PASSIVHAUS IN AUSTRALIA

Why these healthy, comfortable and resilient buildings should be our new normal

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Australians have a choice.

We could work, learn and live in buildings that are a delight to occupy. Homes, offices, schools, factories, hospitals, all with exceptional air quality: the air inside is always fresh and clean, no matter the pollution levels outside.

Buildings where the temperature is always in the Goldilocks zone, not too hot or too cold—no matter if it's 45°C or -5°C degrees outside.

Buildings that use tiny amounts of energy to maintain those comfortable indoor temperatures: up to 90% less than those built to the minimum legal standard.

Buildings that are rigorously tested during the design and construction phase, offering owners and occupiers certainty that they will get the building performance they were promised.

This is not an abstract idea. More than 100,000 buildings around the world are built to the Passivhaus standard that delivers all this. It creates better quality, more durable buildings.

Passivhaus starts with the human experience. How can we create buildings that are healthy and comfortable for the people who use them?

Imagine neighbourhoods where people live in detached homes, townhouses or apartment buildings, visit neighbourhood shops, doctors and professional offices, take their kids to child-care or school or attend tertiary education, go to work: and all those buildings were 20-25 degrees inside, everywhere, all the time.

Fuelling climate change

Buildings produce 40% of Australia's total greenhouse gas emissions:

- 23% associated mainly with the energy used to heat and cool buildings,
- embodied carbon in building materials and supply chain emissions account for a further 18%.

In Europe and progressive North American cities, slashing carbon emissions from buildings is a key part of their strategy for carbon neutrality. It doesn't rely on technology not invented yet. *We know how to do this.*

The air is clean and free from allergens. It's quiet even if there's a busy street outside, because ventilation doesn't rely on windows being left open. Many of these buildings are exporting electricity into the grid. When energy is needed to heat or cool the indoor environment, it's a tiny amount that doesn't burden the electricity grid, even during a heatwave or storm.

Imagine that.

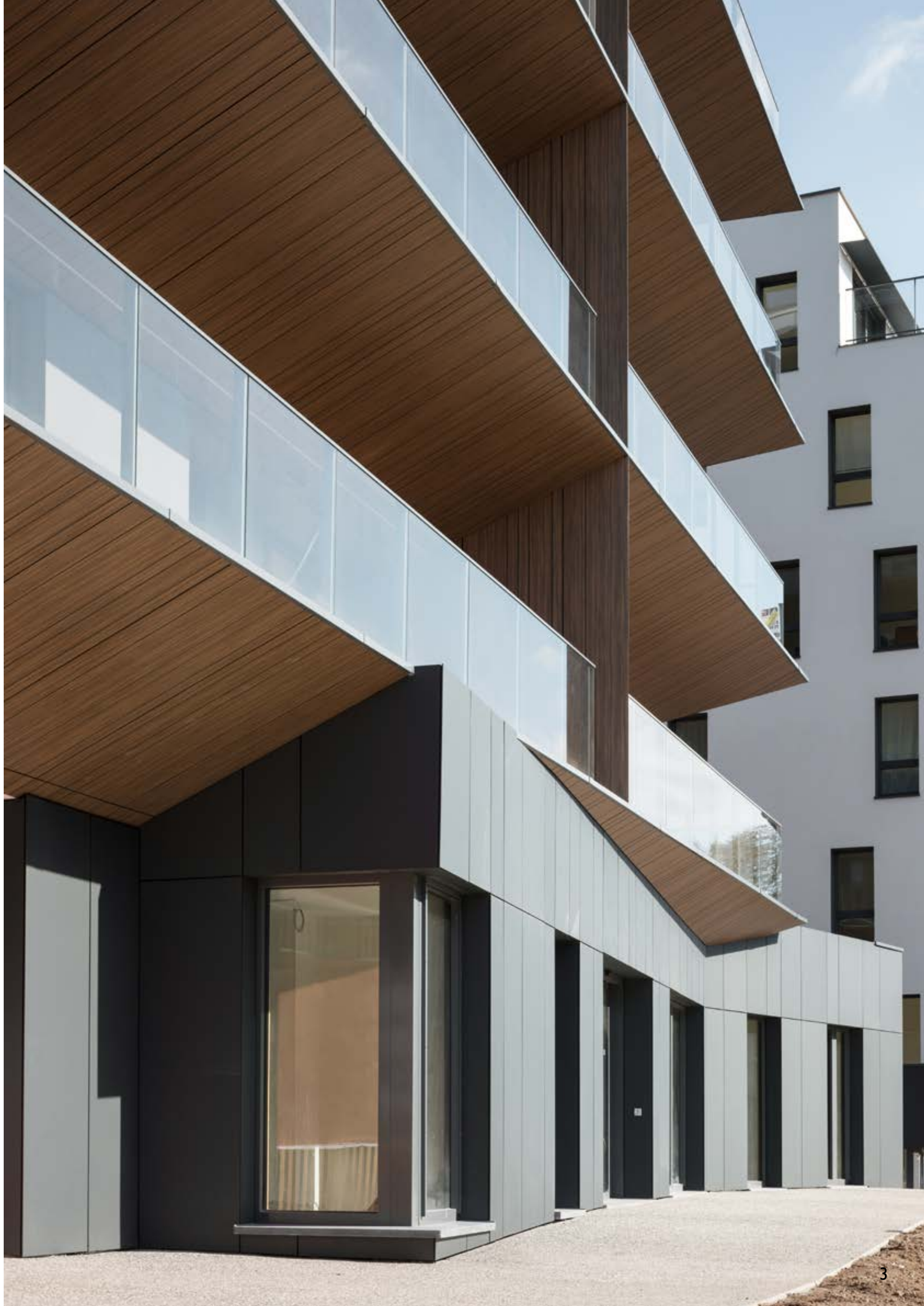
We could all have this—if we prioritise building performance when we design and construct new buildings or renovate existing ones. The rewards are huge.

At an individual level, people would be healthier, happier and more productive, enjoying plenty of fresh air and not stressed by feeling too cold or too hot.

We can expect such buildings, whether owned by families, businesses, not-for-profits or government, to be more durable, need less maintenance, have higher resale values, be easier to lease, and cost much, much less to run.

The collective benefit would be enormous. Fast and wide-scale creation of Certified Passivhaus buildings would vitally contribute to Australia's response to climate change, slashing the CO_2 emissions associated with heating and cooling buildings.

As you'll see in the case studies that follow, Australians are already living in buildings exactly like this.



Twenty-five Certified Passivhaus buildings have been built across the country. They range from homes under 100m² to accomodation for 150 university students, a child care centre, serviced apartments and a museum.

Momentum is gathering. Five years ago, there were just 50 Certified Passivhaus professionals in Australia; now there are over 320. There are architects, consultants, building designers and tradespeople who are qualified to design and build these outstanding buildings.

Australian Passivhaus experts are learning from best practice around the globe, adapting it to our conditions and applying it at speed. We're catching up; and if we have the will we could show the world how to design and build Passivhaus buildings that respond to extremes of both hot and cold.

Any building can be Passivhaus

Passivhaus standards can be applied to any kind of building. Around the world, there are Passivhaus hospitals, aged-care facilities, fire stations, shopping centres, indoor swimming pools, social housing projects, factories, offices and schools. In fact it's easier and cheaper to design larger Passivhaus buildings because of the improved ratio of building perimeter to internal volume. By successfully building single-family homes, we've tackled the hardest projects first.

The business case for commercial Passivhaus buildings is compelling. If there is a premium for building to the Passivhaus standard, the return on investment will likely be swift. Reducing active heating and cooling means simpler and smaller mechanical systems. This dramatically lowers energy consumption and also reduces maintenance costs.

When office ventilation was improved and levels of carbon dioxide and emissions reduced, employees performed 61% better on cognitive tasks compared to the standard office conditions. By further doubling the ventilation in the first setting, cognitive performance more than doubled.

—Harvard and Syracuse University research, 2016

The Passivhaus solution

Passivhaus defined

What's it like being in a Passivhaus building? It's very quiet inside and the temperature is comfortable and constant—everywhere, all the time. The indoor air quality is outstanding thanks to a continuous supply of filtered fresh air. That's good for everyone but especially for occupants with respiratory issues like asthma or those who suffer from seasonal hay fever.

Passivhaus is a freely available standard for extremely energy efficient buildings that are very comfortable to occupy. A Certified Passivhaus building uses no more than 15kWh per square metre of the internal space, per year, for heating and for cooling.

Passivhaus?

aka Passive House (and pronounced the same in any case). The English translation can be slightly confusing. Haus in German means building and any type of building can be built to the Passivhaus standard, not just residential houses.

In this book, when we say Passivhaus, we always mean Certified Passivhaus. Certification guarantees building owners and occupiers that they've got the Passivhaus performance and quality they paid for. Don't settle for anything less.

Getting technical: Key Passivhaus criteria are listed in the appendix.

The standard also sets an upper limit on air leakage (explained on page 18); this stops draughts, cold spots and energy leakage and is essential to achieving an energy efficient building.

A comfortable indoor temperature is also a requirement. Notably, the standard limits overheating as well as a building being too cold (like so many of Australia's freezing 'wooden tents').

In warmer Australian climate zones, Certified Passivhaus buildings typically need little or no active heating. However most Passivhaus homes in Australia have a reverse-cycle air-conditioner, given their energy efficiency and capacity to cool in summer as well as heat in winter if required.

A Passivhaus is so energy efficient that the cost to heat or cool an entire 100m^2 house for a year is scarcely more than the energy used by a late-model fridge.

Cooling would currently only be needed on the very hottest days of a year. But temperatures are rising and heatwaves are becoming more severe. Putting in place the means to easily and cheaply keep cool is a smart way to future proof a home.

FAQ #1

Q. *How much extra will it cost?*

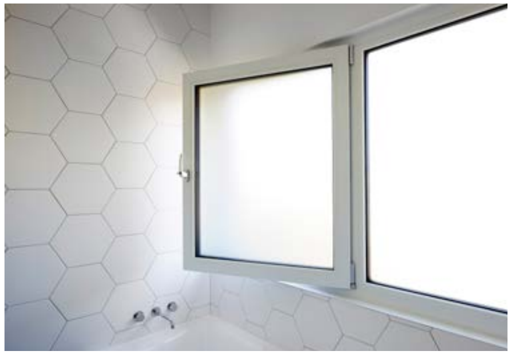
A. Not much. In fact, smart design can deliver Certified Passivhaus performance for the same or even less than an equivalent house built to the Building Code-minimum standard.

When talking about cost premiums, we have to ask compared to what? Compared to another architecturally designed, custom-built home, a Certified Passivhaus may cost 5-10% more. If thoughtfully designed, the cost premium can disappear altogether.

However, most new houses in Australia are built by volume-builders, designed to be both big and cheap. In this section of the market, a Certified Passivhaus may cost up to a third more for the same floor area. But that's like comparing a Porsche to a Mazda. They're both cars that will get you from Point A to Point B, but there the comparison ends.

Overseas experience shows that as Passivhaus adoption scales up, cost premiums drop or disappear. A wider range of Passivhaus components, such as doors, windows, tapes and membranes, are now available in Australia and these include more affordable options.

Also the larger the building, the easier it is to get to Passivhaus certification. Overseas, apartment blocks, offices and other large-volume buildings are being built at no extra cost and we can expect the same to happen here in Australia.



uPVC Passivhaus windows

FAQ #2

Q. *Is this just another name for passive solar? That's been around for ages.*

A. Passivhaus and passive solar have some good things in common but don't confuse the two. Passive solar design is a collection of principles to guide design, but it can't guarantee a comfortable or healthy indoor environment or low energy use. Several passive solar principles are incorporated into the Passivhaus methodology, but Passivhaus goes much further.

A Certified Passivhaus designer will use passive solar gain if it is available—and calculate its effect, including it in the overall performance modelling (see pages 19-20). A Passivhaus will be constantly ventilated, whether anyone is home to open windows or not.

Passive solar design relies on a north-facing orientation for controlled solar gains, appropriate shading, natural ventilation and use of thermal mass to temper fluctuations in internal air temperature.

Passive solar isn't feasible in many circumstances, for instance if building medium-density housing on small sites where the house can't face the sun (or if the million-dollar views are to the south).

Passive solar exponents talk about maintaining comfortable average temperatures, but that average can conceal significant and uncomfortable swings in indoor temperature over the course of 24-hours.

There's also an uneasy trade-off between sufficient ventilation and a comfortable indoor temperature. When outside temperatures are too hot or too cold, windows must be closed to keep inside temperatures comfortable—cutting off the flow of fresh air.

A process and a standard

Passivhaus is a process as much as a standard. A Certified Passivhaus building requires thorough documentation and careful planning, from the initial design phase through to the final stage of construction. The quality of the building is independently verified by rigorous on-site testing and a review of project documentation.

There are three key targets: the number of air changes per hour, the amount of energy needed for heating and/or cooling and the building's total consumption of energy.

As well as the original **Passivhaus Classic**, there are three related standards for new buildings plus another for retrofits.

Passivhaus Plus generates the same amount of renewable energy each year that the building uses. That's total energy use, not just energy for heating and cooling. The calculation also accounts for energy storage losses and the energy cost of transmission—it's an honest reckoning of net zero.

Passivhaus Premium goes further and generates as much renewable energy in a year that the building occupants use in their daily lives. It's set at a level to make a fully renewable energy grid work for everyone.

PassivLaneway, page 82.

A **Low Energy Building** is the next best thing to a Passivhaus. They are just as healthy and durable and contain the same elements but aren't quite as air-tight or energy efficient.

EnerPHit is a standard for retrofitting existing buildings. It has a slightly less stringent requirements compared to Passivhaus, in recognition of the logistical challenges of retrofitting older buildings. (Nonetheless, some European refits do achieve the full Passivhaus standard.)

FAQ #3

Q. *Is Passivhaus relevant to Australia, given it was developed in Europe? Their climate is very different from ours.*

A. Short answer: Yes, Passivhaus is relevant in Australia.

It's true that Passivhaus was developed in Europe but the standard is used successfully around the world. There are over 100,000 Passivhaus projects, in climates as diverse as Antarctica and Sri Lanka.

While the Europeans focus on reducing energy used for heating, in Australia we also need to slash the energy needed to keep it cool and dry indoors. Passivhaus is entirely flexible enough to encompass that goal, because it's a performance-based standard: it is a target to reach. It doesn't dictate how to reach that target.

Our vast continent has many different climates. A Passivhaus designer or architect uses modelling software and local climate files to help shape the design. A Passivhaus building in Darwin for instance, requires less insulation and different glazing to achieve the energy consumption target compared to one in Hobart.

Using hard data ensures Australian building owners get all the benefits of a Passivhaus at a cost and complexity that scales to suit their specific local conditions.

Certification instils confidence

All genuine Passivhaus buildings meet the performance targets outlined in the standard. A Certified Passivhaus has been independently verified: it's a mark of assurance and quality. A highly-trained, independent expert (a Passivhaus certifier) confirms that the building has been constructed as designed and will meet the Passivhaus performance targets. Certification means that the completed building meets the performance predictions that were calculated during the design phase.

Certification provides certainty and peace of mind for all involved. The client is assured that they will get the performance they paid for. The designer knows their work will deliver a comfortable, healthy and energy-efficient building. And the construction team can take pride in producing a quality building that will be a pleasure to occupy.

Certification may bring a premium when a Passivhaus is sold, as is happening overseas (in California, sales of single-family homes with third party certification are averaging a 7% premium).

However, note that Passivhaus is not a trademark so anyone can use it. Beware vague references to "high-performance" or even the phrase "using Passive House principles". Talk is cheap. What evidence backs up those assertions? Adding better-performing components to an ordinary build without any energy modelling can produce unforeseen and very uncomfortable results.

Flexibility

A Passivhaus building can be any size or style, and use a range of different techniques and materials. Certified Passivhaus buildings in Australasia have been variously built with insulated concrete forms (ICF), cross-laminated timber (CLT), Structural Insulated Panels (SIP), straw, in-situ concrete and timber framing and cladding. Client requirements and the designer's preferences can all be accommodated, whether that's a high-end architectural statement or a house that seamlessly blends into a new suburban development.

Collaborating, not competing

Passivhaus gets universal fundamentals right: the ideal conditions for human comfort and health along with extraordinary energy efficiency. If desired, Passivhaus will work alongside other sustainable or specialist certifications. Designers or clients might choose such things as:

- low embodied carbon
- locally sourced materials
- rainwater harvesting
- low-maintenance finishes
- use of recycled materials
- natural building materials
- extensive natural lighting
- designing for ageing in place
- use of prefabricated components
- greater bushfire safety and
- increased durability.

For instance, a building could meet both Passivhaus and Living Building Challenge targets. Such a home would excel in terms of building efficiency, human health and produce net zero water and waste.

Likewise, Green Star has a 'crosswalk' for projects targeting twin certification, automatically providing many Green Star credits for projects that obtain Passivhaus certification.

