Passivhaus in Australia
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ABSTRACT
The Passivhaus, or Passive House, standard is a rigorous, voluntary and performance-based standard for energy efficiency in a building. Originally from central Europe, the standard is finding traction in the Australian market. Proponents of the standard cite an enhanced drive for excellence in energy efficiency, indoor comfort and occupant health and wellbeing. With rising fuel costs, there is also a strong economic case for increasing efficiency in buildings. Whilst Passivhaus is currently expanding across the residential market, Australia will soon also see projects realised in the education, commercial and aged-care sectors, with many others to follow.

This note will outline the criteria and general requirements to achieve the standard, what the impact is for a typical project, and demonstrate how it is easier to achieve Passivhaus in the relatively mild climates of Australia than in the central European climates.

Figure 1: New Monte Rosa Hut. (Image courtesy of Holcim Foundation)
Introduction

Mention Passivhaus to building professionals and you may get an array of responses: a barrage of questions, an unnecessarily strict demand that takes efficiency too far, an unnecessary remedy for a problem we don’t have, or perhaps the panacea for all our building woes. So what is it all about, really?

Rising concern over climate change continues to place increasing demands on the design quality and energy efficiency of our buildings. High performance buildings that provide optimal internal comfort without adding further pressure on the environment require innovative design solutions from architects and engineers. The Passivhaus standard, a design and construction methodology that promotes internal comfort and energy efficiency, has been around for a while now. Is it something new, something different or both?

Imagine a building standard that provided the following:

![Figure 2: The Four Pillars of the Passivhaus standard](Image: Australian Passive House Association)

The Passivhaus design standard is effectively a guarantee of build quality, and being an ‘as-built’ standard (certified once the building is complete) it has marked benefits over the often applied design-only standards prevalent among our many building codes and guidelines. The end result is the only one that matters and so it is paramount that the whole process is managed smoothly to ensure success.

Passivhaus and its origins

Passivhaus, a methodology that addresses these issues, recently came of age in Europe. In 1992, Dr Wolfgang Feist opened the first Passivhaus in the German city of Darmstadt Kranichstein. His team designed and constructed a building in which the full potential for passive design initiatives were maximised, including optimal orientation, shading, good insulation, high performance glazing, airtight construction and mechanical ventilation. This row of four terrace houses achieved excellent internal comfort without the use of any major heating and/or cooling equipment. In southern Germany’s often freezing climate (down to -25°C) this is no mean feat.

Since this pioneering research project, the Passivhaus design principles have been developed and applied across many European cities. In parts of Germany and Belgium, application of the standard has even been embedded in the local building regulations.

The term

In English-language literature on the subject, the terms Passivhaus and Passive House are both used. The English translation of Passive House can cause some confusion, as it is commonly misconceived to be the same as passive solar design and the literal translation to ‘house’ does not pick up the implied meaning of ‘building’.

Based around the principles of the international thermal comfort standard ISO 7730, Passivhaus is known as an ultra-low energy standard, aimed at providing optimal thermal comfort and minimum energy consumption. Compared with typical buildings, a Passivhaus building will consume up to 90% less energy in operation.

Applicable to new and refurbished buildings of any type, the core concept of Passivhaus is to provide a truly energy efficient and comfortable building while maintaining a focus on affordability. With good design achieving so much in efficiency for any building, there is no real limit to the scope and size of a Passivhaus building. Indeed, there is an economy of scale that might be achieved for larger buildings with low surface-area-to-volume ratios, which is one of the most limiting factors for small buildings. The standard tends to be more easily achieved with compact designs; less than compact designs are likely to require an increased building fabric specification in order to achieve the standard.
A Passivhaus building must meet three key criteria to achieve certification:

- minimised demand for heating and cooling
- airtightness of the building, and
- significantly reduced whole building energy use.

A Passivhaus is typically certified upon building completion, with an airtightness test and photographic evidence verifying build quality, though there is no time limit. In its purest technical terms, Passivhaus is defined by the Passivhaus Institut as a building with the following characteristics* (Feist 2007):

1. Heating/cooling demand: 15 kWh/m² per annum OR heating/cooling load: 10 W/m²;
2. Airtightness: 0.6 air changes per hour in a building positively pressurised to 50 Pascals (0.6 h⁻¹ at n50);
3. Total Primary Energy** Demand: 120 kWh/m² per annum (the energy allowance for the whole building, including plug loads).

