III

INDUSTRY CORNER

SUSTAINABLE MICRO-VILLAGES AND THE CARWOOLA HOUSE PROJECT IN CANBERRA, AUSTRALIA

Paul Barnett[1] FAIA, BSc. Arch, B.Arch.

INTRODUCTION

Our needs as social and familial beings change over the course of our lives; however, it has become common practice to build as though these needs remain static through time. The needs of a child, young adult, family, middle age and the elderly are dynamic between generations, and adding to these evolving life needs is the crisis of housing affordability. Three decades ago a house could cost 3–4 times an individual's annual income, today that cost is closer to 10–12 times. In response to these challenges, this article explores the concept of Sustainable Micro-Villages, providing insight into a new approach to energy-efficient housing with reference to our case-study project—Carwoola House.

Sustainable Micro-Villages can be defined as a cluster of integrated dwellings, referred to here as Living Pods. Essentially a "single house" on a single site, these micro-villages can be comprised of two or more smaller buildings that provide private dwelling space for a single person, couples, couples with children, parents, elderly, friends and any combination of social groups. Living pods cluster around a natural garden setting, enhanced by waterharvesting, and are connected with covered, open or enclosed links depending on the climate of the site. The recent iterations of this type of dwelling also incorporate solar passive design, passive house and greenhouse technology.

In Australia, new house designs are evaluated as part of an approvals process for their energy rating.[1] The Australian Building Code requires a minimum 6-star rating, ranging up to 10 stars for any new home to be built. A 6-star rating provides a good level of insulation and energy performance if built correctly, while 10 stars represent the highest level of energy performance and refers to a dwelling that needs no heating or cooling. Sustainable Micro-Villages consistently achieve an 8 to 10-star rating by combining Solar Passive Design principles (good orientation, thermal mass and thermal performance) and Passive House Technology (high thermally performing building with low air leakage, no thermal bridging, high performance glazing and heat recovery ventilation) in various combinations to suit the climate, context and budget.

1. "The Nationwide House Energy Rating Scheme (NatHERS) is a star rating system (out of ten) that rates the energy efficiency of a home, based on its design." (http://www.nathers.gov.au/)

1. Paul Barnett is the Director of Paul Barnett Design Group, an award-winning architecture firm with offices in Canberra and Melbourne (Australia). Paul is a Senior Architect and certified Passiv Haus Designer with the Passiv Haus Institute based in Germany. He and his firm has been designing and building sustainable homes for over 25 years, with a particular focus on Passiv Haus Technology, Solar Passive Design and Sustainable Design principles. www.pbdg.com.au

KEYWORDS

Micro Villages, Living Pods, Naturescapes, Solar Passive, Passive House, Photovoltaics, Waterharvesting, Biophilia, Permaculture, Biodynamics, Water Storage.

BACKGROUND

In our design firm, we have been reviewing the briefing information from our clients over the last 25 years, as well as ideas from our friends and colleagues and there has emerged a relatively consistent pattern of needs. Through life we move from being a newborn wrapped in a very small space, to exploring as children and expanding into a protected space as teenagers. Then as young adults we move into the world and leave the nest. When we mature and create new families, we build our own nest and the life cycle repeats. In Australia, this pattern is not usually taken into account, with traditional housing models focussing primarily on the "nuclear family" at peak demand, i.e., a couple with dependent children.

Evidently, a more dynamic space is required to suit changing needs over time. However, there are several challenges when it comes to creating comfortable and beautiful environments

FIGURE 1. Carwoola House

for people to live out their lives. Among these are housing affordability, creation of community, how to achieve real sustainability, making our habits energy efficient, using and re-suing materials effectively and living in harmony with the natural environment.

Sustainable Micro-Villages are able to respond to each of these issues, and we have found that unique designs can be realised through an integrated, systems approach to energy efficient housing. Our case study project, Carwoola House, has successfully implemented the micro-village concept and living pods system based on a combination of sustainable design principles. Carwoola House (Figure 1) delivers a dynamic village setting that enables the owners to live in a sustainable and adaptable environment, and this is just one example and interpretation of Sustainable Micro-Villages. In this paper, we discuss the Carwoola House project, from brief through design to construction, and also look ahead to planned future works. We explore the elements of the integrated approach, including design philosophy and implementation, technology and materials, and review the outcomes; the house achieved a performance of an impressive 9.8 Stars out of 10 using the NatHERS rating scheme, however, the planned upgrades to the waterharvesting, collection and reuse processes will likely take that figure higher.

