University of Technology, Sydney

DECATHAROOS

SOLAR DECATHLON
[NEW HOUSING]
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DECATHAROOS DESIGN NARRATIVE | DESIGN CONSTRAINTS

LOCATION: The house is an elegant but simple design located on a remote and isolated block of rural open grassland in a coastal woodland area on the New South Wales Sapphire Coast that is surrounded by bush and in a bushfire zone. The nearest towns are a 20 – 30-minute drive in either direction along the only through road, which is a winding two-lane country road. One town, Bermagui, is a fashionable retirement community of just over 1,500 people for well-to-do Sydneysiders. It has excellent cafes and restaurants and an active arts network although it is known for deep-sea fishing. Tathra, to the south of our site, has just 3,500 residents, and is known for its historic wharf dating to 1862 and its commercial fishing community. The area is a mix of densely forested bush, grassland, and farms situated in rolling hills along the South Coast. Every few kilometres there is a river or a lagoon. Access to the site is from a two-lane through road along an unpaved ridge-top road. Neighbours are scarce and not within easy walking distance – it is at least a 10- or 15-minute walk to the nearest house. The site is on a gently sloping hill overlooking a river below and the sea to the Northeast. The location’s remote nature means that our project has to be as independent and self-sufficient as possible.

CLIMATE: The climate is Australian Zone 6, which means that it has a mild temperate climate with a low diurnal temperature range that is typical of coastal areas like our site. According to the Australian Bureau of Statistics, “Zone 6 has four distinct seasons, summer and winter can exceed human comfort range” with temperatures as low as the high-30s Fahrenheit in winter and as high as 100 degrees Fahrenheit in summer. The typical pattern is for cold and dry winters with hot and dry summers, while autumn and spring enjoy very comfortable moderate temperatures. The coastal location does tend to keep temperatures cool at night even in summer. The proximity to the coast provides steady and constant breezes with prevailing wind blowing northeast. Average wind year-round measures between 2 and 3 on the Beaufort Scale. The local climate, combined with excellent exposure to natural sunlight and wind, makes the site ideal for passive heating and cooling and locally generated energy.

CODES AND REGULATIONS: We have addressed building science considerations by trying to plan systematically in our response to the site, bush fire requirements, local building codes, and local climate and by adopting integral solutions to the design challenges. Considerations included planning for a long life by using recycled, durable, non-combustible, and recyclable materials wherever possible; planning for energy, water, and physical independence; and designing for maximal occupant control of indoor and outdoor living.

The most important local building codes are those related to bushfire resistant design, the Bushfire Attack Level (BAL) rating and NSW Planning for Bush Fire Protection 2019. The BAL system provides strict regulations around design for each rating level. The BAL measures the severity of bushfire threat for any given site by looking at the building’s “potential exposure to embers, radiant heat, and direct flame contact.” Our site is extremely bushfire prone, which means that we must design for the most stringent BAL level, BAL FZ (BAL Fire Zone). According to the New South Wales Rural Fire Service, BAL FZ is considered high risk and necessitates protection against “direct exposure to flames from a fire front,” in addition to heat flux and ember attack. (See Appendices for BAL definitions and rules).

In order to comply with the BAL regulations, we followed the NSW Planning for Bush Fire Protection 2019 so that our design has addressed a series of imperatives: “include a series of bushfire protection measures in the site and building design such as keeping a distance between the building and fire hazards; minimizing vulnerability of the building to ignition and fire spread from flames, radiation, and embers; enable appropriate access and egress for public and firefighters; provide adequate water supplies for bush fire suppression operations; and enable property preparedness.” These were addressed by selection of non-combustible and fire-resistant materials, elimination of gutters, integration of water through pools and
retention ponds and flexibility of building elements that hinge and slide to "shut down" the building in the event of a bushfire to make it into a fire-proof, sealed box. Adequate water supply on our site will be a combination of the rainwater that is captured and stored in our tanks and retention ponds underneath the house and water accessible from the river below the site. With no city water available, we had two choices: to capture rainwater or to have water delivered. We propose to capture enough rainwater to accommodate a family of four and guests as well as for most fire situations. We plan to install a grey water system to provide reticulated water for fire-fighting and other uses. Average rainwater on the site is 75 mm per year. In order to meet our goals, the roofs were designed to be substantially larger than the occupiable spaces below for adequate water capture.

In keeping with bushfire regulations, we have included Asset Protection Zones as part of the site design such as a green belt 100 metres wide around the building, and we have created non-combustible fire breaks around the building site. We designed a series of concentric rings that are like land art and will have different stone in them. These zones also create defensible space around the house in the event of fire. (See Site Plan)

The design complies with Australian Local Environmental Plans (LEP) and Development Control Plans (DCPs) for the South Coast region. The DCP regulates vehicle access, landscaping, and building design including allowable Floor Area Ratios. The LEP regulates land-use planning – this area is zoned for single-family homes. The house was also designed to the Australian NATHERS (Nationwide House Energy Rating System) to ensure optimal performance.

INTEGRATION: Our goal was to create a house whose systems are well integrated into the architecture and therefore virtually invisible. The goal was partly achieved by relying on passive heating, cooling and ventilation, which preclude the use of unseemly appliances like air conditioners and condensers; the goal was further achieved by making sure that any systems were considered from the start and therefore seamlessly included into the construction. The placement of solar photovoltaics on the roof like roofing tiles is one example of a well-integrated system. Another example is the inclusion of water retention and cooling ponds that double as landscape enhancements and are also situated in the excavated space underneath the house and therefore allow us to avoid the typical unseemly plastic storage tanks placed somewhere alongside the house.

The house is designed for typical contemporary Australian family structures. According to the Australian Bureau of Statistics, these include couples without children, couples with one child, and couples with two children. The house can be constructed in stages to make it as flexible as possible and to meet the time-of-life needs of its owners as they grow and then shrink. The bedroom wing can function as a secondary suite later in life or as accommodation for firefighters in a bush fire emergency.

The site is currently off grid, which is common for land in regional Australia and therefore common for many building sites. Trying to bring utilities to the site would be prohibitively expensive. For these reasons, we worked to design a house that will be energy and water independent. We used several strategies to achieve this: passive house design to minimize electrical needs for operation for heating and cooling, solar photovoltaics on the roof to create electricity, manual systems for ventilation, the best energy-efficient appliances available to reduce demand loads, and a water capture and retention system that allows the house to capture enough water for its daily needs and to fight bushfires when necessary.

We worked hard to design a house that would be durable and resilient. In order to make the design as durable as possible, we considered the life cycle of all materials carefully. Our choice of materials was partly governed by their expected longevity – the expected life of corrugated metal has a life expectancy of 30-45 years; of concrete is one-hundred years; of structural steel
from between 50 and 100 years; and of rammed earth is over 1000 years! Thus, the primary materials all have very good life expectancies. Durability and resilience also encompass the house’s ability to withstand fire as described above, its ability to accommodate occupants during different stages of life also described above, and its suitability to local landscape and climate. Embodied environmental impact of the building also informed many of our design choices. We preferred non-toxic, low embodied carbon, and recycled materials including materials with low VOC finishes and a new low-carbon concrete made from either fly ash or slag instead of Portland cement.