* For most climates. There are modifications for extreme, hot and/or humid climates.

** The term ‘Primary Energy’ refers to energy in its raw form, e.g. coal. Many European countries, and the Passivhaus standard, use the primary energy assessment to determine the real efficiency of a building. This takes into account the input power required to generate the power we actually use. Using default figures included in the PHPP, the allowance of 120 kWh/m² of primary energy translates to an allowance of 46 kWh/m² per annum of energy actually arriving at the building.

As an energy efficiency standard, Passivhaus has no requirements to consider sustainability of materials or embodied energy. A project that targets sustainability holistically may consider these elements, in addition to complementary factors such as water, transport and biodiversity.

**PHPP and certification**

The Passive House Planning Package (or PHPP) is the software used to verify that a building design will achieve the Passivhaus standard, if constructed as modelled. It is a sophisticated spreadsheet which runs to 30+ tabs and covers inputs such as U-values, windows, shading, ventilation, heating, cooling, electricity, climate data etc. The characteristics and orientation of the thermal envelope are entered together with supplementary information on the buildings systems to determine whether the Passivhaus criteria will be met.

In the normal course of events a Certified Passive House Designer will confirm that the design achieves a preliminary Passive House certification before the project begins construction. At this point an airtightness value of 0.6 air changes per hour is assumed. Once on site, a photographic record of the installation of the thermal performance features is made. When the airtightness envelope is complete a blower door test is carried out to determine the actual airtightness of the construction. On completion of the

![Figure 3. Passivhaus basic construction. (image courtesy Passivhaus Trust, UK)](image)
The Bushbury Hill Primary School is one of the first Passivhaus schools to be built and certified in the UK. The building houses 120 primary school students, a kindergarten for 30 children, and serves children from one of the areas toughest housing estates. The project met the Passivhaus criteria with a strict fixed budget, focussing on optimising a simple design. The outcomes for the client have been credible and genuine, with the principal reporting excellent occupant satisfaction and beneficial learning outcomes.

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Passivhaus building examples
Among the number of realised projects internationally is the world’s first Passivhaus high-rise office building, the RHW.2 building in Vienna, Austria. This building, completed in 2013, houses 900 staff for the Austrian Raiffeisen-Holding Group and maintains many of the design principles typical for high-rise office buildings, such as full-height glazing and open plan offices. The clever energy strategy for the building includes canal heat rejection and reticulation of waste heat from the company’s data centre.
Passivhaus in Australia

Design teams have adapted their techniques to different building types and climate zones across the globe, while drawing on Passivhaus principles. This part of the paper will explore what is behind the standard’s success and what can be learned from an Australian perspective.

At the International Passive House Conference in Frankfurt in 2013, there was a new category amongst the usual Euro-centric sessions – Passivhaus in Hot and Humid Climates. Presentation on projects in a diverse range of geographical locations, such as Spain, Turkey, Mexico and Indonesia, exemplified Passivhaus’ widespread acceptance and adoption, and that it demonstrably works.

Australia, sadly, is falling behind in our application of low-energy standards. Perhaps energy has been too cheap and too easy to come by for too long; perhaps it is not in our culture to be frugal in terms of building energy. Whatever the reason, our landscape lacks any great number of low energy buildings. While there is a multitude of tools available, Passivhaus is the strongest yet to actually ensure the realisation of a high-performance building. Many of the Australian design-stage modelling tools, including NatHERS, BCA and NABERS, have marked shortfalls, including idealised assumptions and no guarantee of the built product matching the design. Although Passivhaus uses what many would regard as just a spreadsheet tool, the basis of the Passive House Planning Package is in pure building physics and there are numerous case studies [Feist 2007, Oram 2011] that have verified the predicted result as being a precise representation of the as-built product.

Passivhaus buildings in the colder climates of central and northern Europe, as well as the northern US and Canada, have been resounding successes. The Belgian government has even taken the standard to Antarctica, at the Princess Elisabeth Station. In hot climates these ultra-low energy buildings are also starting to be built, with projects completed in Spain, Mexico, Greece and Indonesia.