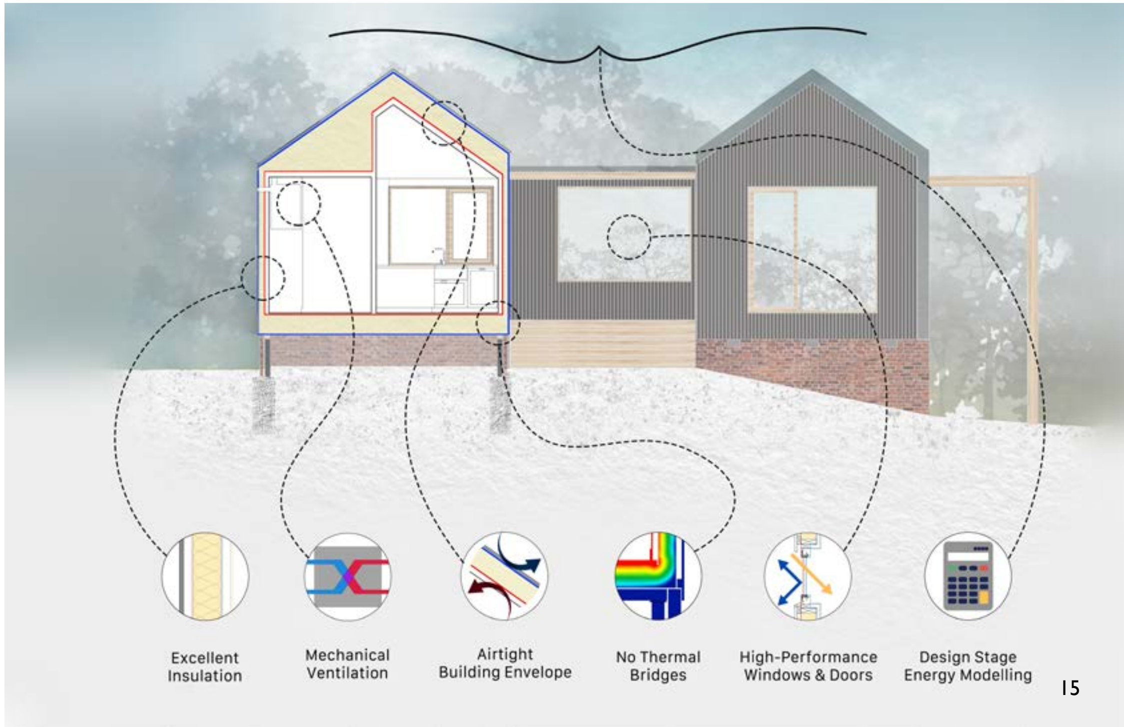
Many of the professionals in the Passivhaus community are proud signatories of the international Construction Declares collaborative movements that have acknowledged we are facing a climate and biodiversity emergency (Architects Declare, Engineers Declare, Builders Declare and Planners Declare).

Passivhaus certification is recognised as being a leading way to take action to meet the declaration.

–Talina Edwards, Architects Declare coordinator, Architect and Certified Passive House Designer

What makes a Certified Passivhaus

Certified Passivhaus buildings can be distinguished by the following elements. They'll be combined in different ways to suit the circumstances, such as the specific climate, aspect, shading, other site opportunities or constraints and client preferences.



Excellent insulation

A Certified Passivhaus building has continuous insulation surrounding its perimeter. The amount and location of the insulation varies depending on the design, the materials used and the building's specific climate zone (this takes into account average temperatures, altitude and whether the site is inland or coastal).

No thermal bridges

Thermal bridges are pathways for temperature to travel in and out of a building. They contribute to significant indoor temperature fluctuations and can also lead to moisture and mould problems.

Passivhaus design minimises or eliminates thermal bridges. This is a key part of why the temperature in a Passivhaus stays within a perfectly comfortable range, no matter what the weather outside.

In conventional buildings significant thermal bridges are typically created where the foundation meets the walls, the walls meet the ceiling and roof and where conductive material such as steel penetrates the exterior of the building.

Passivhaus uses special materials and construction techniques to create 'thermal breaks' at unavoidable junctions or penetrations.

The exterior doors in a Passivhaus are thicker than a regular door and seal to their frame for thermal and acoustic insulation. They are an integral part of the airtight building envelope.

High-performance windows and doors

Even the very best windows let more energy pass through compared to a wall and this is why you'll find high-quality, highly energy-efficient doors and windows in a Certified Passivhaus. Double-glazing is standard, with triple-glazing sometimes used due to specific climate or comfort requirements.

Glazing performance is typically improved in a Passivhaus by using high-quality spacers between the glass panes, glass coatings and argon fill.

Window and door frames are another important consideration. Ordinary windows and doors with

FAQ #4

Q. *Can I open the windows in a Passivhaus?*

A. Absolutely you can. If you want indoor-outdoor flow, to keep an eye on the kids, or the sound of birdsong or ocean to drift through the house, go right ahead and throw open your windows and doors.

But if it's very hot or cold outside, or you have neighbours who mow their lawns at 8am on Sunday or whose kids scream around right outside your home office window—or you live with the roar of traffic or under a flight path—you might appreciate how quiet it is inside a Passivhaus when the windows are closed. Double- or triple-glazing offers significant acoustic as well as thermal insulation.

You don't need to open windows or doors because your home is taking care of ventilation for you, providing fresh, filtered air at a constant temperature and comfortable level of relative humidity. Open windows because you want to, not because you have to.

Bellbrae retrofit, page 48.

thermally-conductive steel or aluminium frames readily let heat in or out. When it's colder outside than inside, the thermal bridge will cause condensation to form on the interior surface of the glass and the window frame. This can lead to mould, air quality issues and can damage the frames and surrounding wall.

In a Certified Passivhaus, the high-performance glass and door and window frames stay at the same comfortable temperature as the air inside the building so condensation and mould are avoided. Heat loss is reduced by about three-quarters compared to thermally-conductive frames.

Airtight building envelope

A Passivhaus has an uninterrupted building envelope that is airtight. This innovation plays a crucial part in ensuring Passivhaus buildings need so little energy to heat or cool. The airtight layer prevents unwanted heat transfer, draughts and cold spots. The internal temperature is maintained by the high levels of insulation. Vapour control and the airtightness layer combine with appropriate insulation to prevent moisture damage to the building structure. This is key to Passivhaus durability.

Attention to detail is needed during construction to make sure the airtight layer is installed correctly.

FAQ #5

Q. *I heard that a Passivhaus is airtight, that doesn't sound healthy. I don't want to live in a sealed box!*

A. Airtight isn't the same as sealed. We love fresh air; and it's good for buildings too.

Passivhaus buildings are actually much healthier than Code-minimum buildings. Ventilating a conventionally-built house relies on occupants opening doors and windows, using extraction fans (if fitted)—or on air leaking in from the sub-floor or roof space. That air can be musty, damp or even mouldy.

A certified Passivhaus is airing itself, thanks to a mechanical ventilation system with heat recovery (MVHR). This small but mighty unit acts as the lungs of your home; it's constantly removing stale, damp air from bathrooms and the kitchen and delivering fresh, filtered air to living rooms and bedrooms. And it's happening continually, without any effort or attention on your part.

Mechanical ventilation

Clean fresh air is great and it's guaranteed in a Passivhaus, thanks to a small continuous mechanical ventilation system. It delivers fresh air (filtered of dust, pollen and other pollutants) and extracts stale, moist air, all at a carefully calibrated level.

A clever heat-exchange system can recover up to 95% of the energy in the stale air being expelled. This is used to warm the incoming air if it's cold outside (and cool the air when it's hot). This prevents unpleasant draughts and ensures the temperature is the same everywhere in the house.

The mechanical ventilation system with heat recovery (MVHR) for a single-family home is typically only the size of a clothes dryer and is often installed in a cupboard in the laundry or hallway. The ducting is concealed in the ceiling with small vents in each room. The system is very quiet and uses less energy than a 50w halogen light bulb.

In areas with high outdoor air pollution or where people suffer from hayfever, allergies or asthma, the filters in the MVHR system can be upgraded. Specialist filters will remove even very small particulate matter, such as is found in bushfire haze.

Energy modelling at design stage

Great performing buildings don't come about by accident or by simply combining these elements, as if mixing ingredients for a cake. Certified Passivhaus buildings are by design greater than the sum of all their parts: they work because of how all those parts interact with each other. Passivhaus designers use a software suite called the Passive House Planning Package (PHPP) to model the different components and the ways they interact, thus accurately predicting overall building performance.

You can't see the PHPP energy modelling when you walk into a Passivhaus building, but you experience it—because the data it relies on and the decisions it guides have influenced every aspect of that building's design and construction.

PHPP energy modelling is the single most important distinguishing feature of a Passivhaus building. It is done during the design phase, modifying the values for relevant elements until desired performance levels are reached.

That is why the Passivhaus standard is both so flexible and predictably reliable. Passivhaus buildings can accommodate local conditions, all manner of site constraints and not least, client preferences. Say a client in Canberra wants a glazed wall to a private south-facing courtyard. The resulting heat loss in winter can be compensated by, for example, boosting insulation levels in the slab or roof or increasing the performance of the windows.

> *"In many ways, Passivhaus is almost impossible to explain. It has to be experienced. If you have any opportunity to visit a Passivhaus, grasp that opportunity. Even better, if you can, stay for a night or a weekend. You won't want to leave and you won't readily forget it."*
>
> —Clare Parry, consulting engineer, founding director of APHA

If the building is constructed according to the design specifications, then it is certain to perform as the model predicted.

Without PHPP energy modelling, there is no way to accurately predict in advance how a building will perform. Getting it wrong can be a disaster: in New Zealand, there have been unfortunate examples of well-intentioned but uninformed architects specifying high-performance components, without understanding their interactions and combined effects. It's resulted in at least one home that overheats so badly in summer it is virtually uninhabitable.

As building physicist and Passivhaus certifier Jason Quinn has argued:

"When we do the maths first, we can modify the design and immediately see how that impacts performance in PHPP. [Vary] the insulation, factor in landscaping that provides summer shade, take into account occupant behaviour … modelling different scenarios is so cheap and simple compared to having builders re-do work on site or leaving disappointed clients to install enormous air-conditioning units in order to survive the summer."

Depth of eaves, shading from neighbouring buildings and trees, orientation: many factors are taken into account by PHPP modelling.

East 37th Street, Vancouver by Lanefab

Choose to build better

Australia's National Construction Code (NCC) urgently needs improvement. We need standards that reliably deliver higher performing buildings, for the sake of people and the planet. The NCC should reflect best practice building science, ensure people's legitimate expectations of thermal comfort and indoor air quality are met and prioritise energy efficiency so that carbon emissions from buildings are significantly reduced. Passivhaus is the end goal the NCC should move towards.

Passivhaus is built on 30 years of rigorous building science and the practical experience arising from tens of thousands of successful building projects around the world.

Australia needn't fear the burden of blazing a trail to substantially better buildings. That work has already been done—we can look to and learn from multiple successful examples overseas. Take Vancouver, which has the greenest building code in North America. Since May 2017, the City requires all rezoning applications to meet low emissions building standards. This has driven a sharp increase in buildings obtaining Passivhaus certification as a way to meet the City's energy performance requirements. Its research shows that Passivhaus certification costs approximately 2-7% more to build but reduces operational costs by 20-25% compared to a minimum-standard house. (The building regulations in Vancouver are a much higher standard than

Australia's. Their energy savings are reduced because of this higher baseline. We would see greater efficiency gains in this country).

This uptake is also creating highly-skilled jobs. For example, the BC Passive House Factory manufactures a prefab panelised system that meets Passivhaus requirements, the first in Canada to do this.

New York City is going even further; back in 2014, its mayor committed to Passivhaus as a central pillar of its plan to dramatically reduce greenhouse gas emissions from the building and construction sector. More efficient buildings will contribute nearly two-thirds of planned emissions reductions.

New York City committed to investing in 150 to 200 high-value projects in its own buildings every year for 10 years, with the aim to prompt the private sector to follow its example. Such commitments are significant as they build experience, capacity and confidence in Passivhaus methodologies across the design and construction sectors.

There are now hundreds of Passivhaus buildings in New York City: new apartment buildings, social and affordable housing projects, student accommodation and also heritage refurbishments.

China has embraced the Passivhaus standard as a key element of its zero energy targets. As of 2019, there were over 70 national or provincial policies

"Don't wait for politicians to act. We can make better choices right now. I decided on a Certified Passivhaus when I began planning a new house in Sydney for me and my family. I knew it might cost more to build but rather than compromise, I saved for a bit longer and increased the project budget.

I have no regrets. I'll have a house that is actually worth the money it cost to build—and it's doing something tangible to address climate change."

—Chris Nunn, Chair, AustralianPassive House Association

Attendees at the 23rd International Passive House Conference tour Passivhaus developments at Gaobeidian Railway City in Hebei province.

to incentivise Certified Passivhaus construction, which have delivered more than 200 demonstration projects. China hosted the 23rd International Passive House Conference and it showcased the huge pipeline of projects planned: over 10 million square metres by the end of 2020.

At the time of writing, they had achieved:

- Thirty buildings certified totalling 370,000m² in Gaobeidian, with a further six million square metres underway.
- In Qingdao, 400,000m² of Certified Passivhaus buildings constructed, with a further one million square metres planned.
- In Beijing, 173 Passivhaus buildings certified, with another million square metres to be built.

In addition to building projects, China has also developed Passivhaus research and training institutes and advanced manufacturing facilities to produce Certified Passivhaus components.

Growing in Australia

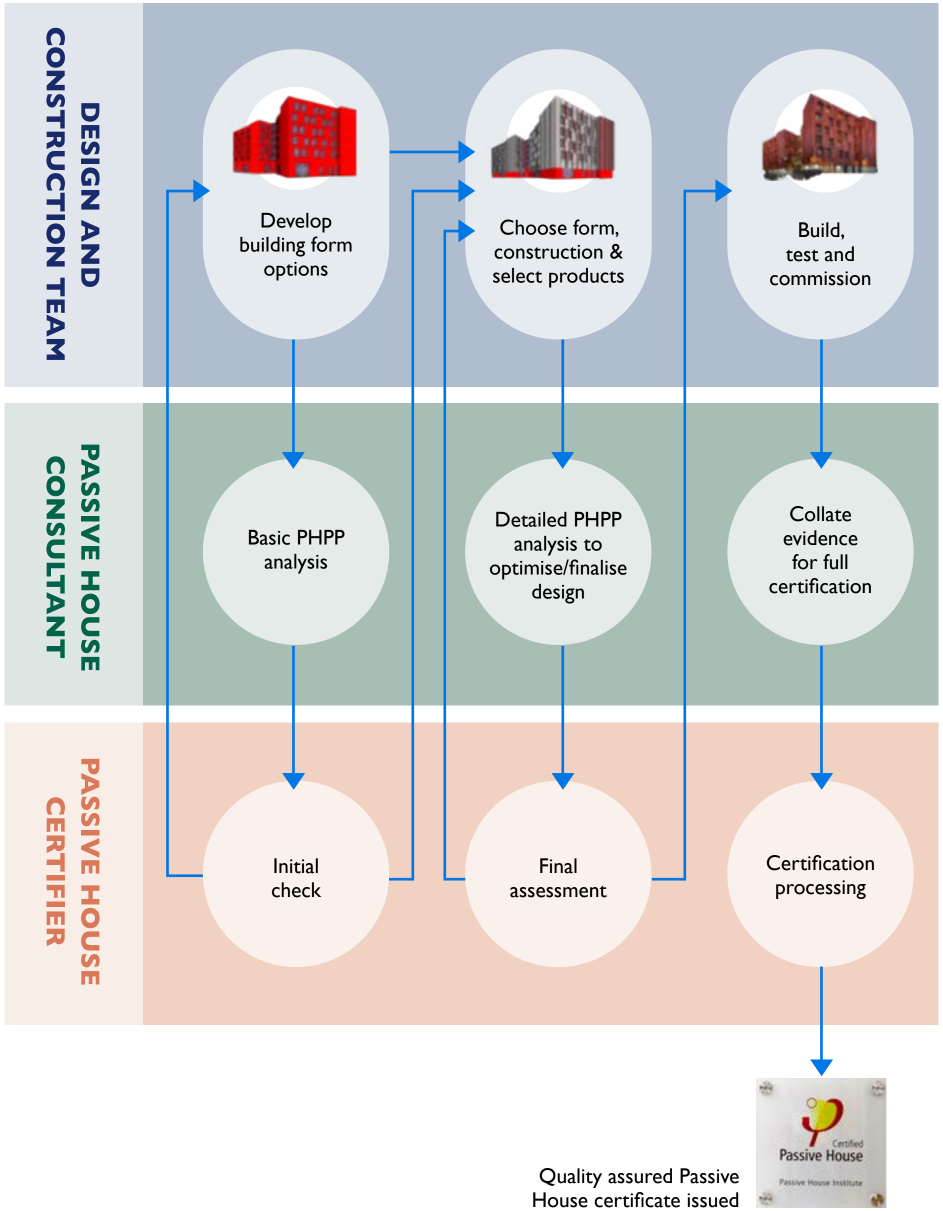
When they said the temperature didn't drop below 16 degrees in winter, I didn't realise they meant inside!"