Australians expect certain things in their homes: open planning, inside/outside living, and modern conveniences. We worked to ensure the design would appeal to the average Australian buyer by taking these expectations into account. Therefore, the house combines an open plan in the main living space with more private bedrooms. The living area connects directly to a large, wrap-around veranda, and can open up to create seamless inside/outside living. It is therefore possible to use the veranda as an outdoor living room, an outdoor dining room, and an outdoor play space.

**TIMELINE AND COSTS:** Another design constraint we worked with was to keep the house as cheap as possible. Home ownership has long been a goal for Australians, yet it is becoming increasingly difficult to realize as housing costs have been rising precipitously nationwide, especially in the urban areas. The average cost per square meter in 2020 for new house construction according to the Australian Bureau of Statistics was $1393. With inflation, we predict $1,500 per square meter, or $150,000 AUD for our house, which would be comparable to $150,000 USD for someone building in the US, earning US dollars. Land costs average about $200,000 for a block large enough for a single-family home of our proposed size, 100 square meters (1,000 square feet). Land clearing and excavation costs should be about $50,000 AUD taking the total for the project to an estimated $400,000. When compared with the average cost for an existing house of this size, $820,000, our house is truly affordable.

We utilized several strategies simultaneously in order to keep costs down. We specified locally available materials, which keep transport costs at a minimum, together with conventional construction technologies, so that local contractors can build the house. Steel-frame construction is common, as is the use of concrete pilings, corrugated metal, and large operable glass doors. Rammed earth has become popular in recent years. As explained below, all of the materials are sourced within a 70-kilometer radius of the building site. Another cost-saving strategy was to use recycled materials and to recommend that the occupants consider purchasing recycled furniture.

We expect the construction timeline to be approximately five months from start to finish. Rammed earth takes about 20 days to build when the entire house is enclosed in rammed earth walls, but we have only partial enclosure. Conventional builds in Australia take 4 – 12 months to construct depending on the site, complexity of the project and its size. Our design is small (1,000 sf), and land clearing will be minimal; there are nominal interior finishes, and there is no slab on grade, so construction should be relatively quick and easy.

**DESIGN WITH COUNTRY:** In Australia today, it is important to design with Country. For our project, this means touching the ground as lightly as possible to preserve local biodiversity, working with Indigenous Australian land management traditions in order to better prevent bush fires, working with local climate for heating, cooling and indoor air quality as described above, and using native flora on our green roof as well as in landscape design around the house. The use of native plants is crucial as they do not require extra water for maintenance like non-native plants; we have selected are all plants that are naturally resilient and regenerate after fire through resprouting or reseeding like: Microlaena stipoides, Themeda triandra, Pteridium esculentum, Dichelachne crinite, and Acacia suaveolens.
DECATHAROOS DESIGN NARRATIVE | DESIGN GOALS

UTS Decatharoos propose a flexible, passive house (passivhaus) design for the unique landscape and climatic conditions that exist on the South Coast of New South Wales, Australia. The house is designed to be bushfire resistant and energy and water independent so that it can be deployed on any typical site in the country whether in remote rural or suburban areas.

The innovative design is flexible in many ways: performance, structural system, integrated services, spatial planning, life cycle, bushfire response, siting, occupant experience, and response to nature. Energy independence, bushfire independence, and passive heating and cooling for thermal comfort independence are critical features. We define ‘independent living’ to mean off the grid but also to mean that the occupants can control their environment.

The house can grow over time to accommodate people’s changing needs in different stages of life. Therefore, the main section can be built first, with additional bedroom(s) and car park added at a later stage. This helps mitigate building costs to make the house more affordable. In the same way that the house can expand from a tiny house for one or two, to a larger dwelling for a family with children or elderly parents, many of its components can be disassembled and deployed in a new structure. The interiors are also flexible; the main building has an open plan that can be furnished to suit the occupants. The inside/outside living offers lifestyle flexibility, and the exterior decks can also double as living spaces configured to suit the occupants’ desires.

In addition, we envision a house that is part of a larger community response to the bushfire threat; it will be equipped with a suite of sensors so that it can act as a data collector for fire warning and monitoring. The house can also double as a fire response staging site during emergencies – it is close to the sea and the main access road for the region plus its open site is ideal for emergency helicopter landings. The bedroom wing of the house can also serve as temporary accommodation for firefighters during a bushfire campaign when such accommodation is often necessary.

Much of the continent is bushland, densely forested, uncultivated native landscape, with flora and fauna that exist nowhere else on the planet. Whilst bushland is a general term that covers many different Australian habitats from grasslands to heavily forested areas, common native species include eucalyptus trees that rely on the cycle of bushfires to reproduce, wattles, bottlebrush trees, and more. The unique beauty of this landscape has long made it attractive to Australian families whether they reside close to an urban centre or in a regional area. Already in the 19th century, settlers and architects recognized the value of designing homes to respond to both the special features of the local landscape and the climate.

The design uses a low waste approach; it uses typical plywood and drywall measurements, 2.4 meters x 1.2 meters, inset between columns – to minimize cuts and waste. It uses locally sourced recycled materials wherever possible and works with the iconic Australian modernist palette of steel structure, corrugated metal, and glass in open plan.

Building operational costs will be negligible since it is entirely off-grid; occupants will not have to pay for any services or utilities, both are fully integrated into the building. Heating and cooling systems are passive, water will be captured by rainwater, and electricity will be generated on site by solar PVs. Energy storage will be lithium-ion battery for now, but we are looking at flywheel or super capacitor technology as a better solution for the near future since they are not combustible. The energy target is net zero or better.
4.1 ARCHITECTURE:

The house is designed to offer an appealing, comfortable and affordable home to the typical Australian family on an iconic Australian site, a gently sloping hill, in a clearing in the bush, above the Murrah River. It is designed to take advantage of all the natural features of the site, work with the local climate, and be durable and resilient. We have embraced the Australian modern tradition of making elegant domestic spaces using simple, straightforward means, open spaces, and inside/outside living.

Figure 1: Site plan showing the region and the site's proximity to Bermagui and Tathra.