These are climates where the extremes of cold or hot make life very uncomfortable, and buildings need to provide refuge and relief. In much of the populated areas of Australia, where the climate is mild to temperate, comfort can be achieved with ease when compared with more extreme climate zones. The temperature differential (or the difference between the outdoor and desired indoor temperatures, and that which our air conditioning and heating systems must abate) is on average around 10–15°C, whereas in places such as Germany and Scandinavia this can be in excess of 45°C. The Passivhaus tool is applicable across all climate zones, from Antarctica to Indonesia. Recovering thermal energy from exhaust air is crucial for buildings designed to the Passivhaus standard and especially those in climates with a large temperature differential. At the Monte Rosa Alpine Hut, a Passivhaus ski lodge, there have been recorded temperatures down to -40°C, while temperatures inside are maintained at a comfortable 20°C, notably with no active heating system.

Around the world there are in excess of 50,000 Passivhaus buildings (IPHA 2014). The real number is unknown; only around 8,780 have attained the official Certified Passivhaus tag (IPHA 2014), with the majority functioning without the official stamp of approval. Indeed, many of the more pioneering buildings have been left unstamped. Anecdotally, there may be more than one Passivhaus building in Australia, and there will soon be at least one certified project.
‘Fabric first’ approach to design

The Passivhaus approach to building fabric is one that is applied without compromise. ‘Without compromise’ is the mantra; thermal bridges are eliminated, insulation is wrapped carefully around every surface of the building, and airtightness is a key concern. There are no single-glazed aluminium windows. Whilst many imagine some 300mm thick R10 wall section, there is no strict requirement to the amount of insulation required. In southern Australian climates, it is possible to build a compliant Passivhaus dwelling using a wall of R4, R6 roof and R2 floor. Though this might be a cut above the base building code requirement, it is easily achievable.

Windows in a Passivhaus building are often one of the most costly and complex elements to get right. Depending on the expanse of glazing, orientation and available shading, it is likely the window specification (glass and frame) required will fall somewhere between the U-value of 1.4 and 2.0, which is not available from every supplier, but achievable nonetheless. Accordingly the local glazing market is catching up, with renewed interest in developing the high-performance end of the window market to overcome the current requirement to import much of the high-spec stock.

Of the three defined Passivhaus criteria, the most difficult to realise is usually the building airtightness. In a leaky building, air infiltration can account for as much as 50% of the heating and air conditioning loads, and accounts for most of the discomfort due to draughts or excessive heat gains. Achieving the Passivhaus standards for airtightness eliminates these problems. To date, airtightness has been almost entirely omitted from design and construction considerations, with specifications on low-energy buildings only starting to include requirements for building sealing. Although the BCA has a whole section on building sealing, the requirements have been vague and difficult to check and enforce. Achieving the Passivhaus level of airtightness requires a building strategy overhaul; building enclosure details are developed at the design stage, and may require a change to the staging of various building processes. It may require careful use of appropriate layers, tapes and/or vapour membranes to form a continuous airtight barrier.

The domestic sector has seen the most research in the area of building sealing, and the results have been particularly poor. A typical Australian home built before 2000 would most likely achieve an airtightness test result in the realm of 10 air changes per hour (ACH), measured in a pressurised building (to 50 Pa), and in many homes can be up to 25 ACH (Biggs 1986). New homes may not be much better. Studies on office buildings reveal the average at around 8 ACH (Egan, 2011). In comparison, the Passivhaus standard requires that the building achieve excellent airtightness of 0.6 ACH, or roughly 15-40 times better than current practice.

Importance of eliminating thermal bridges

Generally, insulation of the building fabric is included to resist heat transfer. Insulation is specified based on its R-value, or thermal transfer resistance. A thermal bridge is a localised area of the building envelope where the heat flow is different (usually increased) in comparison with adjacent areas. Thermal bridges most commonly occur across window frames, structural members, penetrations of the building fabric (e.g. pipe or ductwork) and at junctions of the building fabric (such as where a wall meets a floor or ceiling). In these areas there is an inconsistency in the insulation and this results in a localised change in heat transfer.