—Canadian immigrant to Sydney

The first clients specifying Passivhaus in Australia were mostly people who had lived overseas and were used to far better standards of comfort and efficiency than even newly built Australian homes offered. But this stage of early adoption is over. The Australian Passive House Association (APHA) is actively educating and informing the design and construction industries, including building owners. As of September 2020, there are 328 members of APHA, including 167 certified Passivhaus designers or consultants. Training courses are offered around the country. Passivhaus buildings have been built and successfully certified in five states and territories.

Excellent designs can be entrusted to building firms that are quickly amassing experience in constructing Passivhaus details. The number of Certified Passivhaus Tradespersons in Australia is fast-growing. Certification is proof they are trained in the specifics of constructing these high-performance buildings.

Passivhaus Design and Certification Process



Fine design needs a great builder

The builder's attention to detail and quality matters. While all builders know how to put up sarking, the high performance control layers used in Passivhaus construction require new or better quality techniques.

Builders must also have an understanding of thermal bridging and how to avoid inadvertently creating them.

Getting what you paid for

Certifying a Passivhaus provides an independent guarantee that the project will perform as expected. The actual certification costs are not expensive, just 0.5% or less of the cost of a Passivhaus build.

It happens in two phases that parallel the building design process. The certifier will first review the design and identify any potential issues. If details need to be changed or added, the best time to do that is at the planning stage, not on the construction site.

During construction, once the air control layer is in place but before any internal finishing, a blower-door test is carried out on-site. If the level of air changes is higher than the Passivhaus standard allows, the leaks can be most easily identified and resolved at this stage.

Secondly, a final blower door test is carried out when construction is complete. This offers final verification that the project meets the air changes per hour (ACH) standard.

Detailed documentation must be submitted to the certifier so that he or she can confirm the building was built the way it was designed. This includes photographs, invoices and specification sheets for all the products used. It ensures there were no unauthorised product substitutions and components were correctly installed.

Once approved by the certifier, the project is reviewed by the international Passive House Institute (PHI), which then issues a certificate and recognition plaque and registers the building on the international PHI database.

Internationally, independent verification of building performance is shown to increase resale value and we can expect this to happen in Australia as more people understand the benefits of living in a Passivhaus. (However, to-date Australian Passivhaus homes have not been offered for sale; their owners can't imagine living anywhere else.)

"We need homes that are healthy for our people to live in. But we also need buildings that demand less from the planet."

Talina Edwards, Australian Architects Declare, *au.architectsdeclare.com*

Combating climate change

The electricity and gas used for heating and cooling our buildings is responsible for a quarter of Australia's greenhouse gas emissions.

Increasing the capacity of the national grid requires significant capital investment and increases Australia's carbon emissions. We can't afford to do either.

In climates like ours where energy is needed to cool as well as heat, distributed solar power generation makes even more sense. Cooling demand is highest during the day when the sun is shining, exactly when photovoltaic generation is also peaking.

Improving Australia's buildings has the potential to reduce demand for fossil fuel-derived energy; it's a pathway to mitigate climate change. We already have the tools and the expertise to build radically efficient buildings. *We can do this.*

Many countries are focusing on the built environment as a way to meet their carbon emission targets. Germany, Sweden, the United Kingdom, as well as the examples discussed above, are focused on reducing the energy consumption of residential, commercial and public buildings.

The window for taking significant action to combat climate change is closing and radical change is urgently needed. Passivhaus design encourages systems thinking and offers tools and methods for rigorous, evidence-based decisions about new construction and retrofitting existing buildings. We can build better buildings; indeed, we must.

Creating resilience

Keeping cool
In 2018, Australia earned the dubious title of "hottest place on earth", as temperatures topped 45°C in NSW, Queensland, Victoria and South Australia. The year that followed was the hottest and driest ever recorded. The effects have been far-reaching and for many, life-changing.

Climate change is making itself felt already by more extremes in weather: highs, lows, storms, droughts. We urgently need resilient buildings and other infrastructure that can keep functioning despite these temperature extremes.

Heatwaves in recent years have underscored the vulnerability of Australia's electricity grid. As temperatures rise to levels dangerous for people's health, air-conditioning use increases, overloading the grid and causing wholesale energy prices to soar. (And right as demand spikes, the heat reduces the amount of energy that can be carried by the transmission wires.) A Passivhaus building is safer and more comfortable to occupy during heatwaves, requiring up to 90% less energy to keep cool compared to a conventional building. The same is true in a power outage during a winter storm that brings extreme low temperatures: inside a Certified Passivhaus building, it will stay warmer for longer. That's good for the people who live, learn or work there, but good for the wider community too. If Passivhaus were adopted at scale, the demand on the electricity grid would fall.

Bushfire resilience
The fire danger across Australia in 2019 was the highest it's ever been since 1950, when national records began. The horrific fire season in 2019/2020 focused Australians' minds like never before on the need to plan for bushfire emergencies. The fires were devastating for those directly in their path while millions more people were impacted for weeks by the air pollution caused from bushfire smoke.

Passivhaus buildings are a safer environment when the outside air is full of smoke, dust or other pollution. Mechanical ventilation with upgraded HEPA or ULPA filters can remove most bushfire smoke particulates as well as other pollutants and dust, keeping indoor air quality high.

Adopting Passivhaus at scale

> **We call on governments and regulators at all levels to introduce step-change improvements to the National Construction Code that first encourage and then ultimately require Australian buildings to reach Passivhaus levels of health, comfort and energy efficiency.**

Beware

Tinkering around with small building upgrades may be worse than doing nothing. It risks creating what climate change scientist Diana Ürge-Vorsatz calls "the lock-in effect".

Consider a building owner who invests in an obvious improvement like upgrading windows. Double-glazing in ordinary aluminium frames will perform better than what they replace but fall far short of what is possible: thermally broken frames and double-glazing with low-e coating, warm edge spacers and argon fill. The cheap frames will conduct heat, creating condensation and very likely mould. Yet the money already spent on new windows will create a significant obstacle to further upgrading them for optimum performance and efficiency.

Meanwhile, what else can be done to swiftly bring about broader adoption of the Passivhaus standard in Australia?

Homeowners: if you are contemplating a new build or a major renovation, make better energy efficiency and comfort levels part of your brief. Choose architects or building designers with Passivhaus experience or ask them to bring someone qualified onto the design team.

See the tips for getting Passivhaus performance without blowing out your budget (page 110) if your house will be constructed by a volume builder.

Major renovations or additions are an opportunity to improve the performance of the whole house. Value function as well as form; and factor in


Kyneton retrofit, page 98.

"Passivhaus gets the fundamentals right. It's not business-as-usual with some 'eco-bling' bolted on. It's a system founded on three decades of proven scientific evidence. These are buildings that work."

Andy Marlow, Architect, Envirotecture & APHA board member

the ongoing energy savings realised by a more efficient home. (Plus there are some things money can't buy, like the relief felt when your asthma improves or your kids don't get sick so often over winter.)

If you're buying an existing house or apartment, ask for evidence of insulation values and other better-than-Code construction materials.

Take a long-term view of costs: weigh up not just the purchase price of your new home, but the running costs over 10 or 15 years, including reduced maintenance and repairs. Remember a Passivhaus can reduce heating and cooling bills by as much as 90%.

Policy makers and NGOs: Advocate for improved building regulations that require or reward Passivhaus levels of performance (remember, it's more than just high-performance components; there has to be proper energy modelling at design stage—see pages 19-20). Talk about the benefits for people that flow from living in buildings that stay at comfortable temperatures without needing much or any heating or cooling and that are dry and free from mould.

Owners of social housing projects and aged care facilities: social housing tenants and the elderly are some of the most vulnerable members of Australian society. They deserve and need accommodation that is well-ventilated and stays comfortable and healthy without expensive heating or cooling bills.

St. Loyes Extra Care Scheme, Exeter

The City of Exeter in the UK has built over a hundred Certified Passivhaus social housing units since 2011, which are now built at no extra cost compared to conventional construction. The City currently has other Passivhaus projects in the pipeline, including council offices, supported independent living for the elderly and a public swimming pool.

Developers and designers: Expect initial resistance from clients who will likely focus on how much more Passivhaus performance will cost.

Talk to homeowners about the benefits for their family: fresh filtered air for kids with asthma, more acoustic privacy in dense neighbourhoods, slashing running costs for heating and cooling, comfortable temperatures right throughout the house (not just those rooms with an air conditioner), more resilient in emergencies and potentially higher resale value.

Talk to commercial clients about the operational costs over the lifetime of the building and how Passivhaus performance will slash the cost of heating and cooling the building. Raise the spectre of stranded assets. Explain how they can expect a Certified Passivhaus office block, factory, showroom etc to be easier to lease, especially as more companies report on their triple bottom line or seek to offset their carbon emissions. Any company that values the health and wellbeing of their staff or customers needs to understand the benefits that come from working or studying in a Passivhaus environment.

Read more: Google "Passivhaus: What's it worth? Envirotecture" for a report on costing Sydney's first Certified Passivhaus.

In either case, educate yourself about how to optimise designs for Passivhaus performance without increasing the project cost: a simple rectangular shape, careful design of glazing and shading placement that limits overheating or unwanted heat loss, early consideration and mitigation of potential thermal bridges and optimising materials to minimise construction waste and build time.

Government: Better performing buildings make for healthier people and less burden—on the health system and also the energy grid.

People are more comfortable, productive and healthy (and less stressed) when they live, work or study in an indoor environment where the air is fresh and the temperatures are comfortable all year round.

Winter cold is actually responsible for more deaths than heatwaves: 1 in 15 deaths (6.5%) in Australia are attributed to cold weather, compared to 0.5% for hot weather. Cold temperatures increase blood pressure and other significant cardiovascular risk factors, which can trigger strokes and heart attacks.

Remarkably, more people die in Australia from the cold than in Sweden. Australia's death rate due to cold weather (6.5%) is almost double that of Sweden's (3.9%), and this is largely due to the poor quality of our homes.

The very old and very young are more vulnerable; WHO guidelines call for winter indoor temperatures between 18-21 degrees when babies and the elderly are present. The health effects of a poor indoor environment are particularly severe for people who cannot afford large power bills and who will avoid running heaters or air-conditioning—even during extremes of hot and cold. The consequences of poor quality buildings disproportionately affect the least well-off and most vulnerable people in our society, which just isn't fair.

Legend

Heating (or Cooling) Demand: This is the amount of energy required to keep the home within the acceptable, comfortable temperature range, expressed as the amount of kilowatt hours per square metre per year.

Heating (or Cooling) Load: The power used by an appliance of sufficient size to maintain the comfortable temperature on the coldest (or hottest) days. (Note this is expressed in watts, 1/1000th of a kW.)

Frequency of Overheating: A certified Passivhaus does not overheat—defined as 25°C or above—for more than 10% of the time. The overheating percentage is calculated in PHPP.

TFA: Treated floor area is a measure of the useful floor area inside the home. It includes the roof and slab area and excludes stairways and wall thickness (both exterior and interior).

Form Factor: A ratio arrived at by dividing the total external surface area of the thermal envelope by the treated floor area. A multi-storey building will have a lower form factor than a single-storey dwelling. A simple shape like a square or rectangle will also have a lower form factor than a more complex shape. The lower the number, the less insulation needed in the same climate.

Air leakage: A Certified Passivhaus must come in under 0.6 air changes per hour (ACH) at 50Pa (a measure of air pressure, equivalent to a moderately windy day).

PER demand: Primary Energy Renewable demand measures total energy usage in the house (not just energy for heating and cooling) and includes (a) the power lost to the grid as power is carried from the power station to the home and (b) storage losses (as if the grid were fully renewable). Excess solar power generated in summer needs to be stored for winter use. PER demand is expressed on a per square metre basis per year.

PE demand: Primary Energy demand has been superseded by PER demand but you'll see it referenced in older case studies. It measures total energy usage in the house (not just energy for heating and cooling) and includes the power lost to the grid as electricity is carried from the power station to the home and the losses in converting non-renewable fuels to electricity. Buildings were required to be below 120 kWh/m^2/year.

RE generation: measures the total amount of renewable energy generated onsite. This threshold is relevant to Passivhaus Plus and Passivhaus Premium builds (see page 10).

Details of even more Australian Passivhaus buildings can be found at www.passivehouse-database.org (Advanced Search→Australia)

Australia's first certified Passivhaus buildings

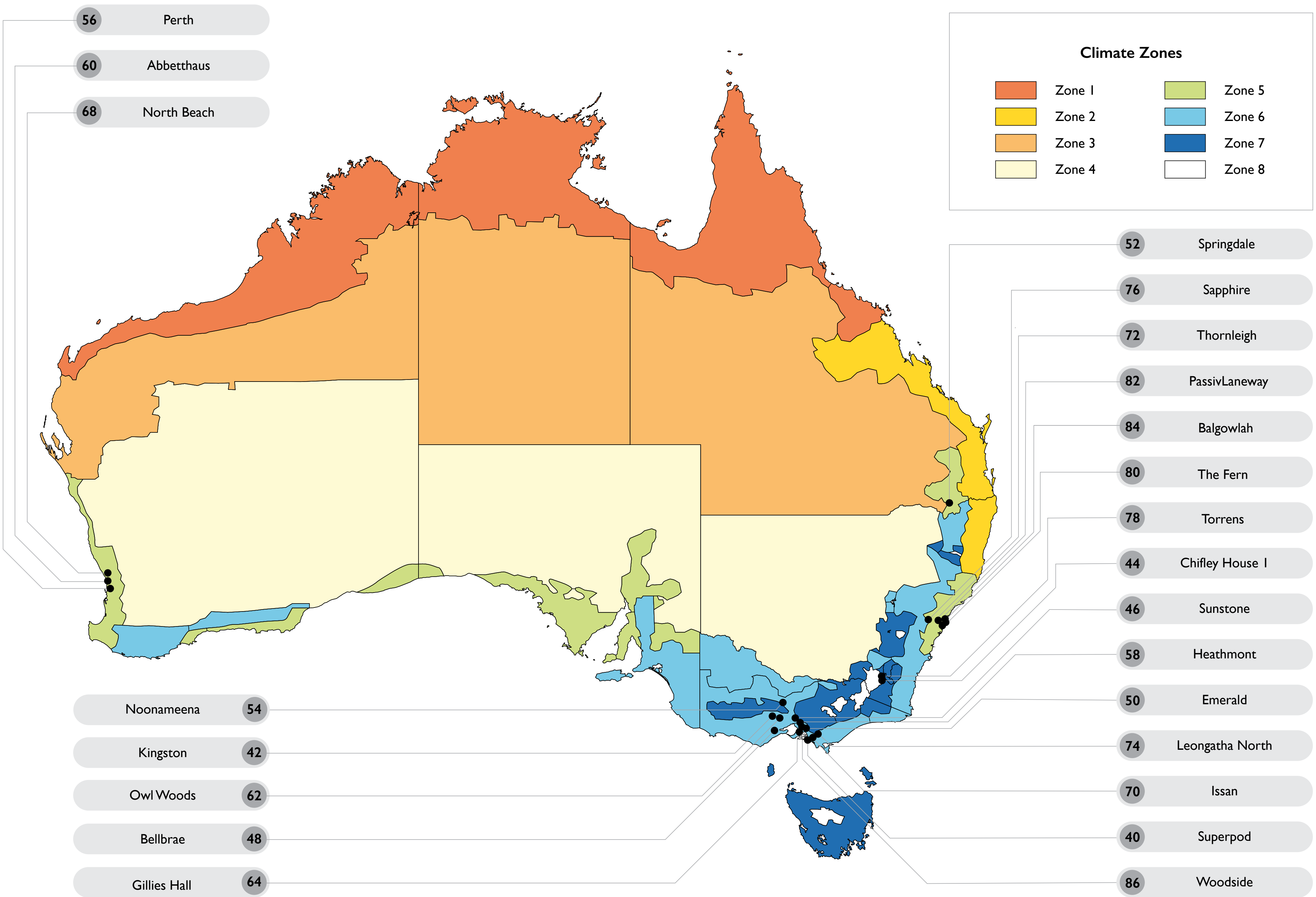
Meet 22 of the first buildings in Australia whose outstanding performance has earned them one of the Passivhaus certifications. They are located around the country and vary in type and budget as well as in their appearance and the materials used in their construction.

Those involved in bringing each of these buildings to fruition believed in the value of certification. Each has been independently verified to perform to the standards established in the design phase: the teams that built them, got it right. Energy modelling means that performance can be accurately predicted as the buildings are designed. Physical testing of the structure confirms the quality of the construction.