In order to take advantage of the site's aspect, the house is located on a north-facing slope in a naturally grassy open area, which has optimal north-facing orientation for effective passive solar in Australia and stunning views to the river below, sea alongside, and expanse of country to the north. Because it is free of large trees or shrubs and because we propose a pilings foundation system, the site requires minimal disturbance of the land for construction. It is also far enough away from forested areas to have a natural Asset Protection Zone, the buffer zone needed between the house and any potential fire hazards. An effective Asset Protection Zone needs to have reduced fire loads, an area from which backburning can be conducted, and an area that permits access for emergency services. The grassy zone around the house fits all these criteria. In addition, our site and landscape design strategy include creating a series of fire breaks that are concentric zones made of 3-metre-wide gravel and other non-combustible crushed stone; although they will help stop fire advancing, they will double as land art. Other flora on and near our site includes native exotic conifer forest, grassland, and banksia scrub, and Mangrove wetland. Sand dunes form the edge between our site and the sea to the northeast.
The house will be made from a recycled steel frame that is sourced locally and mounted on reinforced concrete pilings to minimise disturbance of the land and touch the ground lightly. Not only is this economical but it is in line with decades of architecture in Australia by our best-known architects like Glenn Murcutt. We will use steel from abandoned and dismantled farm out-buildings, wherever possible, since there are many on the South Coast, or recycled steel sourced in Moss Vale, just a few kilometers north of our site.

The house has a minimal footprint in order to keep construction costs down by using as little material as possible: Its configuration also reinterprets iconic Australian bush houses by architects like Murcutt, Russell Jack, Ian Weir, and more, who typically use well-articulated but simple forms. There are three volumes to the house arranged in parallel bars: the main building with one bathroom, the main bedroom, the laundry, and the kitchen, dining and living rooms in a single space is located to the north where the best solar exposure is. Behind this volume, on one side is a smaller wing that can be built together with the main building or added later on, with two bedrooms and a second bathroom; on the other side is the covered car park with protected storage.

The house is approached from above, then entered via a covered and enclosed bridge, firstly by walking between the car park and bedroom wing (if they are built), then through an outdoor space that is flanked by two pools of water. The pools are created and replenished by rainwater captured on the butterfly roofs. The water captured in this way will supply the house with all its water needs and help with passive cooling in summer.
The house is designed to resist fire as much as possible. To this end, the south-facing walls, and many of the side walls, will be constructed from non-combustible rammed earth, made from clay sourced in the riverbed below the site as well as earth excavated for the building foundation pilings and water retention tanks and pools. Rammed earth is fireproof, naturally insulating, and can act as a trombe surface for passive heating in winter. The north and northeast facing glass facades, and all other windows on the house, can be completely covered in a fire event as there will be fire shutters mounted on each window bay. For the window wall on the north and northeast, there are two types of folding shutters – ones that are attached with hinges at the base of the sliding door glazing so that they open by folding down onto the metal decking below and smaller ones mounted above the sliding glass doors that form overhead awnings to provide shading when they are open. The exterior of these panels is made from fire-proof FC Sheeting while the underside is wood. Therefore, when open, the shutters make a wooden floor surface for the outside wrap-around veranda. The door and windows to the rear bedroom block are protected by fire-proof shutters that slide into place when needed and rest in front of the rammed earth façades on either side when not in use.

The rear two south-facing pavilions, which is the cold side of the building, house parking, the building battery and storage, on the right, and two bedrooms, a full bathroom, on the left. The main wing at the front houses the main bedroom, a full bathroom, and the open-plan living space with kitchen, dining, living and laundry. The living spaces are in the north-east section of the wing, where they receive optimal natural light and have spectacular views to the river, bush, and sea. A large veranda stretches across the main living wing and wraps around the corner to offer outdoor living space that connects to the interior spaces for inside/outside living. The access bridge is also family living space.

The building plan is laid out on a 2.4 meter (7.87 feet) by 1.2 meter (3.9 feet) grid. This is the standard size of prefabricated sheeting for most building construction applications and most of the materials that we envision for the house including: plywood, gypsum board, FC Sheeting,
Corrugated sheeting, and blue board. By using sheets of this size as the standard construction module, we substantially minimize cut-offs, which means that there is little waste during construction. In addition, we decided to use glass in the triangle between the top of the rammed earth walls and the roof construction to avoid the need to cut plywood and drywall for those areas, which would have resulted in wasted material.

The dimensions of the retention pools and water storage tanks were dictated by the amount of water needed to provide for a family of four plus guests during a typical year.

Figure 4: Short section showing the skillion roofs that slope towards the water-filtering green roof and retention ponds.

The short section features two skillion roofs made of recycled corrugated steel that slope inwards in a butterfly formation. The north-facing rear roof has solar PVs mounted on it. The south-facing roof is angled and fitted with overhanging roof in dimensions that optimize passive solar gain during the winter months for passive heating. Floors are exposed concrete, which helps with heat capture and heat radiation during winter months. The corrugated profile allows us to dispense with gutters as the corrugations direct the water flow into the retention pools below. Gutters are dangerous features on houses in bushfire zones as they can trap embers and cause the house to catch on fire. Some of the water also falls on a green roof atop the entry walkway. This will be planted with native Australian plants that regenerate through burning and will be detailed to help filter the rainwater in the first stages necessary to make it potable.

The roof construction is exposed on the interiors of the house. It consists of steel beams supporting plywood decking with water proofing membrane, insulation and corrugated metal on top. The steel beams and plywood decking are all visible on the interior. The wood should help balance the cold color of the exposed concrete floor to warm up the space.
The house touches the ground lightly on the back of the slope and is supported by steel columns on reinforced concrete pilings in the middle and front portions. This minimizes disturbance of the ground below and therefore minimizes disturbance to the biodiversity and ecoculture. We use some of the space underneath in the central section for retaining pools and water tanks. The building undercroft is concealed behind gabion walls made from concrete pieces that we will source by breaking up the concrete in an abandoned concrete pad on the site.

Over the threshold, the visitor enters directly into the main wing where the view is immediately apparent. 2.4-meter-high (7.87 feet) floor-to-ceiling glass panels enclose the main living space providing natural light and panoramic views of the unique surrounding landscape. The façade also acts as a passive solar collector in winter.

Figure 5: East Elevation showing the combination of rammed earth, corrugated metal, and glass on the facades.
Figure 6: Construction Details - The detail on the left shows the wall construction of the rammed earth parts of the house; the central detail shows the construction of the enclosure of the bridge element and green roof; and the detail on the right shows the typical construction of the north-facing façade.

To construct the house, we propose using non-combustible materials on the exterior surfaces and anywhere that the house might be under threat of direct contact with fire in the event of a bush fire. Materials will be recycled and locally sourced wherever possible to reduce the carbon footprint of the house. Non-combustible materials include rammed earth for many of the walls at a thickness that allows us to take advantage of the natural insulating properties of the material, which also reduced material costs; low carbon reinforced concrete for the floor slabs and pilings developed by UTS Engineering at the university’s Centre for Sustainable Building; recycled structural steel, which also reduces the carbon footprint by reusing steel; steel grating for the veranda floor; corrugated steel sheeting for the roofs; and FC Sheeting for the fire shutters. In this way, the house can open up for normal everyday use and totally close down in a fire event for maximum protection. The shutter system is simple and quick to deploy – shutters are on hydraulic arms that help lift them, they then lock into place.

