Towards Net Zero

A project home case study by Tina Billing

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I respectfully acknowledge the custodians of this land, the Whadjuk people of the Noongar nation and their Elders past and present. I acknowledge and respect their continuing culture and the contribution they make to the life of this city and this region.

INTRODUCTION:

The Road to Environmentally Sustainable Homes

In order to reach the Paris Agreement 1.5 degree C goal, 11 million Australian homes must undergo radical decarbonisation by 2050 (ECA, 2023). Decarbonisation is the process of reducing and eliminating greenhouse gas emissions (GHG), encompassing both operational (everyday building energy use) and embodied carbon (emissions during the production and disposal of building materials). While existing households can contribute significantly in transitioning towards Net Zero, the role of the architect is crucial during the early stages of building a home.

Buildings account for a 35% of total global energy consumption and 39% of global CO_2 emissions (WBGCa, 2018), with the emobdied carbon of building materials alone, such as cement, iron, steel and aluminum, responsible for 11% (Figure 2.). This highlights how crucial architects are in the transition to reverse detrimental effects of climate change.

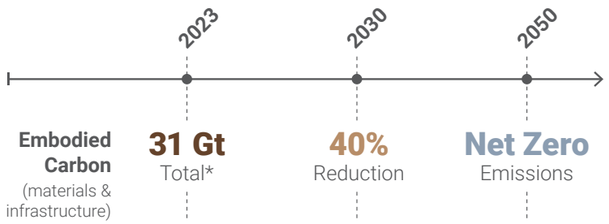


Figure 1. The goal to elimate embodied carbon by 2050. *Source:* WGBC (2019). **Source:* KPMG (2023).

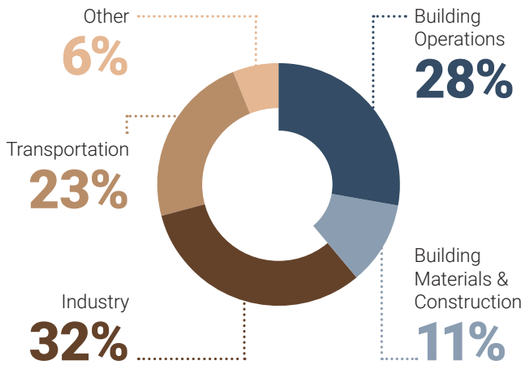


Figure 2. Global CO_2 emissions by sector. *Source*: Architecture 2030 (2018).

For us to reach Net Zero emissions by 2050, a 40% reduction in embodied carbon must be achieved by 2030 (WGBCb, 2019). Although 2050 still seems distant, it's important to note that buildings being constructed now can last for decades and can have a significant impact on reaching climate action targets by mid-century. Architects can establish carbon reduction milestones in the early phases of a project to ensure a building will operate efficiently throughout its lifecyle, preventing the need for retrofitting energy efficient changes later (Cao, 2020).

Decarbonisation is no longer just a buzz word in the housing and construction industry, but a responsibility architects must enact in designing sustainable buildings for future generations.

RESEARCH:

How Can Architects Achieve Net Zero?

Architects have the power to significantly cut emissions in the built environment before construction even begins by adopting low-carbon practices from the outset such as the following.

Choosing Carbon-negative Materials

Carbon negative materials retain more carbon during its existence than is emitted during the procurement and manufacturing of raw materials. Certain materials like wood, straw, clay-straw, cork, and sheep's wool have the ability to naturally absorb and retain carbon throughout their lifespan. Implementing these result in a consistently negative carbon footprint throughout a structure's lifecycle. This is more ambitious than carbon neutrality, which involves counterbalancing the same quantity of carbon dioxide produced during manufacturing of materials.

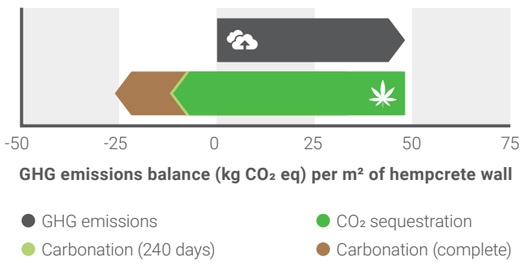
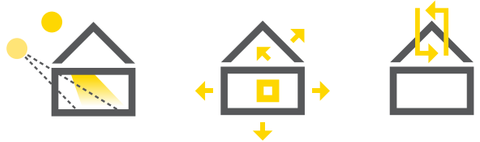


Figure 3. *Source:* Arrigoni et al. (2017).