Special mention goes to one of the earliest certified projects, Bellbrae in Victoria. At time of publication, it is still the only retrofit to earn the EnerPHit certification, but several other renovation projects are competing to be next.

It's been seven years since the first project was certified. In that time, the depth and breadth of the industry has grown exponentially. Australia now has a certified apartment building in Sydney, six-storey student accommodation in Melbourne and a child care centre in Canberra: demonstrating that Passivhaus applies to all buildings in all climates.

This is just the beginning. The project teams from these earlier projects have gone on to do more, to educate others and to inspire building owners to expect (indeed, demand) better. The Passivhaus community is in expansion mode and that's good for people, the economy and the environment.



Climate Zones
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
Zone 7
Zone 8
56 Perth
60 Abbetthaus
68 North Beach
52 Springdale
76 Sapphire
72 Thornleigh
82 PassivLaneway
84 Balgowlah
80 The Fern
78 Torrens
44 Chifley House 1
46 Sunstone
58 Heathmont
50 Emerald
74 Leongatha North
70 Issan
40 Superpod
86 Woodside
Noonameena 54
Kingston 42
Owl Woods 62
Bellbrae 48
Gillies Hall 64

SUPERPOD, VIC

"In Melbourne it is not unusual for the temperature to spin from 40 degrees to 4 degrees in a matter of hours, but in a Certified Passivhaus you don't feel it."

—Superpod developer

The SuperPod Certified Passivhaus is a building system designed to be commercial and completely scalable. It was the first Certified Passivhaus in the world to use a patent-pending steel-faced, sandwich panel construction and a steel frame, with no membranes or plaster.

This innovative Certified Passivhaus system uses steel prefabricated components for a fast on-site build with low maintenance finishes and industrial modernist architectural style. The scalable design is suitable for use in international applications and any building type, including high rises.

Large-scale buildings are not typically made with timber framing in Australia, and in cyclonic and termite-prone regions a steel frame is often required. The steel frame was completely prefabricated and painted off-site, then delivered to site and installed in less than a day.

Insulation was installed on the floor above the structural slab, unusual in these parts of Australia. A second slab was poured over the floor insulation, providing continuous insulation and minimising thermal bridges through the steel frame to the structural slab.

Windows were installed into the pre-designed openings in the frame. The windows were not optimised for solar gain but rather to take in the best views to the east and south. This was a useful test of how a SuperPod performs when solar access is not optimal.

The SuperPod's prefabricated nature means low construction waste, minimal transport required for construction, low maintenance and cradle-to-cradle steel components. The result was a comfortable, modern, prefabricated Certified Passivhaus that was quick and easy to construct.

PASSIVHAUS METRICS

Certified	2014 Passivhaus Classic
Heating Demand	21 kWh/(m^{2}a)
Heating Load	10 W/m^2
Treated Floor Area	73 m^2
Air Leakage @ 50Pa	0.6 ACH
PE Demand	103 kWh/(m^{2}a)

PROJECT TEAM

Architect/Designer
McCabe Architects

Passivhaus Designer/Consultant
Passivhaus Academy, Ireland

Builder
Registered Owner Builder

Passivhaus Certifier
Passivhaus Institute, Germany

KINGSTON, ACT

There were no Certified Passivhaus buildings in Australia when this project began and the design/build team and homeowners worked hard to figure it out themselves. It uses construction materials that are standard in Australia, but this home also has some unique features. This includes a 2kW electric heater connected to the MVHR, which acts much like ducted heating in a traditional home. It turns on automatically when internal temperatures fall below 20°C.

Accoya timber-framed windows were specified: double-glazed where solar access was good, with triple-glazed windows installed elsewhere to further reduce heat loss. (Accoya is produced by a proprietary acetylation process that dramatically improves the durability and stability of timber from fast-grown, sustainably managed forests.)

This was a very challenging site, only 9.5m wide and with a 30m long, 6.5m high wall overshadowing its northern boundary. In such circumstances, traditional passive solar design that relies heavily on solar access becomes difficult. Passivhaus however can rise to the challenge of such constraints. Winter gets cold in Canberra but the high levels of insulation and the airtight envelope retain heat generated by appliances, cooking—and people! This is why so little additional heating is required, even in such a large house.

"Around 2007 there were very clear studies about climate change and the certainty of human causation. We were tired of waiting for a government response and thought, we actually have to do this ourselves as individuals. Certified Passivhaus promised very low energy consumption. It was also quantifiable before construction."

—Kingston homeowners

PASSIVHAUS METRICS

Certified	2014 Passivhaus Classic
Heating Demand	15 kWh/(m²a)
Heating Load	9 kWh/m²
Frequency of Overheating	0.4 %
Cooling Demand	3 kWh/(m²a)
Treated Floor Area	293 m²
Air Leakage @ 50Pa	0.56 ACH
PE Demand	118 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Industrious Design

Passivhaus Designer/Consultant
Industrious Design

Builder
Industrious Design

Passivhaus Certifier
PHI

CHIFLEY 1, ACT

"We enjoy coming home when it is freezing outside. When you shut the door you can't hear the wind or traffic and the warmth of the house wraps around you like a warm blanket."

—Chifley homeowner

The Chifley residence was built in 2014 and is one of the first examples of a Certified Passivhaus in Australia. The project involves two freestanding single-family homes built on neighbouring blocks, each a mirror image of the other. At the time, there were no Passivhaus buildings in Australia, no consultants to help and no examples to follow. Few people had even heard of the standard.

The houses are constructed from prefabricated structural insulated panels, chosen for their simplicity and rigidity and because they provide built-in continuous insulation. They were built to a modest design and budget. The rectangular floor plan makes for a simple structure that is easy to make air tight. The entire airtight barrier was visible during the test, meaning the building could be closely monitored throughout the process. The result is an impressive air leakage rate of 0.1 ACH, an Australian record that still stands today.

However, the goal was not to build an airtight house for the sake of it, but to build the most comfortable house possible. This was achieved and the house barely needs any heating or cooling, despite outside temperatures ranging from -8°C to 42°C. The Chifley Passivhaus costs only $1200 per year in energy costs; that includes heating, cooling and supply charges.

The results speak for themselves and exceeded expectations for the family of four who call it home. They declare they would not live in any other kind of house again.

PASSIVHAUS METRICS

Certified	2014 Passivhaus Classic
Heating Demand	15 kWh/(m²a)
Heating Load	15 W/m²
Frequency of Overheating	7.1 %
Treated Floor Area	127 m²
Air Leakage @ 50Pa	0.11 ACH
PE Demand	111 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Harley Truong/Andrew Verri

Passivhaus Designer/Consultant
Harley Truong

Builder
RJ Building ACT

Passivhaus Certifier
Peel Passivhaus Consulting

SUNSTONE, VIC

"We're still in love with the house."
—Sunstone owners

This small Certified Passivhaus Plus is located in north Melbourne, on a small triangular block in a typical new housing estate. The owners put comfort and economy at the top of their priorities list, so Sunstone is as efficient as possible with both energy and space. The home provides everything its owners require within its $85m^2$ footprint and it demonstrates that high comfort at low cost and low carbon is within the reach of any new home builder.

This suburban house performs dramatically better than its neighbours and has virtually no running costs for heating and cooling. It achieved Certified Passivhaus Plus certification—in fact it generates almost twice as much renewable energy than it uses. This carbon-positive home puts money in its owners' pockets.

The construction has been kept as close as possible to conventional Australian timber frame methods. During the design process improvements in the available materials and components allowed many details to be simplified and reduced costs. Simple roof planes meant SIP roofing could provide a cantilevered verandah without additional roof construction.

The insulation wraps continuously around the outside of the timber frame; there's no need for the standard insulation between studs. The only wall insulation is a standard external render system, using rigid insulation boards with a textured acrylic finish to provide a thermal bridge-free envelope.

The timber frame is entirely within the thermal envelope, which protects it from moisture and thermal movement. The airtight vapour membrane is located between the frame and the insulation. This meant a services cavity wasn't needed as the services run within the frame, without impact on the continuous insulation or airtightness.

PASSIVHAUS METRICS

Certified	2016 Passivhaus Plus
Heating Demand	7 $kWh/(m^2a)$
Heating Load	6 W/m^2
Frequency of Overheating	0 %
Treated Floor Area	79 m^2
Form Factor	3.7
Air Leakage @ 50Pa	0.38 ACH
PE Demand	90 $kWh/(m^2a)$
Generation of Renewable Energy	69 $kWh/(m^2a)$

PROJECT TEAM

Architect/Designer
David Halford, Sustainable Building Design

Passivhaus Designer/Consultant
David Halford, Sustainable Building Design

Builder
Quality Craftsmen Builders

Passivhaus Certifier
Passivhaus Institute Germany

BELLBRAE, VIC

"Having traveled to Europe and experienced very warm, comfortable housing even in extreme climates we wanted to improve our own home, which was miserably uncomfortable most of the year."

—Bellbrae homeowners

This renovated weatherboard home is designed and remodelled to meet the PHI EnerPHit standard, the Passivhaus standard for retrofit projects. Triple glazed windows and a state-of-the-art energy recovery ventilation system were an integral part of the refit. The use of heat recovery ventilation supports optimal thermal performance and indoor air quality, all with minimal input by the occupants.

In retrofit projects, the existing junctions and continuity of the airtight layer are always the major challenge. The use of a combustion heater also required a combustible air feed from outside, to avoid drawing air directly from the airtight home.

A new thermal and airtight envelope around the existing structure was created by insulating directly over the existing weatherboard cladding, creating a continuous thermal break. Blown insulation was used in some areas that couldn't be otherwise accessed. The blower door test result was outstanding.

An airtight membrane and rigid insulation was installed below the rafters and new ceilings fitted. This reduced the room height by just 40mm. The previously uninsulated suspended floor was filled with flexible insulation and enclosed with a weathertight breathable membrane below the joists. Rigid insulation was installed on top before new floorboards or tiles were laid.

The project was also modeled using thermal performance assessment software, FirstRate 5. It achieved a rating of 8.7 stars, well above the level required for brand new builds. It represents a striking improvement to the comfort of the home at the same time as greatly reducing the need for active heating and cooling.

PASSIVHAUS METRICS

Certified	2015 EnerPHit
Heating Demand	14 kWh/(m²a)
Cooling Demand	3 kWh/(m²a)
Treated Floor Area	143 m²
Air Leakage @ 50Pa	1 ACH
PE Demand	69 kWh /(m²a)

PROJECT TEAM

Architect/Designer
Aphi Projects

Passivhaus Designer/Consultant
Grün Consulting

Builder
Aphi Projects

Passivhaus Certifier
Mead Consulting

grünconsulting

AphiProjects EfficiencyMatrix LAROS TECHNOLOGIES FANTECH Intelligent Ventilation pro clima

EMERALD, VIC

The Emerald Certified Passivhaus illustrates the flexibility of the Passivhaus standard. This project's aim was to build a Passivhaus that looked like a conventional-looking family home and used familiar construction techniques.

This project was the builder's first Certified Passivhaus. Conventional design and construction methods were chosen to keep the build as close to mainstream as possible. Its exterior also reflects the surrounding streetscape and passers-by would never guess that this home is unlike any other on the street.

The home is a 180m² single story dwelling, built on a brick footing with timber subfloor. The house uses a traditional timber frame and trusses, Colorbond roof and cement sheet weatherboard cladding. The wall frames are 140mm thick, to allow for high levels of insulation. On either side of the frame is a membrane. The airtight membrane was wrapped to the internal side of the timber frame, while the weathertight membrane was wrapped to the external side, sandwiching the insulation in the middle. Timber battens act as service cavities and attachment points for the plaster internally and weatherboards externally so as to not puncture the membranes.

Uniquely, this home includes a wood-burning fireplace. This is a common feature in Passivhaus buildings in Europe but in most Australian climates a wood burner would overheat a Passivhaus home. The airtight construction of a Passivhaus requires a special type of wood burner that draws air from the outside.

"We could not imagine not living in a Passivhaus now, we are constantly surprised at how comfortable the house is."

—Emerald Certified Passivhaus homeowner

2018 Winner Best Sustainable Home for Master Builders Association Victoria

PASSIVHAUS METRICS

Certified	2017 Passivhaus Classic
Heating Demand	21 kWh/(m²a)
Heating Load	10 W/m²
Treated Floor Area	158 m²
Air Leakage @ 50Pa	0.6 ACH
PE Demand	92 kWh/(m²a)

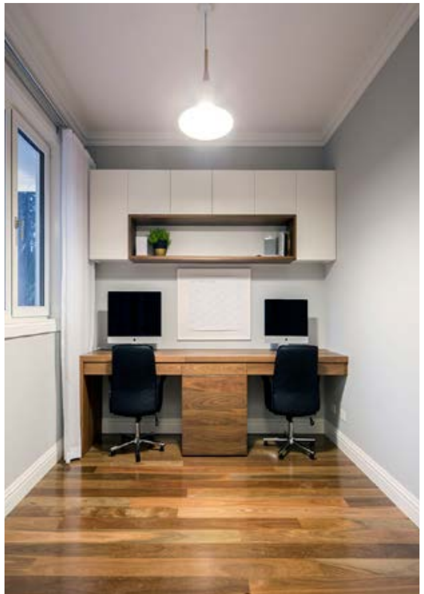
PROJECT TEAM

Architect/Designer
Virtual Home Design

Passivhaus Designer/Consultant
Grün Consulting

Builder
Granted Constructions

Passivhaus Certifier
Clare Parry



SPRINGDALE, QLD

"We would both find it difficult to return to living in a normal house."
- Springdale Certified Passivhaus owners

The remote location of Queensland's first certified Passivhaus made connection to the grid uneconomic. The owners didn't want a generator, so their only choice was to create a home that used no energy source but the sun.

To run on only solar power, the heating and cooling demand had to be reduced to as close to zero as possible. But temperatures here at 744m above sea level range from well below zero to above 40°C and very big daily temperature swings are common, so this was easier said than done.

High levels of insulation were the most cost-effective way both to minimise the cost of the off-grid system and to maintain stable temperatures. The simple rectangular design preferred by the owners is optimised for winter solar gain and summer shade, with concealed bushfire shutters providing additional shade control.

The mechanical ventilation and heat recovery (MVHR) system is integral to achieving near zero heat demand. It also means windows can be left closed on very hot days. That keeps out hot wind and dust but filtered fresh air will still be supplied by the MVHR. This has the twin result of reducing the cooling requirement while keeping air quality high.

The heating requirements were so astonishingly low that no dedicated heating appliances were required. However, a small reverse cycle heat pump air conditioner has been installed, to counter rising temperatures and more frequent extreme weather events.

To keep the load on the solar electricity to a minimum, domestic hot water is provided by a heat pump system with an internal storage tank. The hot water annual demand is about twenty times the heating demand—but this system has the advantage of running throughout the day when solar power is at its peak.

The truly remote location of the home caused some delays in getting tradespeople to site and some even camped to avoid the long travel times. In the end, this project was a great success, keeping its owners comfortable, healthy and completely sustained by the sun.

PASSIVHAUS METRICS

Certified	2017 Passivhaus Plus
Heating Demand	0.14 kWh/(m²a)
Heating Load	1.83 W/m²
Frequency of Overheating	0 %
Treated Floor Area	180 m²
Form Factor	2.9
Air Leakage @ 50Pa	0.36 ACH
PER Demand	48 kWh/(m²a)
Generation of Renewable Energy	82 kWh/(m²a)

PROJECT TEAM

Architect/Designer
David Halford, Sustainable Building Design

Passivhaus Designer/Consultant
David Halford, Sustainable Building Design

Builder
Shawn Palmer Builder

Passivhaus Certifier
Passivhaus Institute Darmstadt

NOONAMEENA, VIC

"Just do it. The minute you walk into a Passivhaus you will never go back!"
—Noonameena homeowner

This project was Australia's first certified Low Energy Building. Located in Central Victoria on the banks of Lake Eppalock, Noonameena (meaning "our bush resting place") is a three bedroom home on eight hectares of rural land. Its architectural form is in contrast to the simple shape more typical of Passivhaus buildings.

Site conditions were the project's biggest constraint. Rocky basalt and volcanic soil with many huge rocks complicated the construction and the cost of connecting to the electricity grid. The extensive views over Lake Eppalock also presented their own challenge, that of maximising the views from the west-facing glazing but without causing overheating. Wide eaves and a deep verandah help shield summer sun.

Split-cycle air conditioning is installed in the main living areas, along with a very efficient wood stove, but they are seldom required; indoors remains at a comfortable, stable temperature. A relatively air-tight home requires a specific type of woodburner. This one draws fresh air from outside and expels smoke through a triple-skin, double-cowled flue.

The home was constructed using a straw bale prefab panel system. This was quick to install and provides a quiet, thermally comfortable home. Combining prefabricated straw bale construction with LEB certification proved a straightforward process.