Typical wall construction features 150 mm of rammed earth on the exterior, with 150 mm insulation made from recycled plastic, then 150 mm of exposed rammed earth on the interior on reinforced concrete pilings. The details show the highly insulated envelope all around and exposed materials on interior surfaces.
Figure 7: Material Wall Legend showing what materials and which construction details are used in each location in plan.

The elevations are an elegant collage of rammed earth, green-colored corrugated steel and glass (to be decided) arranged to be visually interesting. The colours we chose are muted, natural hues like green and ochre that complement the colours in the surrounding landscape.

Figure 8: Tests of materiality on the elevations. Here, we experimented with different combinations of materials to create the most effective visual aspect for the house.

To offset the cold foundation materials, we propose to use a warmer palette on the interiors including exposed plywood decking, blue and green tiles, and some wooden elements. As with the exterior and structural materials, we will source recycled material wherever possible.
Open plan living means that furniture can be arranged to fit the needs and lifestyle of the occupants, providing internal flexibility. We achieve this by pushing services like the kitchen to the edge of the space, against the wall, leaving the center completely open. Necessary light fixtures are positioned on the same structural grid that governs the entire space and are hung from the exposed steel beams on the ceiling to keep a consistent interior.

Furniture pictured in the render is typical of what we envision: warm, wooden pieces and some colorful ones to complement the hard-cold surfaces and neutral tones of the concrete floor, steel structure and glazing. The rammed earth walls also help warm the interiors.

The house interacts with its site by taking advantage of spectacular views, providing the opportunity for inside/outside living with the direct connection between interior living space and wrap-around verandas on the north and northeast sides; as well as the lovely water garden on the south side, something that is not only possible in Australia but part of our architectural design traditions because of the relatively warm year-round climate.

Control of the indoor environment is in the hands of the occupants who can open and close windows for indoor air quality, natural ventilation, and thermal comfort. The glass louvers are visible in the render above as are the floor-to-ceiling operable glass doors on the north-facing façade. See Occupant Experience below.
The house relies on integrated systems to function, most of which are manually controlled as described above. It achieves energy independence by using solar PVs. In future, the house may connect to a community micro-wind system. As described above, the house is designed to capture and store its own water supply for potable and other uses. All these are practical in an area that is off the grid, with no city water or energy supply, and helpful in a bushfire. Water is integrated into the plan in open pools and under-building storage to offer bushfire protection and passive cooling in summer.

Integrated systems include ones for passive heating and cooling. The north-facing glass facades are to allow passive heating in winter; the reinforced concrete floors and rammed earth walls act as heat syncs in winter and help with cooling in summer. Two pools between the two parts of the house offer evaporative cooling. There are louvred clerestory windows across the main North & South façade to create the chimney cooling effect and side windows allow for cross ventilation. Roof overhangs are dimensioned to optimise exposure to the sun in winter and protection from the sun in summer. The house is very well insulated, with triple glazed windows, in order to allow for heat cascade heating from waste heat released by the refrigerator, and the occupants. See Integrated Systems below for technical details.

4.2 ENGINEERING

From the start, the house was designed to use integrated design and passive systems from the Passivhaus approach, which includes effective highly sealed envelope design, comprehensive structural systems, optimized natural daylighting and electrical lighting system design, plumbing system with grey water and black water integrated for optimal water and wastewater management.

Because of the location in a bushfire zone, there were very few choices for a fire resistant or non-combustible structural system. We selected steel frame because we can source recycled
steel, which allows for reduced consumption of other valuable resources including coal, iron ore, and water. Recycled steel therefore improves the carbon footprint of the project. Recycled steel retains its strength and has a very long life, making it an excellent material for long life cycle. And, by using recycled material, we reduce waste.

We chose to work with Passivhaus (Passive House) design principles because they deliver the best results in terms of overall building performance. Passive House design uses a highly sealed building envelope, trombe walls, and solar-facing orientation together with optimized natural light, interior heat cascades, and natural ventilation to create a house whose operation is controlled by its inhabitants and whose operation costs are minimal. See Occupant Experience below.

![Diagram of Passivhaus systems](image)

**Figure 11: How Passivhaus systems work.**

By optimizing natural daylight through the inclusion of windows where necessary to ensure adequate natural lighting, we reduce the need for artificial light thereby reducing energy demand and cost. This can reduce the total building energy costs by as much as a third in comparison with conventionally designed buildings.

Plumbing is designed to be straightforward; it uses blue water for drinking and cooking, and grey water for other functions. We envision treating black water on site in a combination of constructed wetland for the grey water and an evapotranspiration tank (TeVap). Both are low cost to install and maintain and designed for domestic use.

### 4.3 MARKET ANALYSIS

New South Wales has one of the most expensive housing markets in the world; according to the *The Urban Developer*, the city of Sydney’s median house price is $1.3 million AUD, while the median house price for the region on the South Coast where our site is located is between $820,000 AUD and $830,500 AUD for a 3-bedroom house. Propelled by the pandemic and
the population flight from the city, the South Coast has become a new life-style hot spot. Its idyllic locations in untouched native bush, near the coast, coupled with temperate climate, have made it extremely popular in the last two years. Of course, once the pandemic subsides, prices may go down again as city dwellers who bought in remote locations realise the challenges of remote working and commuting by automobile. Most of the South Coast is accessible by one two-lane coastal road only or by public bus that takes almost twice as long as driving a private car. Because of the lack of rail service, the area may be less attractive again in future.

In order to be able to afford the typical family house, therefore, buyers would need a down payment of between $164,000 and $166,000 AUD and an income of at least $125,355 or more per annum. With no down payment, the income range begins at $138,857. According to the Australian Bureau of Statistics, the South Coast’s median weekly income in 2016 was $1,157 for a family, which would make it about $1,302 in 2022. Weekly mortgage payments on a loan would be about $711, which is almost double what is considered an affordable amount (28% of income). In fact, the average resident of the South Coast would not qualify to purchase an existing house at current prices unless the household had two incomes.

The cost of a block of land on the South Coast varies but it is possible to purchase residential blocks for $200,000 AUD in the area where our site is located. Combined with our project construction costs of $150,000, this would make the total cost $350,000 plus any site work, which is within reach of the average resident. Weekly repayments would be about $255 - $280 AUD.

Our proposal is even more attractive when the current state of the for-purchase market in our area is considered: there are very few existing houses for sale. Bermagui has only 4 houses for sale that are a comparable size at the moment and Tathra has 3. There is more vacant land for sale, especially when locations outside the towns are taken into account.