Thermal bridges are, quite literally, bridges across which thermal energy can flow. In winter the heat pumped into a building is lost when it flows out across window frames, for example; in summer the reverse happens with heat from outside being transferred inside to counter the work done by air-conditioning systems.

Those involved in the design of buildings are accustomed to seeing them, including them in our design and simply accepting them. These are, however, imperfections in a thermal envelope. When tallied up across a whole building, these small bridges result in significant energy losses; unabated thermal bridges can result in big energy (kWh) and financial impacts.

Thermal bridges occur everywhere, and can be tricky to firstly track down, and then eliminate. A skilled designer will learn to recognise them. Whilst a small number of insignificant thermal bridges can be inconsequential, the real target for any good building design is to seek and eliminate them, as the effects of thermal bridges are:

- altered interior surface temperatures; in the worst cases this can lead to moisture penetration in building components, condensation and mould growth
- altered, usually increased, heat transfer

The following thermal images show the ‘before’ and ‘after’ of a retrofit program for insulation and thermal bridging measures applied to a terrace office building. These thermal images are taken from outside on a cold night, with indoor heating operational to ensure high indoor temperatures.

The ‘before’ thermal image shows that a significant proportion of the heat pumped into the building to

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maintain comfort conditions was simply leaking to
the outside, mostly across thermal bridges around
windows, doors and at floor-to-wall and roof junctions
(all areas shown white, yellow and red). The amount
and rate of heat loss was significantly decreased in
the ‘after’ scenario (note all surfaces are ‘cold’, or
blue) and the resulting energy required to maintain
a comfortable indoor environment was significantly
reduced. The answer was simple insulation and
thermal bridge prevention methods, including thermal
breaks across fixings and tight air sealing around
windows and doors.

**Air quality – is there more than one solution?**

A Passivhaus building is airtight, necessarily so in
order to enhance comfort and efficiency, as previously
outlined. In order to ensure the building is habitable,
there is a requirement for ventilation to be introduced.
A popular and persistent myth surrounding Passivhaus
buildings is that they cannot include operable
windows. Natural ventilation is very much encouraged
when conditions are suitable. For times of the year
when conditions outside prevent the building from
using natural ventilation, the required solution is a
mechanical ventilation system.

At least one study has shown that the use of
mechanical ventilation with heat recovery (MVHR) is
actually more energy efficient than natural ventilation
for a thermally efficient house in the UK context, when
providing the same levels of thermal comfort (AECB
2009). The MVHR is a simple-to-operate system that
ensures that good air quality is maintained at all
times, regardless of occupant behaviour or presence,
eliminating problems such as odour, stale air and
excess moisture. For maximum energy efficiency, an
air-to-air heat exchanger captures thermal energy –
whether heat or ‘coolth’ – from the outgoing air
stream, keeping a high proportion of the thermal
energy that has been used to condition the indoor
environment inside. The system typically uses 100% outside (fresh) air and does not recirculate exhaust air.
Filtration (typically F7 filter or better) should also
be used to ensure that incoming air does not contain
outdoor pollutants or allergens. An added benefit of the
ventilation system in an airtight building is the exhaust
of VDCs and other toxins that are typically found in
buildings from common items such as furniture and
finishes. While it is possible to select low-emissions
items, in a standard building this may be completely
overlooked.
Integrated design and quality control

Unlike many building rating and certification tools, the ultimate aim of building to the Passivhaus standard is not necessarily the final certification, but rather to achieve exactly what the standard promises to deliver: a comfortable, high quality, healthy building that costs very little to run. The certification is the guarantee of quality, and a verified and marketable result. Looking forward, the driver for success of Passivhaus will be market recognition of its benefits, whereby the capital investment becomes worthwhile given an identifiable return.

The key to achieving the Passivhaus standard on any building is much the same as any holistic measure: it must be integrated from day one. Sustainability in any form cannot be designed as an ‘add-on’. For the client, this means getting expert advice early. For the design team, this means getting everyone together from the concept stage to ensure the aesthetics, functionality and constructability are not in conflict.