Energy efficiency is a byproduct of building to any of the Passivhaus certifications; Noonameena also provides humidity control, lowered dust levels and increased thermal comfort for its inhabitants. The owners say their new home exceeds their expectations and they take pleasure in hosting guests so they can experience Passivhaus for themselves.

PASSIVHAUS METRICS

Certified	2017 Low Energy Building
Heating Demand	23 kWh/(m²a)
Heating Load	18 W/m²
Treated Floor Area	179 m²
Air Leakage @ 50Pa	1 ACH
PE Demand	81 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Urban Perspective

Passivhaus Designer/Consultant
H3Space

Builder
Craftsmen Quality Builders

Passivhaus Certifier
Luc Plowman

PERTH, WA

"The filtered air is good for my hayfever. Plus the home accumulates less dust, so cleaning seems less onerous."

—Perth owner

This is a large family home located close to the ocean on Perth's central coast. It has the distinction of being Australia's first Certified Passivhaus Premium, generating far more energy than it uses each year (see page 10).

The house has undercroft garage parking with basement storage. A split-level design maximises the usable space on the narrow block while keeping within the usual residential height restrictions. Thermal bridges created by the junction of the unconditioned garage under the conditioned space of the house demanded creativity to eliminate. Along with the roof terrace access floor junctions, this made achieving airtightness an interesting challenge although in the end this target was met with ease.

The below ground structure was constructed with insulated concrete forms (ICF), which simultaneously provided the retaining structure and insulation. The upper structure and the roof were formed from structural insulated panels (SIP), providing a full height insulated envelope. The intermediate floors were hung on the inside face to avoid any thermal bridging and only required airtight taping to the panel joints. The middle floor forms the main service zone for DHW and HRV ducts and the nominal amount of steelwork is kept within the thermal envelope to avoid creating any thermal bridges.

Perth is one of the most isolated cities on the planet, so utilising locally produced and fabricated products was the most sustainable solution. The ICF, EPS and SIP were all produced in Perth, as were the double-glazed uPVC windows and doors.

PASSIVHAUS METRICS

Certified	2015 Passivhaus Premium
Heating Demand	5 kWh/(m²a)
Heating Load	7 W/m²
Treated Floor Area	369 m²
Air Leakage @ 50Pa	0.3 ACH
PE Demand	42 kWh/(m²a)
Generation of Renewable Energy	103 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Roger Joyner, Passivhaus Perth

Passivhaus Designer/Consultant
Passivhaus Perth

Builder
Consortium Builder

Passivhaus Certifier
Passive House Academy

FANTECH Intelligent Ventilation

PASSIVHAUS PERTH

pro clima

HEATHMONT, VIC

"We love the light, the comfort, the quiet and the views."

—Heathmont homeowners

Heathmont's owners wanted a home with an adaptable range of uses and where they could age in place. Both have been achieved on this elevated and very steep site in suburban Melbourne. The house combines high-level sustainability with atypical design, including a unique saw-toothed roof and lofty ceilings.

The angular, serrated form was designed to harness south-east views and north-east light but this complex building shape brought some challenges. It decreased the building volume and increased the form factor, which reduces the floor area to building envelope area ratio. To compensate, additional insulation and higher-performing windows were specified.

The complicated nature of the design has been offset through using prefabricated panels. The prefabricated Panellite system was used for the roof and walls, minimising the construction time on-site and reducing construction waste. The semi-submerged lower floor level, a response to the steep site, assists in maintaining a more stable indoor environment. It helps to balance out the often sudden swings in temperature experienced in Melbourne.

The homeowners' living and sleeping spaces are located on the first floor, which is accessed via at-grade entry and parking. This creates an accessible "Livable Home", with the bonus of amazing views over rolling hills. Two south-facing bedrooms will remain delightfully cool on hot summer nights when family members visit. The downstairs self-contained apartment provides for a possible income stream or guest quarters.

The home generates electricity via rooftop PV, harvests rainwater and is surrounded by a sustainable landscape design with native planting, a reticulated billabong and trickling stream.

PASSIVHAUS METRICS

Certified	2017 Passivhaus Classic
Heating Demand	12 kWh/(m²a)
Heating Load	8 W/m²
Cooling Load	5 W/m²
Treated Floor Area	271 m²
Air Leakage @ 50Pa	0.55 ACH
PER Demand	77 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Maxa Design

Passivhaus Designer/Consultant
Williams Energy Design UK

Builder
CarbonLite

Passivhaus Certifier
Clare Parry

FANTECH Intelligent Ventilation

EfficiencyMatrix

pro clima

ABBETTHAUS, WA

"My house is proof that the science behind Certified Passivhaus is spot on. I don't know why anyone would be happy to live in anything less."

—Abbetthaus homeowner

Abbetthaus has been crafted as an ode to desert modernism, prioritising liveability while pushing the boundaries of residential building performance in Western Australia. It showcases what can be achieved on a small infill block–and proves that the Passivhaus standard is just as relevant in hot climates as cold. The house stands in the coastal Perth suburb of Scarborough.

The client is a young professional working in commercial construction, who was highly knowledgeable and demanded best practice when it came to building comfort and performance. His brief was for an innovative and high-performing home that was also simple, affordable and robust. The Passivhaus standard was an obvious choice.

A fresh, light, spacious home with good connection to the outdoors was also part of the brief—and this was to be achieved on a tiny rear laneway site. Further, the 213m^2 block is overshadowed by a two-storey high wall on the north boundary, severely limiting solar access. The solution, both to the site and the climate, was to position the house on the south boundary. This allowed winter sun to flood into the home while minimising overheating in summer. The average internal temperature is a perfect 21 degrees.

The builder, designer, certifier and client worked together to develop a timber construction methodology that achieved Passivhaus performance for little more than the cost of a typical home. The Abbetthaus is a lightweight timber structure on a concrete slab, a solution that balanced sustainability, speed and thermal performance.

PASSIVHAUS METRICS

Certified	2018 Passivhaus Classic
Heating Demand	1 kWh/(m²a)
Heating Load	13 W/m²
Frequency of Overheating	9.4%
Treated Floor Area	132 m²
Form Factor	3.07
Air Leakage @ 50Pa	0.59 ACH
PER Demand	64 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Ben Caine Architect, Leanhaus

Passivhaus Designer/Consultant
Grün Consulting

Builder
Chris Evans

Passivhaus Certifier
Clare Parry

grünconsulting

FANTECH Intelligent Ventilation

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OWL WOODS, VIC

This pioneering project blends biophilic design and Certified Passivhaus performance to create an unique and beautiful home. Owl Woods is located in Trentham in regional Victoria at an altitude of 700m. The challenging climate ranges from snow in winter to summer temperatures of 40°C.

For the new home to be climate-responsive, comfortable, sustainable and energy-efficient, the decision was made to design and construct the building to the Certified Passivhaus standard. Generous visual and physical connections to nature, natural light and materials are integral to the design, whilst the contemporary pavilion-style layout creates diverse indoor environments.

However, this shape brings its own challenges to the project. Simple, rectangular forms can more readily achieve the Certified Passivhaus standard. Owl Woods' separate wings and integrated courtyards increase the external wall area but this could be accommodated by increasing insulation values and using triple-glazed high-performance windows. Modelling the energy performance of the building at the design stage shows how these different elements interact and ensures the design will perform to the required standard.

Owl Woods is proof that creatively designed homes can meet the Certified Passivhaus performance standard; Passivhaus buildings need not necessarily be simple forms.

"High on our priority list was sustainability. The idea of a house with good solar orientation was suggested and this soon developed into a full blown Certified Passivhaus."

—Owl Woods homeowner

2019 ArchiTeam Sustainability Medal Winner, Shortlisted 2019 Sustainability Awards, Finalist 2020 Houses awards, Finalist 2020 BDAA awards

PASSIVHAUS METRICS

Certified	2019 Passivhaus Classic
Heating Demand	15 kWh/(m²a)
Heating Load	11 W/m²
Treated Floor Area	170 m²
Form Factor	3.9
Air Leakage @ 50Pa	0.5 ACH

PROJECT TEAM

Architect/Designer
Talina Edwards Architecture

Passivhaus Designer/Consultant
Luc Plowman, Detail Green

Builder
Craftsmen Quality Builders

Passivhaus Certifier
Clare Parry

GILLIES HALL, VIC

Gillies Hall is Australia's first large-scale building to gain Passivhaus certification. (In fact, at over 5000m², it's the largest Passivhaus in the southern hemisphere.) Located on Monash's Peninsula Campus in Victoria, it contains 150 studio apartments for students plus shared areas consciously designed to foster a sense of community.

Gillies Hall is one of a very few buildings to combine all-electric, low-energy design with a cross laminated timber (CLT) structure. CLT is emerging as an alternative to standard concrete and steel structure. Its use here was instrumental to the project and it significantly reduced the building's embodied carbon. Globally, the manufacture of concrete and steel accounts for about five percent of the world's total carbon emissions. Timber, in comparison, sequesters carbon. CLT made it possible to remove all concrete above the Level 1 transfer floor. Further, because of the comparatively light weight of the CLT panels, the amount of concrete in the columns and foundation was reduced by a quarter.

The CLT panels also function as the building's airtight envelope. Architectural detailing focused on penetrations through the CLT façade. This simplified the construction process for otherwise-complex performance parameters. Gillies Hall achieved a level of airtightness almost 20 times better than conventional building construction and well-exceeded the Passivhaus requirements for thermal bridging.

Heating demand vs load

There are two ways a building can reach Passivhaus certification with regard to energy use for heating or cooling. The first is heating demand; the second is heating load. In simplest terms, the heating load describes the size of the heating system needed to keep the building at a comfortable temperature. This approach also applies to energy use for cooling.

The two alternative paths to certification acknowledge the diversity of climates in which Passivhaus projects may be built. A mild climate with occasional cold snaps will require a bigger heater running for a few days of the year, compared to a climate where winters are cold and long, requiring a smaller heating source used over a long period.

Gillies Hall easily qualifies on both measures.

These design parameters improve the building's ability to provide comfortable living conditions without energy-hungry mechanical heating and cooling systems. Extensive rooftop PV dramatically reduces the hall's reliance on the electricity grid.

Highly efficient heat recovery ventilation systems supply constant fresh air to every room. Continuous, optimised solar shading is provided by the dramatic folded steel structure and cross-flow ventilation effectively purges heat on hot summer nights. System controlled corridor windows provide natural ventilation when outdoor conditions are favourable. Room temperatures remain consistently at 20-25°C with no added heating or cooling.

The building showcases the university's commitment to both first-class student accommodation and achieving net zero operational emissions. The university expects Gillies Hall to be its most efficient building—and at least three times more efficient than their other halls of residence. The project is fossil-fuel free.

"Gillies Hall seeks to transform the student experience and set a new benchmark in environmental building design in Australia."

—Monash University

PASSIVHAUS METRICS

Certified	2018 Passivhaus Classic
Heating Demand	2.6 kWh/(m²a)
Heating Load	5.8 W/m²
Frequency of Overheating	9%
Treated Floor Area	5185 m²
Air Leakage @ 50Pa	0.53 ACH
PER Demand	135 kWh/(m²a)
Generation of Renewable Energy	63 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Jackson Clement Burrows Architects

Passive House Designer/Consultant
AECOM

Builder
Multiplex

Passive House Certifier
Clare Parry

EfficiencyMatrix

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NORTH BEACH, WA

This home is the only one of its kind in Western Australia and one of very few buildings in Australia that has been certified Passivhaus Plus (see page 10).

Most Australian homes rely on passive solar principles to create a comfortable home: thermal mass, glazing to floor area ratios by orientation and cross ventilation.

However, these owners wanted an energy efficient home based on proven engineering methodologies and science. It was important for them to know, not just hope, that their new home would be comfortable and energy efficient, even in WA's blisteringly hot, dry climate. Certified Passivhaus is the only building standard that provides engineering based solutions for proven performance.

Engineering the structure and construction details to meet the Passivhaus standard required only small adjustments to the initial design, mostly changes to wall thickness and minor changes to wall alignment. Instead of focusing on thermal mass, Passivhaus emphasises the importance of continuous insulation. In WA, this is a particularly challenging concept as double brick and thermal mass is about all that people know!

Just because a home is energy efficient doesn't make it comfortable; and just because a home is comfortable does not make it energy efficient. At North Beach, the clients got what they wanted: the best of both worlds.

"It can be hard to explain or understand if you have not experienced it. This is our second winter and our satisfaction continues to grow, we could never again live happily in a conventional home."

—North Beach homeowners

PASSIVHAUS METRICS

Certified	2018 Passivhaus Plus
Heating Demand	15 kWh/(m²a)
Heating Load	13 W/m²
Treated Floor Area	206 m²
Air Leakage @ 50Pa	0.57 ACH
PER Demand	68 kWh/(m²a)
Generation of Renewable Energy	79 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Kellett Design Group

Passivhaus Designer/Consultant
Daniel Kress

Builder
Ismart

Passivhaus Certifier
Clare Parry

ISSAN, VIC

Issan is a modest, modern Australian getaway born from a desire for an economical, low-maintenance and compact home.

When people think of a Passivhaus, they often picture a particular look; a simple square building with little to attract the eye. This rural retreat is not that. With high-level construction detailing, including a striking slanted mono-pitch roof and concealed guttering and downpipes, Issan strikes a refined and elegant form that looks different from every perspective.

The building sits within a small biodynamic vineyard approximately a hundred kilometres south-east of Melbourne. The clients had retired and were spending more time working at the property but they weren't enjoying a two-hour commute back to their Melbourne home at the end of working day. This prompted a decision to build small, simple accommodation on-site that had minimal environmental impact. Inspired by the rural surroundings and farm shed aesthetic, the pared-back design features low embodied energy materials of timber and iron.

The house is entirely off-grid. It's all-electric, running off a 4.5-kilowatt solar PV system with battery storage. That's enough for a refrigerator, induction cooktop and oven in the kitchen (but not a microwave or dishwasher) as well as the MVHR system and the reverse cycle air-conditioner. The solar hot water system is fitted with an electric boost. The house also required stand-alone wastewater and greywater treatment systems and harvests rainwater. It spans three levels, including the semi-submerged basement that will be used as a wine cellar and a multi-purpose loft.

The owners enjoy the thermal comfort of their vineyard retreat, especially compared to their draughty Melbourne home, and look forward to spending more time there in the summers with their children and grandchildren.

PASSIVHAUS METRICS

Certified	2018 Passivhaus Plus
Heating Demand	18 kWh/(m²a)
Heating Load	9 W/m²
Cooling & Dehumidification Demand	2 kWh /(m²a)
Cooling Load	15 W/m²
Treated Floor Area	82 m²
Air Leakage @ 50Pa	0.6 ACH
PER Demand	98 kWh/(m²a)
Generation of Renewable Energy	94 kWh/(m²a)

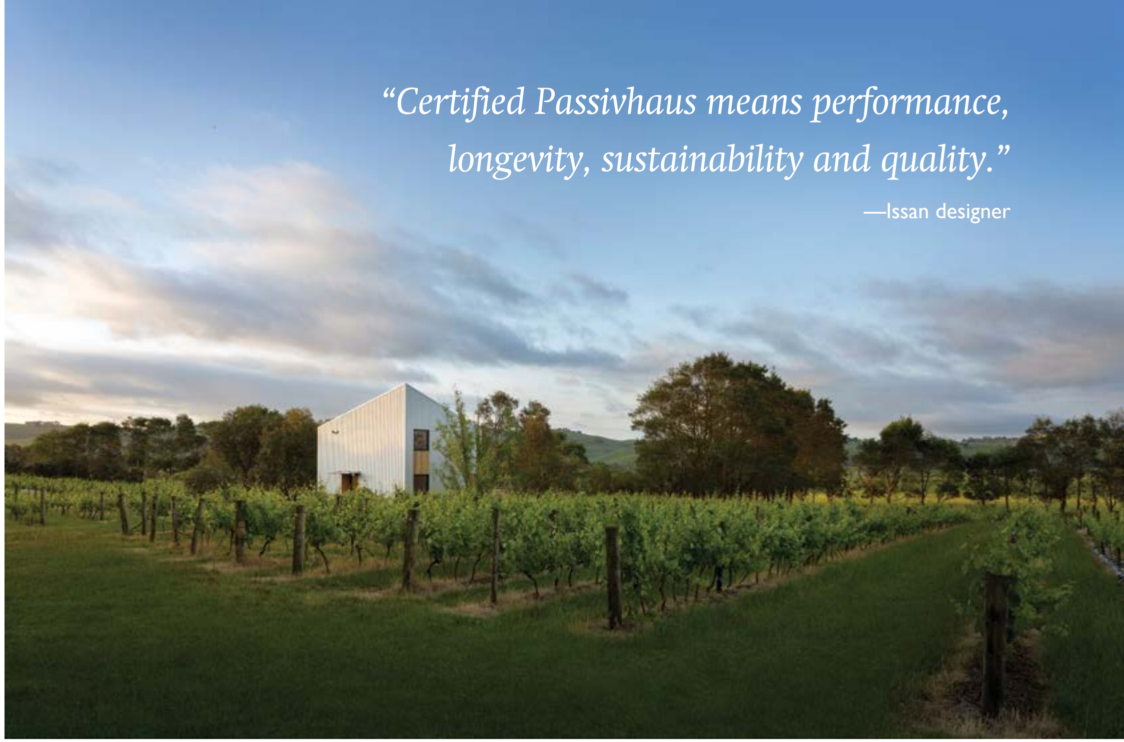
PROJECT TEAM

Architect/Designer
Maxa Design

Passivhaus Designer/Consultant
Detail Green

Builder
Goycon

Passivhaus Certifier
Luc Plowman



"Certified Passivhaus means performance, longevity, sustainability and quality."