THE CARWOOLA HOUSE PROJECT

Our clients, Ann and Alison, had decided to move from Sydney to Canberra for work reasons. Their initial search was for an existing house on a five-acre property that would be comfortable and efficient to run throughout the year. When this proved difficult to find, the couple purchased a 20-acre property at Carwoola, 25 kilometres southeast of Canberra, the Australian capital. With only a few sheds on site, they began visiting project homes for inspiration to build, but new bushfire regulations introduced in the wake of the 2009 fires in Victoria shattered their dreams of a timber house, and the models they visited didn't satisfy their expectations.

> "We didn't want a house that was too big, because the bigger the house, the more you have to clean; and although we don't have family nearby, we only needed space for one or two people to visit at a time.
>
> "We wanted it to be sympathetic to the environment and we worked with Paul to agree on the spatial relationships and how we wanted to use the spaces. We settled on two bedrooms and a study, and a combined living, dining and kitchen area."
>
> Client, Alison

We approached the brief with the concept of Sustainable Micro Villages at the forefront of our design, incorporating artisanship and sustainable technology. The site master planning included greenhouse staging in the future, naturescapes, an orchard and waterharvesting. Being in a rural setting allowed the introduction of additional design parameters such as permaculture zoning and management of living in a bushfire prone region.

The final result is a 9.8-star, solar passive, Passiv Haus, living pod system with a masterplan that sets out the visitor's pod (which was used for living in while the main pod was built) and includes provision in the design for a future greenhouse. The current works in progress include a shade belt of trees to the north and a naturescape complete with waterharvesting and swales, an orchard and hens.

SUSTAINABLE MICRO VILLAGES

The Sustainable Micro Village Concept is made up of 3 environment types: *Living Pods, Greenhouse Transitions* and *Naturescapes*.

I. Living Pods

Living Pods range from a single room to multiple rooms and from private space to social space. They are designed to accommodate the changing familial and social requirements of a "home" over a lifetime. The concept of living pods is primarily concerned with a habitat that supports the inhabitant in all phases of their life, overcoming flexibility restrictions that are evident in traditional housing forms.

In a successfully implemented Living Pod system, families may retain their home as their spatial and financial needs grow, shrink or evolve. Construction or refurbishment can be staged as funds become available, and there is the option to establish an income from rental accommodation, such as Air BnB, when particular pods are not in use.

This concept has the advantage of reducing the burden on children saving for property of their own and enables elderly to be cared for more effectively in a social and familial setting. This new model differs from a traditional single house in that it allows for various combinations of people to live together and/or separately throughout their lifespan. For example, a large family

FIGURE 2. Living Pod Site Section

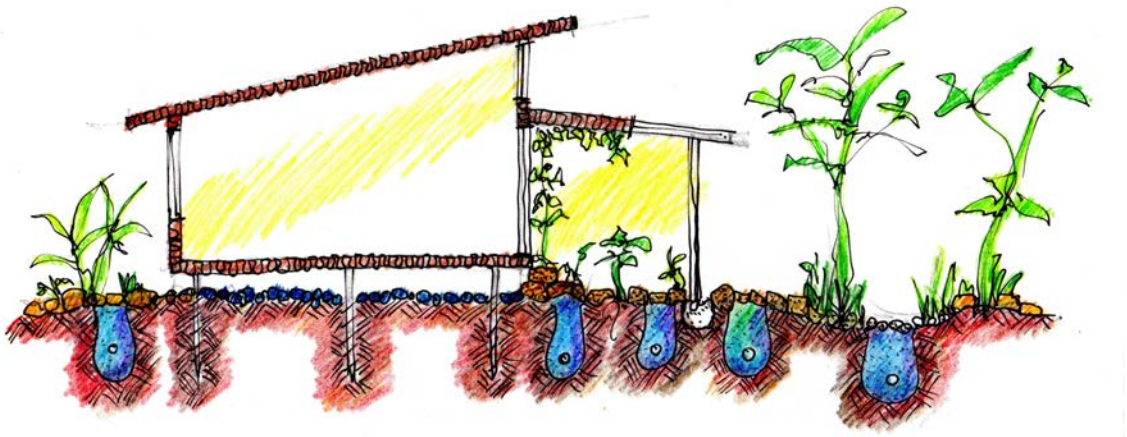


FIGURE 3. Living Pod Cluster Site Section

may use all the living pods as a family unit, whereas a group household may be made up of young children and parents in one living pod with an elderly parent living in their own pod.