Bermagui’s population is comprised of 24.6% older retired couples, 202.2% retired singles, and 15.45% couples with families: while Tathra’s population is comprised of 24.4% older retiree couples, 13.8% retired singles, and 13.8% couples with families. The work that local residents are engaged in are generally lower paid than their counterparts in the cities. Currently, 17.6 % of residents are in the trades, 15.8% are professionals, 14.2 % work in community and professional service, and 45% work in clerical, administrative and laborer roles.

4.4 DURABILITY & RESILIENCE

We built resilience and durability into our design by following the recommendations of CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia’s premier scientific research institution. Resilience is a building’s capacity to prevent and respond to disruptive events while durability is its capacity to last over time. The more durable a building is, the longer it lasts and the better for the environment. Both resilience and durability relate to design choices about building materials, structure, building systems, and function. The factors that affect resilience and durability, though, relate to site, local climate, the users, and the materials and their properties.

When designing for resilience and longevity within the project, we thought it was vital to design for current weather patterns and future weather pattern predictions due to climate change. The CSIRO has indicated that in coming decades, Australia will experience increases in temperature with more extremely hot days and fewer extremely cool days, an increase in heavy rainfall, especially in short-duration extreme rainfall events, and an increase in of high fire weather danger days with a longer fire season for southern and eastern Australia. Particular concern has been placed on extreme weather events, which occur when these weather changes impact simultaneously. Such as when a drought period and extended
heatwave impacts human health, bushfire risk and failure of infrastructure or when high bushfire risk days occur at the same time as conditions that allow bushfires to create thunderstorms, resulting in additional fires caused by lightning strikes.

Using climate model projections distributed by the CSIRO, which have been correct in previous predictions, we have designed for RCP (Representative Concentration Pathway) 8.5, which predicts future weather implications if there is only a limited reduction of Greenhouse Gas Emissions. This modelling predicts Bermagui will achieve a total 1.1°C Average Yearly Temperature increase by 2030 and a 1.7°C Average Yearly Temperature increase by 2050. This temperature increase has a significant implication on the durability and resilience of the design when analysing the life expectancy of the building as extending further than only the next 30 years.

The greatest durability and resilience challenge to our project is fire followed by weather-related climate change such as extreme heat and drought and unusually forceful storms. We have ensured that our building has been stress tested and designed to withstand these changes to climate. We have adopted several design strategies using the four Rs, robustness, resourcefulness, recovery, redundancy and other considerations to create a resilient and durable building:

- The building is on a defensible site, with good views to the surrounding area, easy vehicular and, if necessary, helicopter access. Also, in the event of a blocked land retreat, it has easy access to the coast.
- Robustness is achieved through integrated passive design systems that operate independently from any external services. This allows the building to continue to function in the event that it is totally inaccessible for a period of time due to fire or other extreme weather events since it will generate and store its own electricity, capture and supply its own water, and maintain thermal comfort regardless of the season because of its passive design.

Resourcefulness is a part of the design because of the integrated systems but also because of the built-in fire protections that include non-combustible structure and cladding, a fire shutter system that will close up to protect all the glass surfaces, the gutter free roof design that

- Prevents the accumulation of combustible materials on the exterior of the house, the lack of any protruding elements that could burn, the use of fire proof cladding that is smooth and therefore prevents embers from lodging on external surfaces, the inclusion of enormous water retention ponds and other water storage to enable a protective sprinkler system. The cladding and roofing materials are also waterproof, and the roof structure is strong enough to withstand heavy rain and large hailstones, which have been happening more frequently in recent years. The fire shutters double as protection from hail. Since the house is raised above the ground, on a sloping site, water will drain beneath it; it is also far above the river’s flood line, even for a 1,000-year event. The house will be well insulated, with good roof overhangs to prevent overheating in summer, and operable windows and louvers to allow through breezes for natural cooling. The site has high wind load. The house will have nbn SkyMuster satellite internet or a similar product, systems that were designed for hard-to-reach remote parts of Australia, to keep connected. SkyMuster DC model power supply uses 30 Watts on Standby and 70 Watts in use. If using a 12-volt power system that translates into 2.5 Amps in Standby and 6 Amps while in use.

- Rapid recovery is built into this project in the use of non-combustible exterior materials, which should ensure that there will be minimal destruction in a fire or other event. In addition, there are nominal interior finishes. This should mean that little can be
damaged and therefore what is damaged can be easily repaired or replaced. The main goal is to provide a dwelling that there will withstand attack as much as possible and provide a place to return to after a bushfire or other extreme event.

- Redundancy is incorporated into the house through a series of backup resources in case one of the systems fails under stress.
- Passive building systems and site-generated, independent services should work to minimize any cascading effects of the anticipated threats to the building.

In addition to the above, the house design takes into account numerous aspects of design resilience.

**Design Resilience for functionality**

During an extreme event the building is designed to:
- Provide residential space that safely houses the occupants and others
- House can experience bushfires and other extreme weather events without too much damage
- Quickly bounce back after bushfires and other extreme weather events to be habitable again

**Design Resilience for protection**

- The site perimeter is protected by concentric layers of fire breaks, the exterior of the house is protected by non-combustible, reinforced facades, water underneath the house offers more protection and the house has sprinklers
- The spaces within the house are protected by the non-combustible and sealed exterior envelope, that includes fire shutters over all glass surfaces.
- The design provides for failure and recovery in several ways. Repairs after a bushfire or other extreme weather events should be relatively easy because the design uses recycled, inexpensive and readily available materials that can be easily and cheaply sourced and replaced, the construction is simple with elements exposed for easy access in case repair is needed.

**Design resilience for habitability**

Maintain a healthy environment within buildings that serve as a shelter during extreme events by ensuring the building is habitable even without a power supply.
- The building is naturally ventilated through operable clerestory windows along the main north-facing façade and rear south-facing façade. In addition, operable side windows allow for cross ventilation. We use manually operated only so ventilation does not depend on electricity to work.
- Designed high performance envelopes to seal the house for passivhaus standards
- At 4.8 meters wide, the building is very thin and has windows on both sides of each volume to provide maximum daylighting to the interior.
- The house will have built-in rainwater storage tanks and other water is available from the river just downhill as well as from the sea to the east of the site.

**Resilience in a bigger picture**

- Involve the community / building an interdependent community
- The house is designed to not disturb the site’s ecosystem and biodiversity, but rather help it thrive, by touching the ground as lightly as possible, by minimal excavation for
pilings and water storage, and by not removing much flora to build beyond a small footprint of grass.
- Reliance on locally available, renewable and reclaimed resources for construction and operation make it more resilient
- Anticipated interruptions and predicts for a dynamic future

![Graph showing temperature anomaly from 1920 to 2020](image1.png)

*Figure 12: CSIRO predictions for future warming in Australia beyond 2020.*

**BEGA AWS**

![Graph showing climate data](image2.png)

*Figure 13: Climate data for the South Coast of New South Wales showing the data with which we worked to calculate insulation needs, etc.*
Building passes ASHRAE Residential 2018 Energy code in terms of Solar Daylight Autonomy at 64%, demonstrating the house possesses a highly suitable amount of natural lighting to increase occupant experience. The building design incorporates suitable glazing and wall performance, low SHGC and appropriate shading areas to maximise thermal autonomy. Area-specific Daylight autonomy is shown in below figure 15.