Manufacturing concrete comes at a high cost of raw materials and requires extremely high temperatures over 1000 degrees celcius to process, and emits large amounts of toxic greenhouse gasses into the air. While there is no one-size-fits-all substitute for it, Hempcrete, paired with framing of another material, is a far more environmentally friendly alternative, and even has carbon sequestration capabilities. The hemp plant it originates from absorbs CO_2 from the atmosphere and holds 110kg of CO_2 per m³ of wall (Vosper, 2024). It has a longer lifespan than concrete, and offers superior thermal and acoustic properties (Figure 3.).

Energy Efficiency through Passive Design

Architects can utilise natural elements such as sunlight, wind and shading to decrease a building's energy use. By carefully planning the orientation, building shape, window placement and shading systems, a building can enhance natural light and lessen the need for artificial lighting.



Additionally, other measures can be implemented to optimise energy efficiency, such as ensuring airtightness for effective insulation, innovative HVAC systems such as heat pumps, and smart technologies with sensors to optimise energy consumption.

Figure 5. The Eden Project in Cornwall, England by Grimshaw Architects. The biomes are based on the concept of bubbles. *Source:* iStock.

Material Life Cycle Assessments

A Life Cycle Assessment (LCA) is a methodology that architects can use to measure embodied carbon in building materials, considering every stage from the procurement of raw materials to production, use, and disposal. This includes the extraction of raw materials, manufacturing, transportation, use, and end-of-life disposal or recycling. This holistic approach helps architects make informed decisions about the environmental impact of their designs and material choices (Figure 4.).

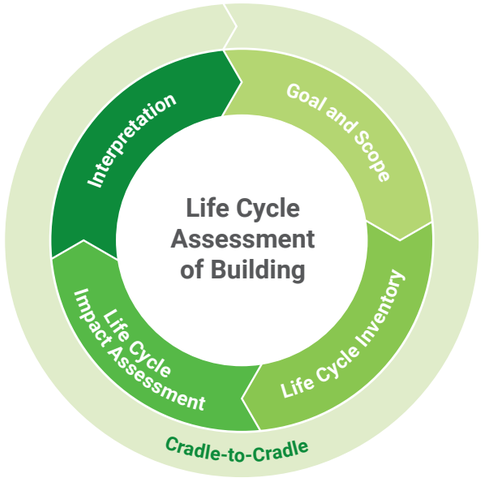


Figure 4. *Source:* HIA (2019).

Adaptive Reuse and Retrofitting

Rather than demolish existing structures entirely, Repurpose old buildings and add eco-friendly features such as better insulation, install automation systems and add renewable energy sources. The use of recycled construction materials can also drastically reduce carbon impact by avoiding the need to manufacture new materials which are environment-costly. By repurposing old structures and choosing to recycle materials, particularly those that are locally-sourced, architects can substantially lower embodied carbon and make a positive impact on the environment.

Biophilic Design and Biomimicry

Biophilic design is a philosophy based on the idea that humans have an inherent connection with nature and thrive in environments that reflect this. By incorporating natural elements such as tree canopies, plants, water, natural light, natural shapes and patterns, a building can not only offset its carbon impact, but will also enhance occupants' health, wellbeing and productivity. The Bamyan Provincial Hospital located in Malaysia is a revered example of biophilic design. Others include the residential towers of One Central Park in Sydney, and the Amazon Spheres in Seattle. On a broader scale, biomimicry aims to mimic nature's designs, processes, and systems to create harmony with the environment. Some ways to apply this principle include dynamic shifts in light, biomorphic forms like columns shaped like tree stalks or beehive hexagons, and designing for human-nature connection such as private nooks and spaces for meditation. The Eden Project in England is one such example of biomimicry in architecture (Figure 5.).

Forrest Rd

Sienna Wood Hilbert

Eleventh Rd

Lannam Rd

Ninth Rd

Astoria Blvd

The Oriana House

The Avenues Estate

Wungong River

Hilbert

Rowley Rd

5 mins drive

Tonkin Hwy

Air pollution from local landfill

Landfill

Masters Rd

Masters Rd

Hopkinson Rd

N

The Oriana is a single detached house design that includes a master suite, a home office, an open plan dining and living room, a home theatre, and three additional bedrooms

ANALYSIS & CRITIQUE:

Project Home Case Study

The Oriana design is part of a house and land package by Dale Alcock Homes. Located within the newly developed estate of Sienna Wood, in Hilbert WA, it sits on the southern edge of the City of Armadale, approximately 42 minutes away from the Perth CBD.

Perth has a mediterranean climate consisting of hot dry summers and mild wet winters, with a reported rainfall between 350–650 mm in 2023, 15-40% below the annual average (BOM, 2024), a stark reminder of the negative effects of climate change.