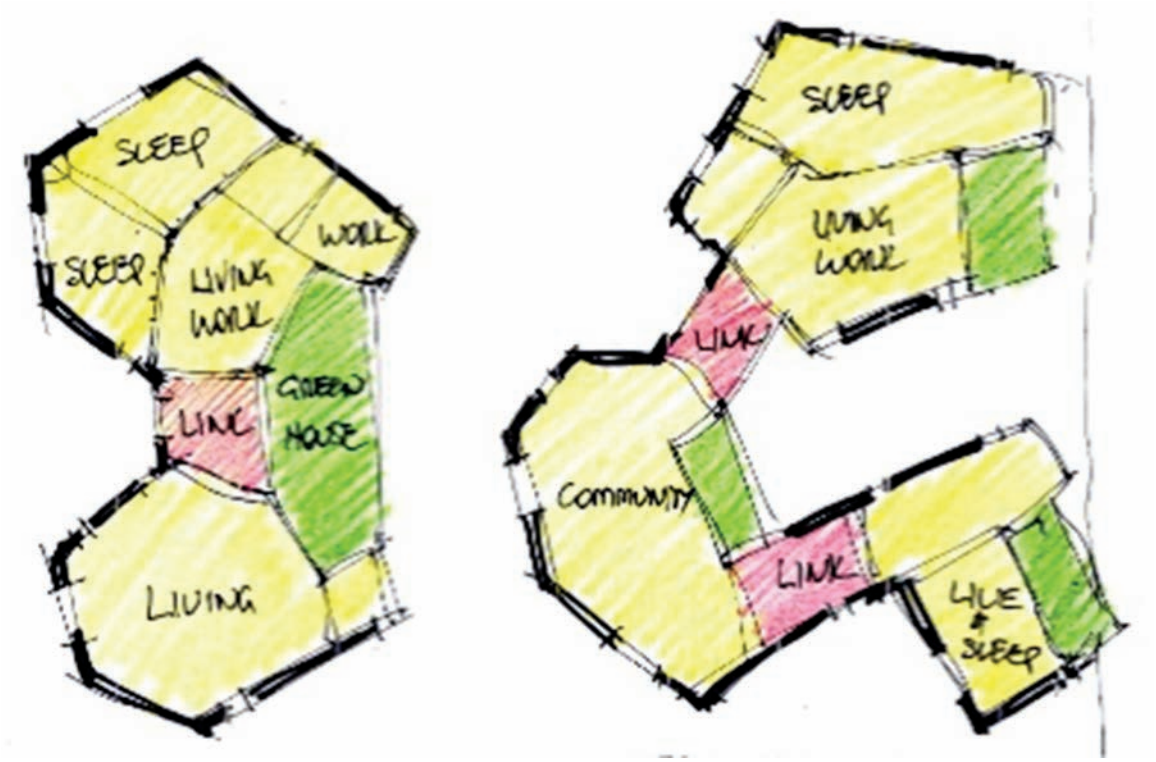
II. Greenhouse Transitions

When creating micro villages that are comprised of two or more connected dwellings, there is the opportunity to enhance the experience and benefit of nature through both the external and enclosed connections. The enclosed connections are designed as greenhouse rooms that connect inside to outside and provide a transition between the two. A greenhouse may serve many functions in the micro village precinct.

Primarily, the Greenhouse is a modified environment that helps balance the extremes of seasonal temperatures and climatic conditions by linking internal space with external space—the Living Pod with the garden. In cold seasons the greenhouse adds to temperature generation through plant life and passive solar gain. Through summer months, sunlight is eliminated from the greenhouse glazing and the greenhouse works to shade and provide coolth through the soil, rock and plant enclosure.

Greenhouses generate fresh air and can be a source of beautiful scents from flowers, herbs and foliage. They provide a source of food with fruits and vegetables, as well as providing a contemplative place to sit, walk, stand, lie and heal amongst an enhanced nature biodiversity space. Being warm in winter and cool in the summer makes them a comfortable place for pets and people. They extend the growing season for food and allow an intimate connection with nature all year round, an integral part of a sustainable micro-village precinct

FIGURE 4. Single Site Living Pod Cluster



III. Naturescapes

The design of a Naturescape is primarily concerned with the opportunity to enhance water collection that will feed everything that follows. Water can be collected in several ways: by diverting overland flow water, by capturing rainwater directly, and by re-directing roof water back through the Naturescape before it returns to the local stormwater system or rural waterways. The water is returned cleaned and purified form the natural filtering process of the waterharvesting trench system.