A Psychrometric chart was not available for the surrounding area of Murrah. The closest available data from Thredbo Village is shown in figure X. Thredbo village enables thermal autonomy, without internal heat gain strategies, 3.47% of the time year-round. It is worth noting that Thredbo Village experiences significantly cooler average annual temperatures than the Murrah region (Figure 17). Therefore, we derive that the thermal comfort for the Murrah area is significantly higher than 3.47%.
Murrah has 5 out of 12 months with an average maximum temperature between 21 and 26 degrees celsius, shown in figure X. Based on the Solar Daylight Autonomy maximum of 12 hours (see 4.6 Integrated Performance), we assume that 2.5 months out of 12 months is spent within the Thermal Comfort Zone shown below in red. Therefore, Murrah would spend around 20.8% of the year within the thermal comfort zone, with potential to improve this through internal heat gain and other strategies. Since our house is designed to maximise internal heat gain, as well as other strategies such as thermal mass and night ventilation, it can be deduced that, at minimum, the house is thermally autonomous for over 45.6% of the year. As this is a highly conservative estimate, we gauge that the house performs exceptionally well in terms of remaining within a comfortable thermal zone for a significant portion of the year.

4.5 EMBODIED ENVIRONMENTAL IMPACT

The dwelling will use locally procured and recycled materials wherever possible to minimize shipping distances and thereby keep the carbon footprint as small as possible and minimize waste by using materials that might otherwise be headed for landfill. We are also using materials with long life-cycle expectancy. As explained in the design description, steel structure will be recycled and sourced locally, rammed earth and gabion walls will come from material on the site, corrugated metal will be sourced locally from scrap material, insulation will be recycled plastic.
Figure 18: Sources for materials in the project. The map shows that we propose to source all materials within a 70-kilometer radius from the site.

Figure 15 shows the locations for all the materials we propose using in the project, the distance each source is from our site, and the total travel time required to ship the materials from their source to our site. Following Living Building Challenge principles, we will be able to source everything we need within less than a 100-kilometer radius from the site, which minimizes the carbon footprint by minimizing fossil fuels used to transport materials.

The entire building is designed to the standard panel size of plywood and drywall to minimize construction waste and allow for re-use of components at the end of life to enable cradle-to-cradle cycle and not promote cradle-to-grave material usage.

We intend to use anything disturbed on site, like the excavated earth, in the design.

The various indicators to measure the environmental impact of the materials used on site are described in the table below. After assessing the baseline materials available in the market, and frequently used commercially, we were able to understand which materials we needed to focus upon to make the necessary changes to impact the carbon footprint of the building in a positive way.

ENVIRONMENTAL IMPACT OF MATERIALS USED IN THE PROJECT: The materials for the project were selected with environmental impact in mind for embodied carbon, expected life, ability to recycle or reuse in order to avoid waste down the track, source location – as local as possible to avoid transport costs and pollution caused by transport, VOC content, and toxicity.
Figure 19: Embodied Carbon by Materials in the house.

As seen above, the materials where the embodied carbon can be reduced in the building and will show the most impact is concrete and steel. Assessing these materials specifically we have identified where and how the carbon impact of the material can be reduced.

Concrete

In terms of Concrete, including substitute cementitious material (SCM) or including recycled aggregates in concrete can reduce the baseline carbon impact as seen below:

Figure 20: Embodied Carbon reductions CRM and Recycled Aggregate.

We are thus able to reduce the global warming potential of the concrete portion of our building by around 25%. And, we propose to work with the low carbon concrete that uses fly ash and slag being developed by engineers at University of Technology Sydney: https://techlab.uts.edu.au/low-carbon-future/.

Reinforced steel

Similarly, reinforced steel was assessed in terms of improved strength and including recycled content, the latter of which shows of more than 60% reduction in Global warming potential as compared to generic steel.
With this assessment in mind, a local vendor was contacted, and recycled steel is procured for use on site which greatly reduces the footprint of the building.

In addition to both these assessments, we have kept in mind the following to further reduce the environmental impact of the building:

- Optimize design capacity for reduced volume
- Standardize the design for reduced waste generation (See above grid choice)
- Opt for pre-cast concrete and off-site steel fixing to reduce waste
- Identify and engage with suppliers early to develop specification types as required.

Goal: Achieving net zero waste house with integration to local community waste management plan.

Minimizing Household Waste

Waste during construction was not our only concern: we also researched ways to minimize waste in daily operation of the house. The typical Australian household waste consists of: 2.4% Masonry materials, 8.8% metals, 51.6% organics, 17.7% paper & cardboard, 9.7% plastics, 6.5% glass, 2.4% textiles, leather and rubber (as of 2020). The two main contributors of the typical Australian household waste therefore are organics, and paper/cardboard, waste types we target for repurposing.

Repurposing Waste for Compost

<table>
<thead>
<tr>
<th>Problems</th>
<th>Causes</th>
<th>How to overcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maggots</td>
<td>there is wet organic waste material (fish, meat, bones, milk, coconut milk) or uncovered compost</td>
<td>Avoid wet organic matter and cover the compost with a layer of soil</td>
</tr>
<tr>
<td>Bad odor (ammonia)</td>
<td>too much nitrogen, too much green waste</td>
<td>add brown waste and open the compost to add more oxygen</td>
</tr>
<tr>
<td>Bad odor (rotten eggs)</td>
<td>lack of oxygen or too moist</td>
<td>add the brown trash, open the compost to add oxygen and stir the compost</td>
</tr>
<tr>
<td>Lumpy fertilizer</td>
<td>too moist</td>
<td>add the brown trash, open the compost to add oxygen and stir the compost</td>
</tr>
<tr>
<td>Too dry</td>
<td>lack of water, too much brown waste</td>
<td>add water and green waste</td>
</tr>
<tr>
<td>the compost is moist but not warm</td>
<td>Lack of green waste</td>
<td>add green waste</td>
</tr>
</tbody>
</table>

Figure 22: Waste for compost.
Paper Collection for reuse in house

Paper use has to be reduced, however, the paper that is used and needs to be thrown away can be repurposed as a fire starter and wraps for shipping or storing items, and even window cleaning.

Recycling Technologies

Integration of the Recycle Mate App into the home smart technology can help homeowners to recycle correctly.

4.6 INTEGRATED PERFORMANCE

Our site is in climate zone 6 where the shoulder seasons of spring and autumn are ideal for human comfort, but summer and winter can exceed the comfort range.