Its proximity to Armadale landfill facility means that air pollution is carried over by south westerly winds towards the estate. Local residents of the neighbouring Avenues estate frequently express frustration over unpleasant odours coming from the landfill facility (Brookes, and Hastie 2023).

Other complaints from locals include the lack of playgrounds for children, a shortage of tree cover, leading to extremely hot summers and high electricity bills, and an absence of habitat corridors for the local wildlife (Brookes, and Hastie 2023). These highlight the pervasive issues of urbanisation on rural land, stemming from developers prioritising the construction of high numbers of properties over the creation of liveable spaces, to the detriment of the environment.

The Oriana floorplan lists a myriad of inclusive modern features such as ducted air-conditioning and stone benchtops, although there is no indication of the type of insulation that will be installed nor a fully electric heating system throughout the design. A large amount of space is allocated for the master zone and home office, in total almost equivalent to the remaining space designated for the additional three bedrooms and wet areas of the house.

Although the Dale Alcock website guarantee the installation of an electric underbench oven, the included cooktop will remain as a gas cooktop.

Some positive features of the package include the installation of LED lighting, and that the property has the advantage of facing North, which favours abundant sunlight during the day, but this comes with a caveat: most of the south-facing rooms will be poorly lit throughout the day, and there are inadequate window placements for natural light and proper ventilation.

The Positives:

- Favourable North-facing position for optimal light and heating in winter
- Effective zoning of adult and children areas
- Energy efficient LED lighting
- Energy efficient electric oven
- Generous allocation of exterior for vegetation

The Negatives:

- Inadequate compensation for poor lighting and ventilation in the south parts of the house, requiring additional artificial lighting and high amount of energy required for cooling and heating
- Tiny, restricted bedrooms for children with minimal connection to the outdoors or natural elements
- Hot water systems are likely powered by gas which emits methane, a highly toxic greenhouse gas.
- Excessive amount of space allocated between two living areas
- Outdated open plan offers very little noise insulation, particularly between the kitchen, dining and living rooms.
- Aside from the ample opportunity for outdoor landscaping, little consideration is given towards a more biophilic-friendly layout, such as pre-built raised planters, in-built water features for sensory stimuli (while also providing hydration for local wildlife) or a outdoor space for individual refuge.

RE-CONFIGURING:

Improving Our Building Stock

Living Area

The existing floorplan allocates three individual social spaces; the living room, lounge room and alfresco. This is excessive and could be put to better use. The living room is a large-volume area, which creates a light vacuum.

The living room can be re-configured to feature an auxiliary feature, such as an internal garden space. This would better connect the occupants with the outside, as well as provide passive cooling via transpiration and allow more light to reach the inner recesses of the living area.

Passive Cooling

With minimal foliage and single-glazed windows, the west side of the property will receive full sun during the summer month, causing the house to heat up very easily.

Planting deciduous trees on the west-most garden would provide natural dappled light in summer, while shedding their leaves for the cooler winter months. Double-glazed windows would provide further insulation all-year round, retaining the desired internal temperature.

Outdoor Spaces

Currently, the home and land package offers an over-use of paving and basic landscaping surrounding property, which doesn't provide any sustainable benefits to the house.

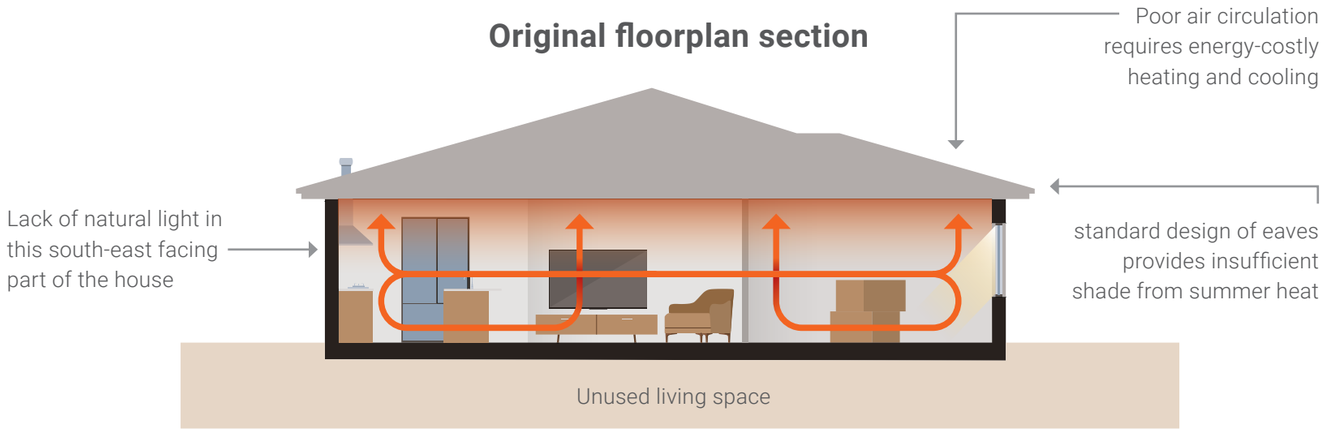
Some paving and grass spaces could be replaced with nutrient-rich mulch, providing plants and trees with much needed water retention during summer. A vegetable garden would also make better use of some grass areas, encouraging urban farming. This could all be coupled with the installation of a rainwater system and grey water recycling systems, which could provide the garden with an off-grid water source.