—Issan designer

THORNLEIGH, NSW

The first Certified Passivhaus in Sydney epitomises the benefits of a well-sealed home. Nestled carefully between a busy road and the northern train line, this home is a refuge from the hustle and bustle of city life.

The airtight, ventilated and well-insulated structure not only provides a comfortable indoor environment, it drastically lowers noise pollution levels. The final blower door test for Thornleigh yielded a result of 0.39 ACH, well below the Certified Passivhaus limit of 0.6 ACH. This compares to the average for a new Australian home of 15.4 ACH! Thornleigh is 44 times less leaky and far less noisy.

While the windows in a Certified Passivhaus can be opened, this is not required as the integrated mechanical ventilation system supplies constant fresh air. Leaving windows closed significantly reduces the noise from traffic, creating a calm and peaceful internal environment.

The cost-effective windows are uPVC with an aluminium external skin. They were imported from a market where triple-glazing is standard, so ordering double-glazing would have added cost and manufacturing time. The difference in cost between imported Certified Passivhaus windows and Australian windows of the necessary quality was minor, and will be quickly recouped through tiny energy bills.

This pioneering project met the requirements for Passivhaus Plus as it generates as much renewable energy as it uses over the course of a year. The original brief was for a house using passive solar principles but through careful design optimisation it was built to Passivhaus standards for less than was first quoted for passive solar.

PASSIVHAUS METRICS

Certified	2019 Passivhaus Plus
Heating Demand	9 kWh/(m²a)
Heating Load	10 W/m²
Treated Floor Area	183 m²
Air Leakage @ 50Pa	0.39 ACH
PER Demand	62 kWh/(m²a)
Generation of Renewable Energy	30 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Envirotecture

Passivhaus Designer/Consultant
Envirotecture

Builder
Red Cedar Constructions

Passivhaus Certifier
Luc Plowman

FANTECH Intelligent Ventilation · Logikhaus · DETAIL GREEN · Envirotecture

LEONGATHA NORTH, VIC

This four-bedroom home in East Gippsland is built entirely from cross-laminated timber (CLT). It was a wonderful opportunity to push the boundaries and explore new possibilities. The challenge lay in the compliance issues that arise when using non-conventional building methodologies and materials. Passivhaus buildings and the use of CLT are both common practice in Europe but the Australian building industry lags years behind. Getting all interested parties 'on the same page' was essential to the success of the project.

The CLT structure was built from sustainably-sourced spruce supplied by Binderholz. Despite having been manufactured on the other side of the world and ordered off CAD drawings a year before construction, each prefabricated component fit together with millimetre precision on site. An outstanding airtightness result of 0.33 ACH was achieved.

The house is built on an insulated concrete slab and has double-glazed windows imported from Europe. It takes in 360 degree views of the surrounding vineyards. The design and how the home sits within its environment is quite unique for the area. It respects the natural and industrial surrounds and already looks as though it has been on the site for many years.

"Coming in from the cold or the hot at the end of the day is always a reward."

—Leongatha North homeowners

PASSIVHAUS METRICS

Certified	2017 Passivhaus Classic
Heating Demand	16 kWh/(m²a)
Heating Load	10 W/m²
Cooling Load	21 W/m²
Treated Floor Area	234 m²
Air Leakage @ 50Pa	0.33 ACH
PER Demand	52 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Aphi Projects

Passivhaus Designer/Consultant
Grün Consulting

Builder
Aphi Projects

Passivhaus Certifier
Clare Parry

EfficiencyMatrix

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SAPPHIRE, NSW

This is one of the most healthy, comfortable and energy-efficient houses ever seen in NSW but its achievements don't stop there. It is also built to BAL-FZ (Flame Zone), the highest Bushfire Attack Level rating, and is the first Certified Passivhaus to receive the Healthy House Australia certification.

In order to build a truly healthy home, the build team worked with a building biologist throughout construction. The home was constructed and finished with sustainable and low-VOC products. Rubbish and recycling were carefully separated throughout the build and excavated material was reused on site for landscaping. The house was then cleaned without chemicals and tested to determine that the chemical, CO_2 and EMF levels met the Healthy House Australia certification requirements.

A ventilation system extracts stale air and delivers fresh, filtered air throughout the entire house so there's no CO_2 build-up inside—perfect for people with respiratory issues or those seeking a healthier indoor environment. It's also 90% more energy efficient than a regular house, which greatly reduces the environmental impact. This four-bedroom house costs as little as $3.80 a day to run: that's not just for heating and cooling but hot water, appliances and lights as well. Thanks to a solar PV system, the Sapphire Certified Passivhaus is carbon-zero.

The builders, Blue Eco Homes, consider Certified Passivhaus to be the future for housing in Australia because of how this standard prioritises sustainability and healthy living.

"These are the homes of the future"
— Sapphire home owner

PASSIVHAUS METRICS

Certified	2019 Passivhaus Classic
Heating Demand	9 kWh/(m²a)
Heating Load	10 W/m²
Treated Floor Area	183 m²
Air Leakage @ 50Pa	0.39 ACH
PER Demand	62 kWh/(m²a)
Generation of Renewable Energy	30 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Ingrid Donald Architect

Passivhaus Designer/Consultant
Laros Technologies

Builder
Blue Eco Homes

Passivhaus Certifier
Luc Plowman

TORRENS EARLY LEARNING CENTRE, ACT

Torrens Early Learning Centre is a daycare and kindergarten facility and is the only privately-owned Passivhaus educational facility in the world. The client's goal was to build the healthiest and most sustainable childcare centre in Australia and meeting the Certified Passivhaus standard was a key performance requirement.

The centre caters for up to 90 children plus around 20 staff. It consists of two two-story buildings linked by a large external deck and playground. The first was an adaptation of an existing building's footprint and while it aimed for Passivhaus certification, it did not meet the final airtight criteria. The second building houses six large classrooms and met the Passivhaus Premium standard.

Windows were carefully designed to distribute natural light into the classrooms while also shielding unwanted heat gain in summer. The mechanical ventilation system was proven during bushfires in January 2020, when Canberra had the dubious distinction of the worst air quality in the world. (Air quality index readings above 200 are considered hazardous; readings in Canberra peaked at 7700.)

The client offered some advice for those considering commercial Passivhaus projects. Firstly, employ main trades and sub-contractors who are certified Passivhaus tradespeople or at least trained in the methodology. Second, while there may be a cost premium compared to a Code-minimum build, low operating costs mean a quick return on investment.

"As a commercial building, it is world-class in its thermal efficiency, and therefore highly energy efficient. My other buildings cost me $15,000 a year in electricity, while Torrens costs only $36. And that is mostly the grid-connection fees!"

—Torrens Early Learning Centre owner

Commendation for Sustainable Commercial Construction, Master Builders Award

PASSIVHAUS METRICS

Certified	2017 Passivhaus Premium
Heating Demand	15 kWh/m²/year
Heating Load	12 W/m²
Cooling & Dehumidification Demand	1 kWh/m²/year
Cooling Load	4 W/m²
Treated Floor Area	768 m²
Form Factor	2.4
Air Leakage @ 50Pa	0.6 ACH
PER Demand	54 kWh/m²/year
Generation of Renewable Energy	143 kWh/m²/year

PROJECT TEAM

Architect/Designer
Christie Hartfiel Architectural Design / CanPLAY / VRD Design

Passivhaus Designer/Consultant
H3Space

Builder
Phil Bates Building Services/ CarbonLite / CanPLAY

Passivhaus Certifier
Luc Plowman

THE FERN, NSW

"If we don't stop emitting copious greenhouse gases, we're all going to die."

—The Fern developer

The Fern is already famous, with good reason. It's Australia's first certified Passivhaus apartment building, nestled in the heart of Sydney's Redfern. The 11 one-bedroom apartments include a wheelchair-accessible apartment, large, semi-enclosed balconies that work as outdoor rooms and two-level apartments on the top floors. The main atrium has two 15m-high living green walls.

The developer was drawn to the Passivhaus methodology when the passive solar design principles he was familiar with proved too rigid to apply effectively in this tight city setting. The northern facade of The Fern is a firewall, ruling out any solar gain from the north at all! The east-west orientation is unfavourable from a passive solar point of view but the developer saw that the Passivhaus methodology had the tools to overcome all the challenges of this city infill site.

A multi-level, high-density building is able to maintain a constant internal temperature much more efficiently than a standard single-storey residence, as it has a higher floor area to building envelope ratio. Even with the challenging site and structural, fire and residential code requirements, The Fern provides comfortable temperatures, peace and quiet and constant fresh, filtered air. The building requires minimal active heating or cooling; the 2kW split system air-conditioner in each apartment is a quarter of the size that would be typically specified in an ordinary building.

There are 21 kilowatts of PV on the roof and The Fern generates around 20% more power than it uses. It's net positive for energy and also carbon-neutral.

National HIA Greensmart Award for Multi-Residential Housing 2019

PASSIVHAUS METRICS

Certified	2019 Passivhaus Classic
Heating Demand	14 kWh/(m²a)
Heating Load	14 W/m²
Cooling & Dehumidification Demand	16 kWh /(m²a)
Cooling Load	16 W/m²
Treated Floor Area	325 m²
Air Leakage @ 50Pa	0.3 ACH
PER Demand	139 kWh/(m²a)
Generation of Renewable Energy	170 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Steele Associates Architects

Passivhaus Designer/Consultant
Grün Consulting

Builder
Steele Associates Construction

Passivhaus Certifier
Luc Plowman

PASSIVLANEWAY, NSW

"It's hard to explain to family and friends in the UK that Sydney feels colder in winter than the UK, because most Australian houses are built like fancy tents. It feels great to be able to look forward to winter time."

—PassivLaneway homeowner

The PassivLaneway shows that quality buildings can be delivered regardless of size, and that the humble 'granny flat out the back' doesn't have to be a shed-like construction fit only for unruly teenagers or desperate renters.

This compact home is a site-specific gem set in the northern beaches of Sydney. It sits atop a laneway garage, its geometry determined by council constraints and neighbourhood privacy concerns. Yet it commands treetop views of the district giving a sense of space beyond its small footprint.

The east and west elevations are blank walls to shield neighbours, while the balcony is provided privacy and light by an intricate timber screen. The more visible long elevations are clad in blackbutt, which will gracefully weather over time.

One of the biggest challenges was achieving airtightness in such a small building. Council constraints forced a non-rectilinear floor plan which resulted in an increased surface area to volume ratio. Squeezing in a centralised mechanical ventilation with heat recovery (MVHR) system given very limited void spaces was a challenge for both design and construction.

The externally insulated wall system guarantees 100% insulation coverage. In a small building this was critical to reduce the impact of the framing timbers. It also resulted in a more robust construction system for on-site construction. The MVHR ensures fresh air 24/7 although the doors can often be found open on a gorgeous autumn day.

PASSIVHAUS METRICS

Project Certification	2020 Passivhaus Plus
Heating Demand	11.4 kWh/(m²a)
Heating Load	13.4 W/m²
Cooling Load	16 W/m²
Cooling & Dehumidification Demand	23 kWh/(m²a)
Treated Floor Area	58.5 m²
Air Leakage @ 50Pa	0.52 ACH
PER Demand	53 kWh/(m²a)
Generation of Renewable Energy	96 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Envirotecture

Passivhaus Designer/Consultant
Envirotecture

Builder
Imac Developments

Passivhaus Certifier
Clare Parry

FANTECH Intelligent Ventilation

grünconsulting Envirotecture Logikhaus IMAC DEVELOPMENTS

BALGOWLAH, NSW

This is a small two-storey extension to an existing 1920s Californian bungalow that creates more room for a growing family of five. The decision was made to design and build to the Passivhaus standard so that the family could thrive in a home that was sustainable and healthy.

Indoor air quality was of particular importance as the health of their children was the clients' foremost concern. Avoiding asthma triggers such as mould, pollen and dust was vital. The interior of the home has exposed timber walls, floors and ceilings that contribute to the healthy, natural indoor environment.

The other major attraction of building to the Passivhaus standard was economic. The clients found that by refinancing to a clean energy home loan at a much lower interest rate, saving on electricity bills and eliminating gas bills, they would save an estimated $100,000 over 30 years. This wasn't even taking into account the unquantifiable health benefits of living in a Passivhaus environment.

Retaining the large established eucalypts on the site, maintaining privacy and providing a connection to nature all shaped the building form. The extension is a cross-laminated timber (CLT) structure that was prefabricated in Austria, including the stair and cut-outs for lighting, power and equipment. It was installed in just over 15 hours, despite a complex environment for the crane which had to navigate a long overreach above the existing house, trees on the street, a power cable and the trees in the backyard. The efficiency of the CLT installation allowed for the entire building to be waterproof, insulated and airtight within one week. This meant the family could keep occupying their existing house while the extension was completed.

PASSIVHAUS METRICS

Certified	2019 Passivhaus Classic
Heating Demand	6 kWh/(m²a)
Heating Load	13 W/m²
Cooling Load	15 W/m²
Cooling & Dehumidification Demand	12 kWh /(m²a)
Treated Floor Area	100 m²
Air Leakage @ 50Pa	0.4 ACH
PER Demand	83 kWh/(m²a)
Generation of Renewable Energy	0 kWh/(m²a)

PROJECT TEAM

Architect/Designer
Betti & Knut Architecture

Passivhaus Designer/Consultant
Laros Technologies

Builder
Conor Murphy

Passivhaus Certifier
Luc Plowman

WOODSIDE BUILDING FOR TECHNOLOGY AND DESIGN, VIC

The Woodside Building for Technology and Design is a landmark, representing the latest thinking in tertiary education and world-leading energy-efficient building design. It is the largest certified Passivhaus project in the southern hemisphere. The five-storey, smart-technology enabled building serves as a living lab for IT and engineering students and researchers. They can experience first-hand how an integrated design approach can increase occupant comfort and indoor air quality and dramatically reduce energy consumption.

Woodside was deliberately designed to allow students to learn from the building itself. Visual access to plant rooms through glazed windows provides an insight into the role of different components of plant equipment. Part of the raised floor has laminated glass, showing how the mechanical, electrical and hydraulic services function. Structural steelwork and exposed piles include sensors that show how stresses and vibrations on structural elements change in different load conditions and temperatures.

The overarching design challenge was to provide a building which maximises daylight and reduces energy demand. Detailed coordination amongst trades and designers was required to find suitable and maintainable equipment and systems.

The building was also certified by Climate Active, becoming Australia's first carbon-neutral construction project. This illustrates how the Passivhaus standard can readily fit with other sustainability initiatives. The builders implemented energy efficiency initiatives on-site, calculated all emissions produced from fuel and energy use and purchased carbon credits to offset those emissions.

Woodside generates its own power via 230 kilowatts of solar panels, contributing to Monash's commitment to achieving net zero emissions for its campuses by 2030.