Figure 23: Australian Climate Zones. Light blue is Climate Zone 6. While Climate Zone 6 represents a small part of Australia’s land mass, it is one of the most populate parts of the country.

As seen from the graph above, our site has almost an equal number of cooling and heating degrees throughout the year with a summer mean temperature of 20 degrees and a winter mean temperature of 9 degrees.

Figure 24: Plot from Cove Tool.
From the Cove Tool plot above, we see that about 87% of the time between October to April, the outdoor air conditions lie between 10 degrees C and 24 degrees C and natural ventilation is possible, whereas in winters it averages about 56% of the hours.

**Figure 25: Integrated Systems in the building.**

The lower temperature limit is set at 10 degrees as the house is integrated with heat exchangers that help in heat recovery ventilation, conditioning the cold incoming air with the warm air expelled from the space when temperatures are below 18 degrees C.

The building is designed to achieve low energy requirements by following the Passivhaus standards. The project specifications that help achieve that are as below:

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Bridging</td>
<td>Minimized or eliminated</td>
</tr>
<tr>
<td>Airtightness</td>
<td>&lt;1.0ACH @ 50 Pa</td>
</tr>
<tr>
<td>Frequency of overheating</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Mechanical ventilation heat recovery efficiency</td>
<td>&gt;80%</td>
</tr>
</tbody>
</table>

The building envelope is designed to help the house perfectly insulated and keep the heat loads trapped when the operable windows are closed. It implements earth coupled slabs to reduce heat dissipation in cooler months and capitalise on earth-cooling strategies in summer. The roof is designed with ventilation openings promoting cross-ventilation and the integrated roof space creates a thermal buffer zone promoting ventilation in summer (cooling) and sealing capabilities in winter (heat retention).

The house is oriented towards the North-east to enable optimal solar heating and daylighting. The glass north wall strikes a balance between passive solar heating and yield of natural light for ambience, task and mood settings. It promotes early natural lighting and suitable shading is provided in the afternoon to cut harsh setting sun. Internal courtyards maximize the sun exposure to bedrooms whilst protecting the space against harsh southerly winds.
Opaque Envelope | R-Value (m².K/W) |
---|---|
External walls | 4.76 |
Roof | 5.88 |
Floor | 2.77 |
Glazing | U-Value (W/m².K) / SHGC |
Glazing | 1.15 (Triple Glazed, low-e) / SHGC 0.5 |
Window frames | 1.3 |

The insulation installed will be continuous to create a perfect thermal envelope of the space negating any possible uncontrolled heat flow in or out of the building. Similarly, there will be a continuous airtightness line designed and shown in the plan and section of the building. This well-sealed envelope will ensure that the internal loads from occupants and equipment negate the need for active air conditioning systems.

The north-facing roof slope will have integrated PV panels that aid in on-site energy generation. The roof pitch and direction maximize solar generation potential and with, an area of about 190 square meters of potential area, the PVs are able to generate enough energy for the house to run and to produce excess energy for storage during suitable sky conditions. Figure 26 highlights the spread of sunlight hours that the building is exposed to on average over the course of a year. The maximum sunlight hours per day for the building in its geographical position is 12 hours.

![Figure 26: % Sunlight Hours per Day. The South Coast averages between 6 and 8 sun hours per day all year.](image)

Although we propose to start operation with conventional lithium-ion battery storage, we have selected flywheel technology for the near future because it is cheaper than lithium batteries (1/10 the price per kWh), fire-proof whereas batteries are combustible and dangerous in bushfires, better for the environment since there are no toxic rare-earth metals in the technology, less likely to fail, better in extremes of heat and cold, and longer lasting than batteries – over 25 years compared with 3. Flywheels also are usually produced with recycled steel, which conforms to our larger ambitions for the project, and, unlike conventional batteries, their storage capacity does not degrade over time. Lastly, flywheels are particularly well suited to remote locations like our site because they are easy to install and are easy to manage. (See Appendices)
The energy generated from the solar panels is used to spin the flywheels during the day when the sun is shining and at night when the panels are inactive the energy stored in the flywheel is discharged to power lighting and other devices.

In addition, we foresee the installation of micro wind generators in the near future as these prove effective where there are wind speeds more than 16 km/h and the site/township located on a hill next to the water makes the most use of the 5m/s average wind speeds available throughout the year. The advantage of wind energy is high, but as the cost of investment is also high, we plan to collaborate with the Bermagui township’s pledge for “Clean energy to eternity” and invest along with the local council and other investors in setting up a micro wind farm. This is aided by the meeting carried out in July last year (2021) where the funds were agreed to be used for “Solar gardens and other potential sources of renewable energy including wind, wave, tidal and biomass”. What this does is not only help our site achieve net positive energy production, but also uses the excess renewable/clean energy produced to offset others electricity consumption and reduce reliance on gas/coal consumption which proves to be the biggest issue in Australia till date.

4.7 OCCUPANT EXPERIENCE

The house is designed to provide a relaxing retreat in the Australian bush where the occupant can enjoy nature and inside/outside living in a spectacularly beautiful location. The occupant’s experience begins with the slow approach along the drive. The house will appear gradually – its west-facing side and roofs will appear first as a glint of green metal and rammed earth, the car port entry next. From the car port, the views are obscured. The occupant leaves the car, walks through the gap between car port and bedroom wing, where sight is narrowed to focus on the front door, onto a bridge over the retention pools where water and landscape are the visual focus. From the bridge, grassland and bush are visible to the right and left, the front door is straight ahead. Once over the threshold, the vistas explode in all directions offering views to the river below, rolling hills opposite and the sea to the side.

The house site and floor plans are highly functional. The double bar arrangement allows for the house to be constructed in 1, 2 or 3 phases to accommodate financial and life-style circumstances of the occupants. Program is placed as logically as possible and spaces are held to a minimum size: the car port is nearest the road, the main living spaces are north-east facing for maximum passive solar benefit and to capitalise on the views, the extra bedrooms are in the protected back corner.

The house’s spaces are designed to provide maximal function with the minimal footprint. There is almost no space wasted on internal circulation. Instead, most spaces are connected directly to one another or accessed from outside terraces, which is possible in the mild Australian climate. Cooking, living and dining occur in one large, open, flexible space that can be furnished to suit the occupants’ lifestyle requirements. The living area is on the north-east facing side of the house so it has dramatic views, receives direct sunlight for most of the day, and has floor-to-ceiling glass doors that can open to the surrounding terraces to allow the occupants to enjoy the mild local climate and the joys of inside/outside living. The wrap around terraces are therefore extensions of the interior spaces and conceived of as exterior living spaces. In addition to the requisite barbecue, the terraces will have dining table and chairs and lounge chairs.

The orientation of the outside spaces makes them protected from prevailing winds so that they should be comfortable year-round.

