Clayton Road	Annual Estimates*	
	Oakleigh East, VIC, Australia,	C02 emissions(Tons): -0	
House Type	Townhouse, inside unit	Annual Savings**: $921	
Cond. Area	970 sq. ft.		
Rating No.		* Based on standard operating conditions	
Issue Date	March 30, 2021	** Based on a HERS 130 Index Home	
Certification	Inspected and Tested		

REM/Rate - Residential Energy Analysis and Rating Software v16.0.6
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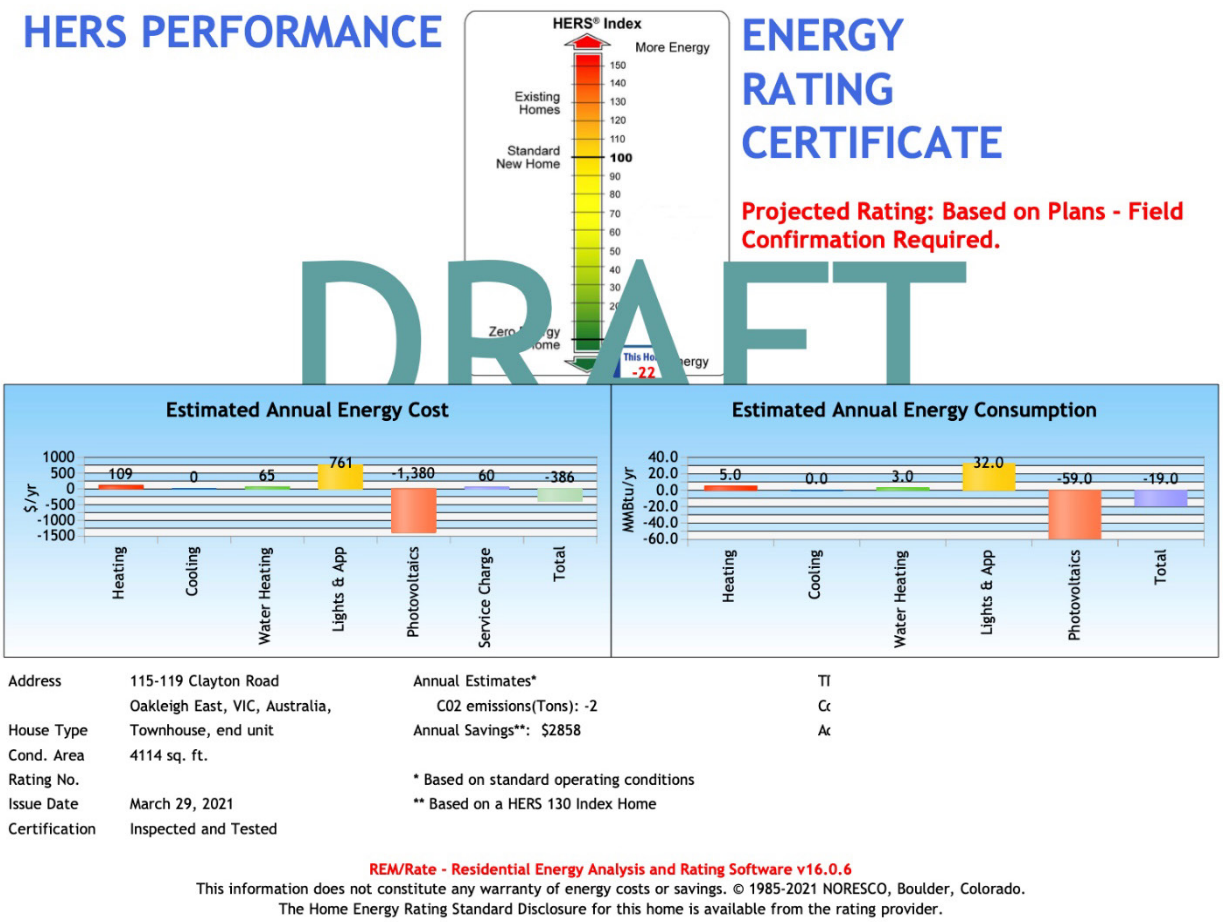
The Home Energy Rating Standard Disclosure for this home is available from the rating provider.



HERS PERFORMANCE

ENERGY RATING CERTIFICATE

Projected Rating: Based on Plans - Field Confirmation Required.

Address	115-119 Clayton Road	Annual Estimates*	
	Oakleigh East, VIC, Australia,	C02 emissions(Tons): -2	
House Type	Townhouse, end unit	Annual Savings**: $2858	
Cond. Area	4114 sq. ft.		
Rating No.		* Based on standard operating conditions	
Issue Date	March 29, 2021	** Based on a HERS 130 Index Home	
Certification	Inspected and Tested		

REM/Rate - Residential Energy Analysis and Rating Software v16.0.6
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The Home Energy Rating Standard Disclosure for this home is available from the rating provider.

Figure 73. *HERS Performance Certificate for Model 1 (single unit)(Top) Model 2 (multipurpose space and accessible unit)(Bottom)*