PASSIVHAUS METRICS

Heating Demand	9 kWh/(m²a)
Heating Load	13 W/m²
Treated Floor Area	15,860 m²
Form Factor	1.25
Air Leakage @ 50Pa	0.6 ACH
PER Demand	74 kWh/(m²a)
Generation of Renewable Energy	64 kWh/(m²a)

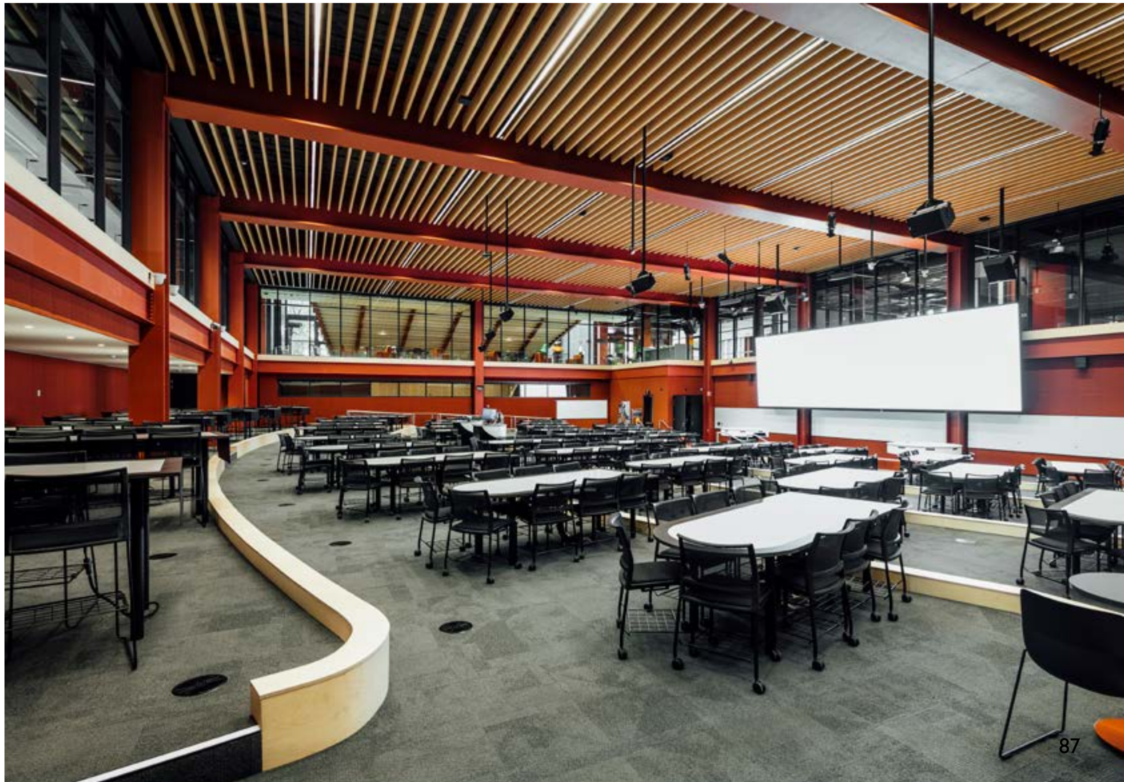
PROJECT TEAM

Architect/Designer
Grimshaw Architects

Passive House Designer/Consultant
Aurecon

Builder
Lendlease

Passive House Certifier
Passivhaus Institute, Germany



Other projects

The following projects illustrate both the history and the future of Passivhaus in Australia. The stories that follow span from some of the pioneering high-performance buildings in this country through to complex projects still in the design phase.

Some of the more recent buildings have been completed and are awaiting their official certification results. Some early projects like the Butterfly House didn't meet the certification standard but this retrofit project is included here because of how influential this building was in the early stages of Passivhaus adoption in Australia. It was very highly awarded and much publicised.

It is encouraging to see the first councils, school boards and business owners understand the value of the Passivhaus standard.

Monash University features again in this section with the Woodside Building for Technology and Design. This is a groundbreaking development: at nearly 16,000 square metres, it will be the largest Passivhaus building in the southern hemisphere and arguably the largest purely educational Passivhaus yet built anywhere in the world. By committing to radically better new buildings that combine net zero operations with Passivhaus performance, Monash creates an example for other tertiary institutions to follow.

APHA is excited about the future and the myriad and interesting Passivhaus projects its members are involved with. We look forward to having to revise this book to keep pace with developments! In the meantime, new projects and breakthroughs will be posted to our social media feeds.

Index

PASSIVE BUTTERFLY, VIC

This 2016 project attempted to retrofit a circa-1910 weatherboard house with a heritage overlay to the PHI EnerPHit standard. It didn't reach its target but nevertheless became one of the most recognised and studied examples of high-performance retrofits in Australia.

The owners had lived in Scandinavia, so their expectations of indoor comfort were at odds with what ordinary Australian homes offered. They were also strongly motivated to reduce their environmental footprint by minimising energy usage. Passivhaus was the obvious solution and one they were already familiar with.

The project demonstrates that while a builder with Passivhaus construction experience is desirable, a willingness and flexibility to learn is even more important. The successful partnership between the building designer, builder and client underscores the importance of teamwork and an openness to new approaches.

In hindsight, the owners would have made some different choices, including pushing harder to remove all steel from the structure, better positioning of the airtightness layer within the wall assembly and installing a weather tight barrier underneath the floor to support more insulation and reduce air movement. Despite that, the heating system turned out to be oversized!

"If we had our time over, we'd have pushed even harder to ensure Passivhaus performance. Don't compromise! And we wouldn't have worried so much about a complicated and expensive heating system, which it turns out we don't really need. The building fabric is what does the work."

—Passive Butterfly homeowners

National Association of Building Designers Best Sustainable Design - 2018
Sustainability Awards Single Dwelling Alteration or Addition - 2018
Sustainability Awards Best of the Best - 2018

PASSIVHAUS METRICS

Heating Demand	26 kWh/(m²a)
Heating Load	11 W/m²
Frequency of Overheating	6.1 %
Cooling Demand	10 kWh/(m²a)
Cooling Load	6 W/m²
Form Factor	3.9
Air Leakage @ 50Pa	1.2 ACH

PROJECT TEAM

Architect/Designer
EME Design

Passive House Designer/Consultant
eZed

Builder
Ridge Developments

SACRED HEART PRIMARY SCHOOL YEA, VIC

The client realised early on that the Passivhaus standard was ideal for schools; the comfortable and healthy learning environment it creates can be expected to increase students' wellbeing and attention. The automated systems alleviate the teaching staff from responsibility for controlling the internal environment, leaving them free to focus on the learning needs of students.

This project was delivered at no extra cost and well within the budget of Catholic Education Melbourne. There was no special allowance for Passivhaus design features—in fact, it reduced the budget by nearly seven percent, due to savings in the mechanical and electrical systems.

The client deserves credit for pioneering: back in 2017, this was the first Passivhaus school building in the southern hemisphere. Some challenges did present themselves, mostly to do with the high-quality components. Domestic heat recovery ventilation systems could not deliver sufficient flow, while commercial systems in Australia were too large and expensive. Ultimately a suitable European unit was imported. Thankfully, appropriate systems are now available locally.

The air tightness requirements presented a particular challenge. Air leakage is not enforceable in AS4000 contracts so the issue was finding a builder willing and able to provide the necessary standard of construction even when there was no contractual obligation to do so. Remedial work will be required to achieve the Passivhaus airtightness standard.

"The stable temperatures, acoustics, daylight and draught-free constant fresh air (without the need to operate controls or windows) make this building a very comfortable learning environment."

—Judy Degenhardt, School Principal

Read more:

Closing the performance gap: Passive House for schools in Renew magazine bit.ly/PHschools

PASSIVHAUS METRICS

Heating Demand	12 kWh/m²/year
Heating Load	15 W/m²
Cooling & Dehumidification Demand	2 kWh/m²/year
Cooling Load	14 W/m²
Treated Floor Area	195 m²
Form Factor	3.7
Air Leakage @ 50Pa	1.3 ACH
PER Demand	82 kWh/m²/year
Generation of Renewable Energy	52 kWh/m²/year

PROJECT TEAM

Architect/Passive House Designer
David Halford,
5c Sustainable Building Design

Builder
Darjelyn Construction

Passive House Certifier
Luc Plowman

BENDIGO SOLDIERS MEMORIAL INSTITUTE MILITARY MUSEUM, VIC

The memorial building is heritage listed for its architectural, social and historical significance. Its external street-facing loggia functions as a publicly accessible honour roll and to this day remains the focus of Anzac Day ceremonies in Bendigo. The architectural firm of Lovell Chen was engaged to ensure the viability of the public building through restoration, reconstruction and adaptation.

The project combined conservation of the fabric of the original 1921 building plus the addition of a two-storey pavilion. This new space has enabled the organisation to become a borrowing and lending institution at a national level. The extension will be the first government building in Australia to be constructed to the Passivhaus standard and the first Passivhaus museum in the southern hemisphere.

Both the existing building and its new pavilion are designed to meet the City of Greater Bendigo Sustainable Building Design Scorecard but the new gallery and storage areas well surpass those requirements. The pavilion is an ideal project for Passivhaus certification, as the ground floor exhibition space requires 24/7 climate control and a very high standard of air quality.

Maintaining a AA-standard environment for both the gallery and storage spaces could have made for expensive running costs. However the chosen combination of high levels of insulation, an airtight envelope and an energy recovery ventilation system have produced a highly energy-efficient building, slashing operational costs for mechanical systems and delivering a space that is very comfortable to occupy.

A highly-insulated airtight envelope houses the environmentally-controlled gallery, with the collections store located above. This inner box is surrounded by a ventilated, naturally-lit, timber-lined circulation space. In turn, it is enclosed in glass and a perforated screen made of weathering steel cladding.

Operational affordability was a factor in the choice of materials and finishes. Further, the Passivhaus standard required the elimination of thermal bridges. This was achieved by the use of a predominantly timber structure, minimising the use of structural steel.

During the construction phase, the architects worked closely with the contractor and project manager to ensure the Passivhaus details and approach were understood and implemented. This was particularly important as the subcontractors did not have prior knowledge of the Passive House standard.

Two workshops were held to introduce the tradespeople to the specific materials and detailing, and project managers were responsive to questions as the project evolved. Staff from the main contractor completed extra externally-delivered training during the course of the project and appointed an 'airtightness champion' on their team.

Some remediation of the ventilation system was required to ensure correct functioning. It points to the value of close (and early) collaboration between mechanical engineers and the Passivhaus designer on a project with complex mechanical systems.

According to the City of Greater Bendigo, achieving a Passivhaus level of performance for this project provides for energy savings of up to 90% compared with typical existing buildings and over 75% compared with average new best-practice constructions.

The $5.1 million project was funded by the federal and state governments, the City of Greater Bendigo, Bendigo District RSL and the local community. Construction was completed in 2018 and Passivhaus certification is pending at time of publication.

PASSIVHAUS METRICS

Heating Demand	22 kWh/m²/year
Heating Load	10 W/m²
Cooling & Dehumidification Demand	1 kWh/m²/year
Cooling Load	7 W/m²
Treated Floor Area	232 m²
Form Factor	3.3
Air Leakage @ 50Pa	0.5 ACH
PER Demand	56 kWh/m²/year

PROJECT TEAM

Architect/Designer
Lovell Chen

Passive House Designer/Consultant
Grün Consulting

Builder
Nicholson Construction

Passive House Certifier
Clare Parry

KYNETON, VIC

This project is a renovation and extension of a nineteenth-century, weatherboard pattern book cottage. It used to be cold, dark and expensive to run, but not any more. The street-facing section of the cottage is retained, while a more recent extension at the rear of the house is being replaced with a high-performance timber-framed construction. It's been designed to meet the EnerPHit standard, the special Passivhaus certification for refurbishments.

This project is both interesting and challenging, in part due to balancing heritage restoration requirements with modern energy-efficient criteria. The front door and windows exemplify the architect's elegant solutions: these are modern Passivhaus components but cleverly styled to match the heritage exterior.

The owners' desire for generous natural light across the full depth of the plan—without exceeding the width of the existing frontage—was a challenge. The design achieved this through a stepped roof profile with clerestories that allow daylight deep into the house's interior. This also contributes valuable warmth during sunny winter days.

Lift-and-slide doors at the rear of the house provide a new and welcome connection to the north-facing, private backyard. To prevent overheating, a deep verandah shades this wall of glass from hot summer sun while invisible integrated blinds protect the clerestories. Windows are triple-glazed and there's even a cat door with a Passivhaus air-tight seal.

The standard stud wall thickness in the existing construction required the use of closed-cell, high-performance insulation. A grid-connected PV array has been installed, which will bring this project up to the the EnerPHit Plus standard—over the course of a year, the house will generate more energy than it consumes.

PASSIVHAUS METRICS

Heating Demand	14 kWh/m²/year
Heating Load	10 W/m²
Cooling & Dehumidification Demand	2 kWh/m²/year
Cooling Load	17 W/m²
Treated Floor Area	188 m²
Form Factor	3.8
Air Leakage @ 50Pa	0.4 ACH
PER Demand	58 kWh/m²/year
Generation of Renewable Energy	50 kWh/m²/year (target)

PROJECT TEAM

Architect/Passivhaus Designer
David Halford, 5c Sustainable Building Design

Builder
Stuart Lee, Craftsmen Quality Builders

Passive House Certifier
Luc Plowman

FANTECH Intelligent Ventilation · Logikhaus · DETAIL GREEN · Sustainable Building Design · CRAFTSMEN QUALITY BUILDERS

VANQUISH, QLD

Vanquish is high-end living at its best. This open plan, two-storey home has expansive glazing connecting the indoors and outdoors. The building is a combination of mass and lightweight materials, which challenges many of the stereotypes about what a Passivhaus looks like.

The project has successfully blended the outdoor beach style synonymous with luxury sub-tropical homes with the rigorous performance required by the Passivhaus standard. The climate is challenging: there are excessive sensible (dry) and latent (wet) heat loads for about 40% of the year, winter temperatures can drop to nine degrees overnight and air quality can be an issue. Passivhaus offered the ideal answer to all these challenges.

The developer found the Passivhaus standard to offer a very informative process that did not have a major impact on the budget when considered early in the planning stage. His advice is to work closely with the architect at the concept stage and commit to Passivhaus certification early, before the design is significantly developed. The primary challenges faced by this project were a lack of Passivhaus-savvy tradespersons and a mature supply chain of Passivhaus products.

The home has a bespoke energy recovery ventilation system to supply fresh air and control the internal humidity when relative humidity is high. This is synced to the air-conditioning to allow fresh air supply, cooling and dehumidification to work in unison. The house boasts a PV array sufficient to power the home and triple-glazed windows to counter the high window-to-wall ratio. FSC timbers were used throughout the house along with low or no-VOC products and paints. Unfortunately, this ambitious project narrowly missed the airtightness criteria. Vanquish had aimed for Passivhaus Plus, but as this book goes to press it is awaiting certification as a PHI Low Energy Building.

PASSIVHAUS METRICS

Heating Demand	3 kWh/m²/year
Heating Load	7 W/m²
Cooling & Dehumidification Demand	9 kWh/m²/year
Cooling Load	16 W/m²
Treated Floor Area	260 m²
Form Factor	3.3
Air Leakage @ 50Pa	0.68 ACH
PER Demand	115 kWh/m²/year
Generation of Renewable Energy	86 kWh/m²/year

PROJECT TEAM

Architect/Designer
Joe Adsett

Passive House Designer/Consultant
John Moynihan, Ecolateral

Builder
Solaire Properties/ARP

Passive House Certifier
Luc Plowman

STIEBEL ELTRON DETAIL GREEN pro clima®

COPPIN ST, VIC

This renovation tests the limits of what is possible and affordable on a tight, noisy, inner-city site but will deliver an exemplary level of comfort, energy-efficiency and acoustic performance. It is targeting the PHI Low Energy Building standard: not quite a Certified Passivhaus but featuring the same components and still performing well in excess of a Code-minimum building.

The design and construction team rose to meet a number of challenges. This overshadowed infill site receives little winter sun, so there's barely any solar gain in winter to boost indoor temperatures. The small footprint and the clients' desire for a high ceiling in the living space produces a high form factor (this measures the ratio of the building envelope to the floor area). This means higher heat losses and construction costs on a per square metre basis compared to a typical larger dwelling.

Reactive clay soil required a highly engineered concrete slab foundation. Budget constraints rule out an insulated floating slab, so mitigation of thermal bridges through the footings will be required.

The project will achieve zero carbon operation through adoption of 100% electric systems, a rooftop PV array and green energy supply. The design calls for a prefabricated, panelised wall assembly. This will arrive on site as a flat pack and be craned onto the receiving frame. Timber will be sustainably sourced and concrete with a high recycled content is preferred.

Developing a Passivhaus design has been challenging given the limitations of budget and the site but it's been an exciting journey nonetheless.