The house uses human-controlled manual passive systems only which means that the occupants have control over every aspect of indoor comfort – temperature, amount of fresh
air, amount of natural light, and degree of openness to the surrounding environment. The ability to control the interior environment, coupled with tremendous access to natural light and air, will enhance the occupant’s health and well-being. Manually operated systems also enhance human health as they require physical engagement with the house and its environment.

The occupant’s health is further considered through the careful selection of internal finishes throughout the design. The design specifies the use of low Volatile Organic Compound (VOC) materials to provide good indoor air quality for occupants. It ensures that all internal finishes meet International and Australian VOC levels specified in the WELL and Green Star Standards.

<table>
<thead>
<tr>
<th>Internal Finish</th>
<th>Volatile Organic Compounds</th>
<th>WELL and Green Star Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rammed Earth</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Painted Plaster Board</td>
<td>1g/L</td>
<td>16g/L</td>
</tr>
<tr>
<td>Ceramic Tiles</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Tile Grout</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Waterproofing Membrane</td>
<td>&lt;1g/L</td>
<td>250g/L</td>
</tr>
<tr>
<td>Window Glazing</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Polished Concrete</td>
<td>0.04 mg/L</td>
<td>&lt;1mg/L</td>
</tr>
<tr>
<td>Timber Plywood Ceilings</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The building also uses recycled and second-hand finishes and furniture where possible to further reduce VOC levels.

**4.8 COMFORT & ENVIRONMENTAL QUALITY**

The strategy for indoor environmental quality is simple: to rely as much as possible on passive systems and human control. There is no conventional HVAC as such systems are not required for a passively serviced building. Instead, as mentioned above, heating, cooling and ventilation occur by opening and closing windows and shutters.

As much as this house is carbon neutral, bushfire resistant, and passive, it is also smart in a way that minimizes electricity overuse. There is huge potential to introduce new technologies to maximize occupant comfort, including:

- Temperature Sensors (Thermostats) in each room that inform the occupants when adjustments to the indoor environment might be beneficial
- Thermal cameras that identify occupant body temperature and recommend adjustments to room temperature accordingly
- Smart, highly efficient, and strategically placed LED mood lighting determined by weather conditions, time of day, temperature, seasons, manual preference etc.
- Integrated appliance safety technology to eliminate/greatly reduce the risk of user-created accidents (oven-fires, toaster fires, etc.)
- Waste sensors that notify occupants when rubbish needs to be disposed
- Roof cameras to monitor leaf/bark build-up in gutter and notify occupants when cleaning may be required - reduces bushfire risk
- External sensors that activate sprinklers when bushfire is near (or plug-in to fire warning systems)
- Wifi capable appliances
- Smart appliance reminders
Appliances have the highest possible energy ratings to minimize electricity demand:

<table>
<thead>
<tr>
<th>Kitchen</th>
<th>Manufacturer &amp; Link</th>
<th>Cost</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kettle</td>
<td>Russell Hobbs</td>
<td>$75</td>
<td>Save up to 66 percent energy saving by boiling one cup (235 ml) vs 1 L</td>
</tr>
<tr>
<td>Induction Cooktop</td>
<td>Fisher &amp; Paykel</td>
<td>$1,799</td>
<td>Safer use, as it only heats once pan or pot is placed on the ceramic surface and stops when it is removed. Additionally, it has a heating efficiency of 86% as it heats the cookware, not the stovetop</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>Electrolux</td>
<td>$1,899</td>
<td>5-star Energy Rating at 310kWh/yr</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>V-Zug Adoradish</td>
<td>$5,999</td>
<td>5-star energy rating at 11.2L/cycle</td>
</tr>
<tr>
<td>Oven</td>
<td>Miele</td>
<td>$8,899</td>
<td>Has multiple features, which all contribute to energy savings and reduced heat transfer. The features include an eco fan, economy grill, residual heat utilisation, automatic switching and air clean catalyser</td>
</tr>
</tbody>
</table>

| Laundry            | Asko Pro Wash       | $2,099 | 5-star energy rating at 52L/wash                                        |
4.9 ENERGY PERFORMANCE

The strategies for energy performance in the project are to integrate energy generation and storage into the house and minimize demand loads wherever possible since the house is completely off the grid and will have no grid interaction.

The roof over the car port and rear bedroom wing will have about 90 square meters of solar PVs in order to generate energy for the house. Backup energy will be stored in a flywheel system with capacity for 12 Kwh system. There will also be a solar hot-water heater on the roof.

There will be no conventional HVAC in the house. Natural ventilation and passive heating should cover required comfort levels.

In order to reduce plug loads, all appliances will be Energy Star rated; roof overhangs will keep the interiors shaded and cool in summer as will the cross ventilation and chimney effect ventilation; and the house will have a user’s manual to explain best practice and best use including powering down appliances when they are not in use and refraining from purchasing unnecessary devices.

Energy performance was assessed using the Nationwide House Energy Rating Scheme (NatHERS). This allowed for the assessment of thermal comfort of the home without any other energy systems. Establishing the compliance energy targets that need to be met by each new single residential dwelling was done using the 2020 BASIX Thermal Comfort Protocol as the NCC 2019 Amendment 1 describes as necessary for all NSW, Australia dwellings. The assessment was carried out in Bers Pro v4.4.1.5 which is one of the approved NatHERS softwares and the modelling was done in accordance with the NatHERS assessor handbook and NatHERS technical notes.

Strategies used to reduce the overall heating and cooling loads were using high amounts of insulation in the walls, ceiling, roof as well as the floor, both suspended and slab on ground concrete. Also, the use of low u-values and varying SHGC values that is consistent with triple glazing provided great overall thermal performance for the building. Eave lines and shading devices were also considered based on the need for daylight to come through while still providing shading where needed.
Compliance requirements for new single dwelling home in NSW Climate 6 are:
(page 18 BASIX Thermal Comfort Protocol 2020)

<table>
<thead>
<tr>
<th></th>
<th>Heating Load</th>
<th>Cooling Load</th>
<th>Star Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete slab on ground</td>
<td>73.5</td>
<td>31.5</td>
<td>N/A</td>
</tr>
<tr>
<td>Suspended Floor</td>
<td>78.4</td>
<td>34.6</td>
<td>N/A</td>
</tr>
<tr>
<td>Approximate for our dwelling</td>
<td>75.0</td>
<td>32.5</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Figure 28: Loads achieved for new single dwelling home in NSW Climate 18.**

<table>
<thead>
<tr>
<th></th>
<th>Heating Load</th>
<th>Cooling Load</th>
<th>Star Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>For our dwelling</td>
<td>16.9</td>
<td>7.8</td>
<td>8.8</td>
</tr>
</tbody>
</table>

**Figure 29: NatHERS Heating and Cooling Loads calculations for our house.**

Please see the Appendices – the NatHERS Decatharoos Calculations Summary for a detailed breakdown of the materials in the project, their R and U values, and performance for heating and cooling.