Soil profiles are sculpted to create ways of holding the water for the Naturescape and to feed the soil while underground trench systems are created to hold water for long periods after the rain has stopped. The effect of the surface profiling and the sub-surface trenching systems is to raise the moisture content of the soil.

The Naturescape system has been implemented and studied in several areas over the last two decades with unprecedented results. It has been found that similar trees, both within the naturescape and others located just away from the naturescape, demonstrated a dramatic difference in growing pattern. Those in the Naturescape grew at a rate of over 3 times that of the same trees located just 20 metres away. It has become evident that Naturescapes are powerful supporters of natural eco systems.

To create a naturescape, we remove the compressed soil, terrace the landscape to capture rainwater, reverse the water runoff and allow the water to seep into the ground. The water harvesting channels are placed like arteries of a body through the ground, which feeds moisture to all the roots of our new environment.

FIGURE 5. Orana School Naturescape after 10 years

Dry laid rocks (Figure 6) are used to form terraces and provide a natural haven for animal life, such as geckos, lizards and beetles. They provide a place for creeping plants, succulents and ground covers to take root and benefit from the coolth from the rocks in summer and the moisture emerging from the waterharvesting trenches. We condition the removed soil from excavation by adding soil improver and natural biological solutions that are found in normal healthy soil. Once improved, the soil is placed back into the terraced structure that is now fed by overland flow, direct rain and diverted rain form adjacent buildings.

The water is now held and distributed underground. Trees are planted around 1 every $10m^2$ and grow to become a canopy that provides an understorey in summer for the next layer of plant and animal activity to be created. In Canberra, we use mostly deciduous trees as shade in the dry summer months and open the understorey to light and sun in winter: a solar passive house in nature.

By mimicking nature, Naturescapes create a dynamic sustainable garden. They are fed directly by rainwater, grey water, and collected roof water. Roof water is re-directed back through the Naturescape before it returns to the local stormwater system. Underground trench systems hold water for long periods after the rain has stopped, redistributing it to the surrounding soil and plants, which raises the moisture content of the soil.

Naturescapes are healing environments. They create personal and social space, spaces that nurture and natural environments for growing food and flowers and to enhance the biodiversity of the local flora and fauna.

FIGURE 6. Carwoola House Waterharvesting Trench

Waterharvesting

We have environments that were created over 20 years ago by the original developer of waterharvesting, Paul Totterdell, and supported by Tim Edmondson, who worked extensively at the Orana School for Rudolf Steiner Education in Canberra. These environments have now reached maturity.

The environments create havens for small bird populations that can struggle to find protection in an urban environment, where trees may be placed as a feature but not as part of a forest. Nature turns up when the right conditions are in place.

The wonderful thing about these landscapes that mimic nature is that they improve over time. The soil is kept moist if there is periodic rain, as the water harvesting channels hold the water and allow moisture to spread out in the soil. After a few years, the tree root system finds its way to the channels and starts to mimic the shape of the trenches and forms a natural root channel where the water is taken up directly from the channel and feeds the trees and plants.

If the summer is a dry spell, the residual moisture in these environments lasts much longer than normal. Its only after a sustained dry spell that the smaller plants may need watering via the water harvesting channels, thereby allowing water take up from the channel, rather than the surface. Even on a clear night, we see water enter the system from dew forming on the roofs.

When we create and live in the micro-village environment, we are reminded continually of the pulse of the planet and the seasons and how what we do influences the earth. In managing a living pod system, greenhouse plant and soil and the abundance and cycles of a naturescapes, we are participating in a sustainable eco-system.

What we buy, how we make compost free of pollutants and antibiotics, what we consume and what waste we create, what standard of health we set, and how we own responsibility for our physical, mental and spiritual health are brought up in the consciousness imbued in a sustainable micro village setting. This consciousness extends from briefing, though design and construction

FIGURE 7. 3D render of a micro-village suburb.

and covers how we live with ourselves, each other, family and friends, our neighbours and how we may evolve as conscious human beings.

On a broader scale, when micro-villages are extended through a suburb, we create a new paradigm for sustainable living. They enable a re-connection with the traditional village structure and organic pattern of habitat, focussing on people and nature. The concept encourages a lifestyle of walking and physically engaging with the earth, and as a result our life span and quality of life is enhanced through the increased physical nature of the Living Pods. Social interaction and the spirit of cooperation is also embodied in the village.