PASSIVHAUS METRICS

Heating Demand	23.5 kWh/m²/year
Heating Load	18 W/m²
Frequency of Overheating	3 %
Cooling & Dehumidification Demand	3 kWh/m²/year
Cooling Load	25 W/m²
Treated Floor Area	81 m²
Form Factor	5.0
Air Leakage @ 50Pa	0.5 ACH (target)
PER Demand	52 kWh/m²/year
Generation of Renewable Energy	14 kWh/m²/year (target)

PROJECT TEAM

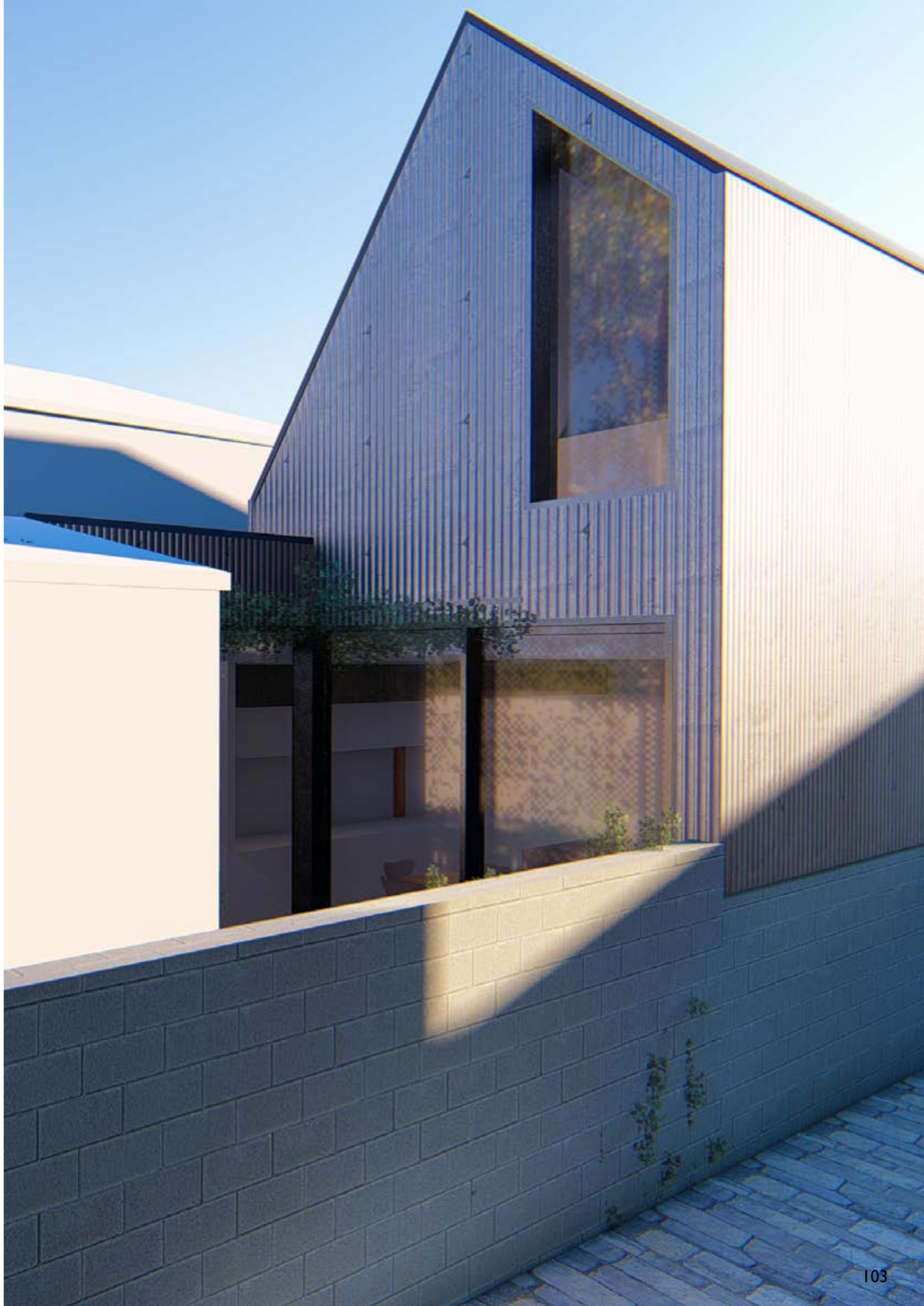
Architect/Designer
Kerstin Thompson Architects (concept design only)

ARKIt (from scheme design to contract documentation)

Passive House Designer/Consultant
Atelier Ten

Builder
Yet to be appointed

Passive House Certifier
Luc Plowman



GLENROY COMMUNITY HUB, VIC

This community facility will provide a new home for the Glenroy library and kindergarten and includes maternal child health services, a community health provider, neighbourhood learning and childcare services.

Moreland City Council is a carbon neutral organisation and it set the highest sustainability benchmarks for this project. The community hub is targeting Living Building Challenge Petal Certification and Passivhaus Classic certifications. The radical energy-efficiency of a Certified Passivhaus building fits perfectly with the Living Building Challenge's 'energy-positive' requirements. The building will generate electricity via a rooftop PV system, designed to produce 125% of the building's annual electricity demand.

This project raised several challenges not found in residential buildings. Removing the thermal bridges created by the structural framing requirements emerged as a key issue. This was achieved by locating the thermal layer on the exterior of the structural steel and utilising load-bearing, thermally-broken products where required. While quite common elsewhere in the world, this approach is not yet common practice in Australia. This allowed the building to achieve reasonable U-values without the need for thick external walls.

Considered selection of the services equipment and the window system was made during the design stage, as these components are important to meeting the Passivhaus criteria. The process for managing the risks of overheating went more smoothly than expected. A consultant experienced in Passive House design and construction was involved very early on in the design and this will greatly benefit the project.

The community hub is currently under construction and is scheduled for completion by the end of 2021.

PASSIVHAUS METRICS

Heating Demand	14 kWh/m²/year
Heating Load	12 W/m²
Cooling & Dehumidification Demand	1 kWh/m²/year
Cooling Load	14 W/m²
Treated Floor Area	3767 m²
Form Factor	2.65
Air Leakage @ 50Pa	0.6 ACH (target)
PER Demand	155 kWh/m²/year
Generation of Renewable Energy	83 kWh/m²/year (target)

PROJECT TEAM

Architect/Designer
DesignInc Melbourne

Passive House Designer/Consultant
WSP Australia and Detail Green

Builder
Building Engineering

Passive House Certifier
Clare Parry

Conclusion

This book records how individual people and organisations have taken bold action, inspired by their commitment to a better world. Notable among them are Oliver Steele (The Fern), Natalie Colbert (Torrens Early Learning) and the leadership team at Monash University (Gillies Hall, Woodside). They have pioneered the adoption of Passivhaus methodology in diverse building types, recording firsts not just in Australia but the southern hemisphere.

No less noteworthy are those families who five or six years ago chose to build new homes or renovate their existing ones to the Passivhaus standards. Those who go first clear the way for those who follow.

Australia didn't invent Passivhaus. But we are leading the world in demonstrating its relevance in hot climates and how it can create energy-efficient, gloriously comfortable and healthy buildings in some of the most challenging climates in the world.

Right now Australia and the world faces more urgent challenges than ever. COVID-19 has disrupted the way we work and study, how we spend time with friends and family and how we spend our leisure time. It has exacerbated existing inequalities and the gulf between the haves and the have-nots.

The lucky among us have grappled with how to keep working from home while homeschooling children, swapping tips on how to keep toddlers from bombing our Zoom calls. This book is a product of lockdown, prepared by people collaborating virtually across Australasia.

A handful of APHA members have volunteered countless hours to produce this book because we believe in the better world that Passivhaus makes possible.

We believe in the worth of a comfortable, healthy home for our families.

We believe in the importance of social housing that provides health and comfort for the most vulnerable Australians.

We believe in the value of offices, shopping centres, factories, schools and hospitals that improve people's wellbeing.

We believe in the urgency of transforming Australia's built environment so that it generates more clean energy than it consumes rather than being a glutton for fossil-fuel derived energy.

We believe in the value of striving to design buildings that are carbon-neutral or even carbon-negative.

Building better isn't just a theoretical discussion for building science geeks. It's a discussion for everyone who likes clean air, comfortable temperatures—and who wants a habitable world for their grandkids. That is to say, all of us.

We invite you to join us.

Andy Marlow
APHA
October 2020

AUSTRALIAN PASSIVE HOUSE ASSOCIATION

The Australian Passive House Association is an independent, not-for-profit organisation that promotes Passivhaus certification as a way of providing superior indoor comfort and air quality, while reducing Australian buildings' energy use and carbon emissions.

We achieve this through three key objectives:

PROMOTE | We work with closely with industry groups, government, and other organisations to amplify our impact and our diverse audience includes:

- Members of the public, engaging with the standard in their own projects
- Building owners, management and facility managers
- Property developers and commercial investors
- Building contractors, product retailers, wholesalers, manufacturers and suppliers
- Architects and building designers
- ESD consultants, engineers and technical specialists
- Education providers

SUPPORT | Leading change by educating, promoting and supporting the delivery of Certified Passivhaus buildings in Australia. We believe everyone should live and work in healthy, comfortable, low-energy, resilient buildings.

ADVANCE | Education is at the forefront of what we do; our aim is to educate and inform building and design professionals on the benefits of Passivhaus. These include masterclasses in particular technical areas and delivering Certified Passivhaus training.

APHA is a vital industry resource and offers many benefits to members, including discounted training, events and software; free membership to IPHA and Passipedia; entry into our member directory; access to technical documents and our webinar archive and much more! We offer a variety of membership levels, including individual and company memberships suitable for different business sizes.

Discover more on our website www.passivehouseaustralia.org. Use the 'Find a Professional' tab to locate certified Passivhaus professionals in your area.

You can follow us on social media @passivehouseaustralia

APPENDIX I: HOMEOWNERS

How to afford performance

If you value all the benefits Passivhaus delivers, it's possible to have a Passivhaus building without increasing your budget. However, it is almost certain to cost more if you try to graft Passivhaus performance onto an already finished design! Specify high-performance from the beginning and ensure Passivhaus expertise on your design team.

Other strategies new homeowners have used to control costs include:

- Slightly reducing the footprint. With clever design, shrinking the house by 5-10% often isn't even noticeable.
- Simplifying the shape of the building. The more corners, the more thermal bridges, the more and bigger windows all have an impact on cost and performance. A simpler form will be cheaper and faster to build than a complex shape.
- Compromising on fit-out. Kitchens and bathrooms are the big-money rooms. Significant savings can be made here, while still ensuring rooms that are highly-functional, durable and appealing.

  It's also much easier to upgrade your kitchen in years to come compared to upgrading your building envelope!
- Reconsidering what is essential: is that third toilet or a triple garage really more important than clean fresh air and tiny power bills? Fundamentals before fashion.

"If you are concerned about cost, make your building smaller and build a bigger shed."

Superpod Passivhaus developer

APPENDIX II: ARCHITECTS/BUILDING DESIGNERS

Passivhaus Classic criteria

Heating	Demand or Load	≤ 15 kWh/m²a ≤ 10 W/m²
Cooling	Demand* or Load	≤ 15 kWh/m²a ≤ 10 W/m²
Primary Energy—Renewable	Heating, cooling, hot water, auxiliary electricity, domestic/common electricity	≤ 60 kWh/m²a
Airtight	Tested at a pressure of 50 Pa	n50 ≤ 0.6 h-1
Internal temperature	Excessive temperatures (time > 25°C)	< 10%

*Variable limit in humid climates, to take account of dehumidification (calculated in PHPP)

Source: Passivhaus Institute, 2016

Passivhaus ventilation

—Joel Seagren

The Passive House Institute (PHI) has demonstrated that ventilation through building fabric air infiltration is unreliable and of unknown quality. Combined with the unreasonable expectation of occupants to be regularly opening and closing windows plus thermal discomfort, dust, and noise ingress, PHI has recommended the use of MVHR systems. These systems provide fresh outside filtered air at close to room temperature in a reliable manner throughout the year. They also provide considerable energy savings, particularly in climates with cold winter and hot summers.

Moisture, particles (dust, smoke etc) and CO_2 accumulation are the main concerns within a building but other contaminants such as volatile organic compounds (VOCs) that may be present are also diluted to much safer levels by a MVHR. This is achieved through careful placement of supply and extract grilles that remove moist and odorous air and supply fresh filtered air.

PHI's recommendation is that all MVHR units are fitted with F7 filters on supply air which will remove up to 95% of particles with a size of 2um or larger. Finer grade filters are available such as F9 and HEPA but they would be considered for special application only.

From an operational and maintenance perspective, good MVHR systems are designed to have very low requirements. Typically boost switches are fitted to bathrooms, toilets and kitchens to provide a short increase in flow rate during use, with the MVHR unit automatically returning to design airflow rates on completion. There are very few other reasons for owners to make changes to the operating settings of their MVHR unit.

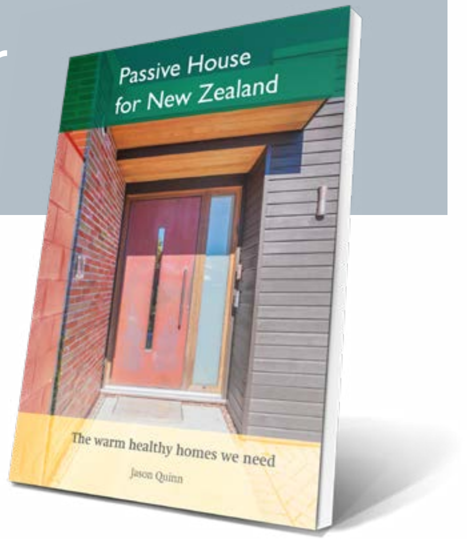
In terms of maintenance, MVHR units will provide an alert to check the filter condition after six months. If on inspection these require replacement because they are covered in particle matter, this can be easily done by the building owner in a couple of minutes.

MVHR suppliers in conjunction with certified Passivhaus consultants can provide MVHR system designs for projects. Their knowledge along with experienced installation and commissioning teams will ensure that owners get a high-performance ventilation system operating at low power consumption (25–50 watts on average) and low noise levels.

Joel Seagren is Deputy Chair of the APHA board and Intelligent Ventilation Solutions Engineer at Fantech.

The yellow ducting shows where the moist, stale air is being extracted from wet areas; the red ducting illustrates the fresh, filtered air being delivered to bedroom and living areas. The heat exchanger uses the energy from the exhaust air (brown) to heat or cool the incoming outside air (green).

Passive House for New Zealand



Jason Quinn of Sustainable Engineering Ltd is the sole Passive House certifier in New Zealand. He also consults on high performance building in Australia.

His 2019 book, *Passive House for New Zealand: The warm healthy homes we need*, was the inspiration for this project.

The 100-page, full-colour book describes the problems with New Zealand's poorly performing homes, especially the issues with cold and damp and the health problems these conditions create. Mostly it sets out solutions, arguing for the relevance and need for Passive House-standard construction. It includes 24 case studies of single-family homes and more varied Passive House projects that were pre-construction at time of publication.

Special offer for readers of *Passivhaus in Australia*:

download the Passive House for New Zealand ebook free here:
www.sustainableengineering.co.nz/APHAoffer

Plus, get a free email briefing each month, containing exclusive subscriber-only content. Get informed, independent commentary on issues, opportunities and the latest news in high-performance building—in Australasia and around the world.

Read an example/sign up here:
www.sustainableengineering.co.nz/newsletter

CREDITS

A number of APHA members, many of them also members of APHA's board, generously volunteered their time and expertise to bring this book about. Andy Marlow conceived of the project and was then tasked with making it happen; his excellent project management skills and unfailing availability to answer questions and make decisions kept the project on track despite a global pandemic and regional lockdowns. Clare Parry contributed early drafts. Talina Edwards contributed to the project direction and along with John Beurle, Mia Radic and Chris Nunn, offered input into successive drafts. Special credit goes to Mia Radic and also Marcus Strang who sent countless emails and organised hundreds of files to compile the many case studies that make this book come alive.

Last but certainly not least, APHA offers warmest thanks to New Zealand's Passivhaus certifier, Jason Quinn of Sustainable Engineering, whose book *Passive House for New Zealand* was the inspiration for this project. Jason generously allowed us to use the graphical format, some graphics and crib from the text. That book's editor and designer (Rachel Rose and James Chatterton respectively), brought their skills to this project also.

Those named above work for the following companies that provide professional services to the Passivhaus community.

talina edwards ARCHITECTURE elemental design

SUSTAINABLE ENGINEERING LTD

grünconsulting PASSIVHAUS + SUSTAINABILITY

Envirotecture

passive house services

PASSIVHAUS DESIGN & CONSTRUCT

HIP V. HYPE

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p 8 UPVC window at Thornleigh Passivhaus. Photo: Brandee Meier Photography

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p 16 Passivhaus external door at Owl Woods. Photo: Tatjana Plitt

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CASE STUDIES

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References are available at bit.ly/PHiArefs

Expect more.

We have the knowledge and the materials to design and construct buildings where people can enjoy comfortable temperatures and fresh air all the time. Those buildings have the tiniest energy bills for heating and cooling because they've been designed to stay at an ideal temperature no matter what the weather outside.

This solution is the Passivhaus standard. It's flexible enough to work in any climate zone, for any kind of building: not just homes and apartments but schools, offices, factories, shops, hospitals, gyms, anywhere people need to gather indoors.

Passivhaus is backed by 30 years of rigorous building science and the practical experience gained from tens of thousands of successful projects around the world.

Inside you'll find examples of inspiring projects from around the country that have been certified Passivhaus. You'll read about why it matters and what it takes. It's not that hard. But the problems it solves are real and fixing them matters.

This book is for everyone who cares about Australia's climate change response, their kids' health, their employees' productivity—and their own comfort. It's a book for policy makers, advocates for social change, architects, engineers and builders; and for anyone planning on building a new home or renovating one.

www.passivehouseaustralia.org