A certified Passivhaus is a guarantee of quality and the Passivhaus Institut works hard to ensure that the stamp that bears the name upholds its integrity. The Institut has established individual certifications for Passivhaus professionals to assist building owners and designers to realise projects with ease. The following certifications are available for Passivhaus professionals and building components:

- Certified Passive House Designer or Consultant design professionals, likely an architect or engineer, with ability to work with the PHPP
- Certified Passive House Tradesperson builders and tradespeople who have been trained to apply the exacting requirements
- Certified Passive House Components high performance building components including window frames, glazing, skylights, external doors, curtain walling, wall panels, insulation, heat pumps and ventilation systems
- Certified Passive Houses a completed building that has been certified as meeting the Passivhaus standard

It should be noted that a Passivhaus building can be realised and certified without the use of certified designers, consultants, tradespeople or products. These certifications have been established to provide clear direction in the market, but are not prerequisites to success. Additionally, many of the certified components, including fabric components such as windows and insulated panels, have been certified with central European climates in mind and will likely exceed requirements for milder climates such as those in most regions of Australia. The engagement of a Certified Passive House Designer and/or Tradesperson can help project teams with these tasks, having demonstrated the required knowledge and expertise to prepare and execute a design according to the stringent requirements of the standard.

Cost and ease of build

With the first projects in Australia currently in various stages of design and construction, information on costs is not yet readily available. With many of the pioneering residential projects sitting at the ‘luxury’ end of the market it will also be difficult to equate this to a typical dwelling. Long-term tracking data from Europe, as part of the Passive-On project, shows that a residential Passivhaus project is likely to require between 3-8% more in upfront costs (Passive-On Project, 2007); however many projects have been completed with no additional investment (Architute, 2012). Any additional costs are quickly recouped through lower operating costs, usually within around five years or less. For example, the additional investment in materials such as insulation is partially offset by the significant reduction, or even elimination, of heating and air-conditioning systems. With the health, wellbeing and comfort measures introduced by the stringent build quality, there are many benefits that also cannot easily be quantified. Applications of the standard in healthcare, education, aged care and social housing could have widespread benefits.

The current unknown factors in building to the Passivhaus standard are the availability of specialist products and materials, and the availability of skilled tradespeople and builders. The former is improving steadily; there are now a number of Passivhaus-specific product suppliers. Companies already in Australia whose offerings include appropriate products overseas are starting to make them available locally, due to the persistence of consumers. The number of builders and tradespeople is increasing much more slowly, though the work of suppliers and design experts to educate on the benefits of this type of construction methodology is helping to spread the word.

Current supply is well short of meeting demand. The main difference from the construction perspective regards putting in place the appropriate processes and taking the time to ensure that the build quality is appropriate, in order to achieve a building that is airtight and free from thermal bridges. Anecdotally, many are unwilling to take on projects, at the risk of delivering an underperforming product, or are significantly hiking up construction costs to shield themselves financially. Given sufficient education and training, these issues are gradually being overcome.
Conclusion

Any good building is designed around providing not just an aesthetically pleasing structure, but also the essential provisions of comfort, shelter and a healthy indoor environment. As we move into a more sustainable future, the hefty building systems, associated energy bills and greenhouse gas emissions must also be reviewed. When adopted as part of an integrated approach, the Passivhaus standard ensures energy efficiency, comfort, excellent air quality and low operating costs through just three major areas of focus: insulating correctly, good building sealing and reducing total electrical loads. The standard is about the very basic elements of building well and, with the core elements based in physics, it is backed up by decades of research and real world exemplars. With advantages including an enhanced quality of life and future-proofing against from energy price escalation, Passivhaus has established itself as a leading international standard for comfortable, healthy and affordable low-energy buildings, by scale and diversity of application.

References


About the author

Clare Parry is the Chair of the Australian Passive House Association, the official Australian affiliate of the International Passive House Association. One of the few Certified Passive House Designers in Australia, Clare is currently working on a number of active projects in the education, commercial and residential sectors. In 2013 Clare was awarded the AIWA Future Leader Award. Clare is also a Green Star and LEED Accredited Professional, NATHERS and NABERS Assessor and a member of the Living Futures Institute, International Passive House Association (IPHA) and Chartered Institute of Building Engineers (CIBSE). Clare is a keen hockey player and cyclist, and lives in bayside Melbourne with her partner and their dog, Ralph.

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