Ventilation and Lighting

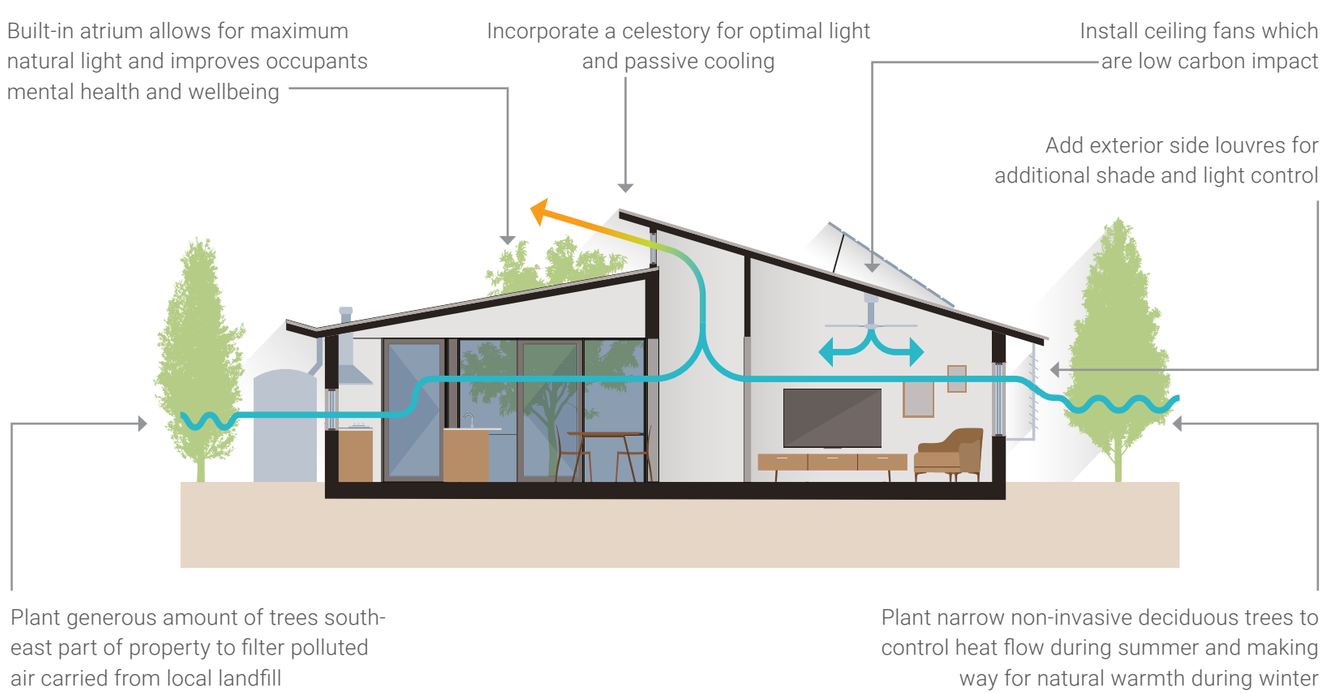
The existing floorplan offers no natural ventilation or lighting in the kitchen or living areas.

A clerestory would create natural airflow, allowing hot air to rise and exit through the roof. By adding windows in the kitchen, more natural ventilation could be introduced allowing air to cycle through the living area and back out through the clerestory. This would improve overall air quality and natural cool the main living space.

Original floorplan section



Reconfigured floorplan section



Total area = 232 m²

South-facing bedroom with small window receives little to no light

Small, cramped bedrooms and wet areas make uncomfortable zones for growing children

Doubling up on living areas causes unused and wasted space;

West facing windows blasted by full sun and heat in summer

Large volume area creates a light vacuum in this area, poor air circulation and contributes to high energy usage for heating and cooling

The open plan results in too much noise coming from the kitchen and dining

Insufficient natural light & ventilation

Over-use of paving surrounding property instead of planting greens

Single glazing windows causes poor insulation from daylight heat

BEFORE

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N

SCALE 1:100

Plant a vegetable garden

Replace grass with nutrient-rich mulch to keep vegetation cool and retain moisture during summer

Install a heat pump to maximise efficient heating during winter

Convert original living room into an internal garden

Allocated additional windows to improve ventilation

Install a rainwater collection system and recycling grey water for potable and non-potable purposes

Install renewable energy sources

Plant deciduous trees which make way for sunlight during cold months

AFTER

ANALYTICAL ARCHITECTURAL DRAWINGS:

CONCLUSION:

Barriers to Net Zero and Opportunities

The Oriana house and land package offers prospective buyers several benefits for a modest-sized family home, such as some electrical appliances, and ducted air-conditioning, and boasts generous communal spaces as well as effective zoning for work-from-home purposes. However it offers very little in the way of Net-Zero solutions, and missed opportunities for the occupants to combat climate change positively. A full transition towards an electric heating system, coupled with a better passive layout, or even upgrades to its thermal insulation would drastically reduce the amount of operational carbon this house would generate over its lifespan. Applying biophilic principles throughout the design of the property would also go a long way towards enhancing the occupants' relationship with the outdoors and improving ecological harmony.

BIBLIOGRAPHY:

Sources and References

Arrigoni, Alessandro, Pelosato Renato, Melià Paco, Ruggieri Gianluca, Sabbadini Sergio, and Giovanni Dotelli. 2017. "Life Cycle Assessment of Natural Building Materials: The Role of Carbonation, Mixture Components and Transport in the Environmental Impacts of Hempcrete blocks." *Journal of Cleaner Production* 149: 1051-1061. https://doi.org/10.1016/j.jclepro.2017.02.161.

BOM. 2024. "Greater Perth in 2023." Bureau of Meteorolgy. Accessed 17th August 2024. http://www.bom.gov.au/climate/current/annual/wa/perth.shtml

Brookes, Sarah, and Hamish Hastie. 2023. "The Good, The Bad and the Ugly: What's It Like Living on Perth's Urban Fringe?." WA Today. 9 November 2023. Accessed 17th August 2024. https://www.watoday.com.au/national/western-australia/how-s-the-serenity-but-where-s-the-amenity-life-at-perth-s-edge-20230919-p5e5z4.html.

Cao, Lilly. 2020. "Urgent Issue: 10 Strategies to Decarbonize Architecture." ArchDaily. Accessed 14th August 2024. https://www.archdaily.com/938866/urgent-issue-10-strategies-to-decarbonize-architecture> ISSN 0719-8884/.

Carbon Cure. 2023. "Checking In On GHG Emissions Reductions and Removals in Construction." Accessed 12th August 2024. https://www.carboncure.com/concrete-corner/the-construction-industrys-role-in-achieving-net-zero-ghg-emissions-globally/.

ECA. 2023. Energy Consumers Australia. https://energyconsumersaustralia.com.au/wp-content/uploads/Stepping-Up-Report-Final.pdf

HIA. 2019. Housing Industry Association. "Elements of the Life Cycle Assessment." Housing Industry Association Limited. Accessed 14th August 2024. https://hia.com.au/resources-and-advice/sustainable-homes/sustainable-home-design/articles/elements-of-the-life-cycle-assessment#:~:text=A%20Life%20Cycle%20Assessment%20(LCA,of%20when%20considering%20an%20assessment.

KPMG. 2023. "Tackling embodied carbon within Australia's construction and infrastructure sector." Accessed 13th August 2024. https://kpmg.com/au/en/home/insights/2023/10/embodied-carbon-management-construction-infrastructure-sector.html/.

Smith, Nick. "Panoramic of Tropical jungle Biome stock photo." Photograph. iStock Photo. February 2014. https://www.istockphoto.com/photo/panoramic-of-tropical-jungle-biome-gm468754665-34270996?clarity=false.

Vosper, James. n.d. "Hemp Carbon Storage." Carbon Futures. Accessed 13th August 2024. https://carbonfutures.com.au/hemp-carbon-storage/

WGBCa. 2018. World Green Building Council. https://worldgbc.org/thecommitment/

WGBCb. 2019. World Green Building Council. "Bringing Embodied Carbon Upfront." Accessed 13th August 2024. https://worldgbc.s3.eu-west-2.amazonaws.com/wp-content/uploads/2022/09/22123951/WorldGBC_Bringing_Embodied_Carbon_Upfront.pdf.

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Thank you to Dillon Gorton and Brad Shirvani
for your tutelage. It’s been a privilege.