DESIGN THEORY

When we design a micro-village, we work through a range of design parameters that are interpreted uniquely to each brief and site.

1. Siting
   For Carwoola House, we utilised an existing land platform from an earlier building site with 270° views to the north, east and south and was shielded from western sun and fire source by a 2-metre-high rock ledge. The site is nestled in to the hill.
2. Space-making
   Spaces such as entry, veranda, transition halls, bedroom, utility and social spaces are looked at in their relationship between the site, the views, the sun, the winds, and the way the clients wish to express their living. When we commence a design process, we ask the client's what they are wanting to imagine both now and each decade for the remainder of their life. This often brings up quite challenging responses. Our buildings are built to last and they need to serve the owners and subsequent owners and the environment for the duration of the building's life span, which can be hundreds of years.
   With space making, we use an abstract idea and discuss interactions between habitats. This enables people to understand the relationship between activity, contemplation and rest. It's from here that we commence the site planning and spatial planning of the building and surrounds as an integrated bio system.
3. Geometry
   Geometry defines the spaces that are generated through space making. Geometrical patterns, such as organic, crystalline, radial and rectilinear are considered when responding to spatial needs. The simplest geometrical form for construction is a rectilinear geometry, but this does not always serve the way spaces interact or function within.
   For Carwoola, we adopted a combination radial and crystalline geometry. When you arrive at the home, you are greeted by a plane of brickwork protecting the western face of the house from the bushfire source, western sun and prevailing dusty winds. As you enter the home through this blade, you move through a tapered transition space that narrows and then expands to arrive at a heart-shaped faceted living space that rises in height and serves as the symbolic heart of the home both in activity, geometry and proportion.

   Creating a sense of journey and transition and arrival is the purpose of the way geometry enhances spatial principle. All our work is generated this way with each project delivering its own unique combination of geometry defining space.
4. Structure
   Structure defines space through defining geometry. With this building walls are load bearing with wind shear walls timber internally.

FIGURE 8. 3D Perspectives

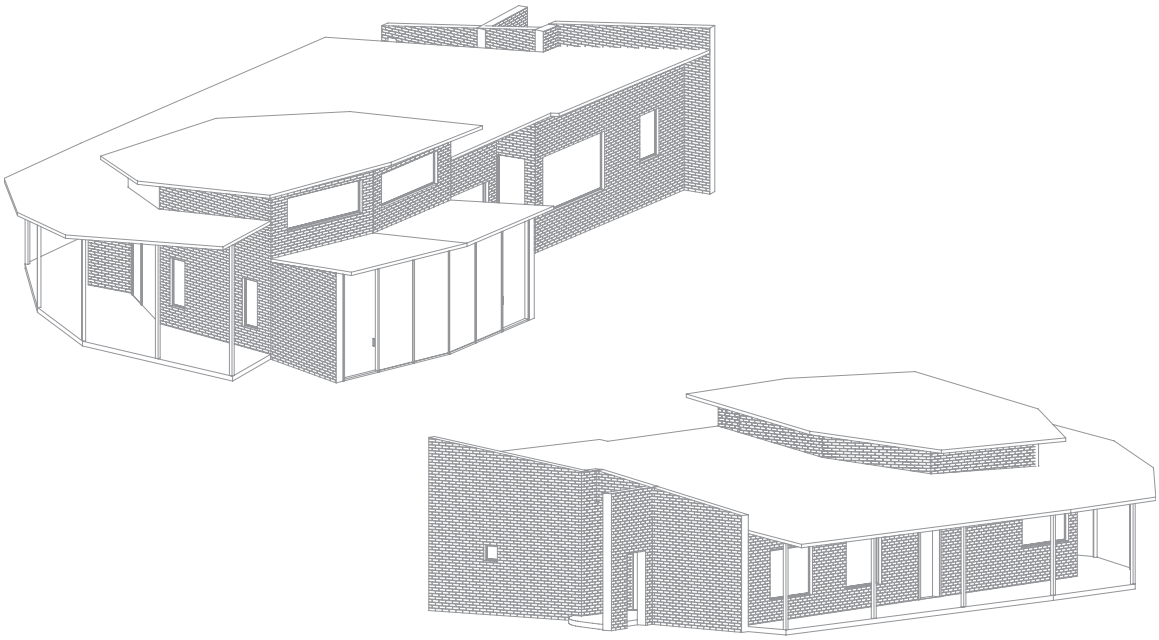
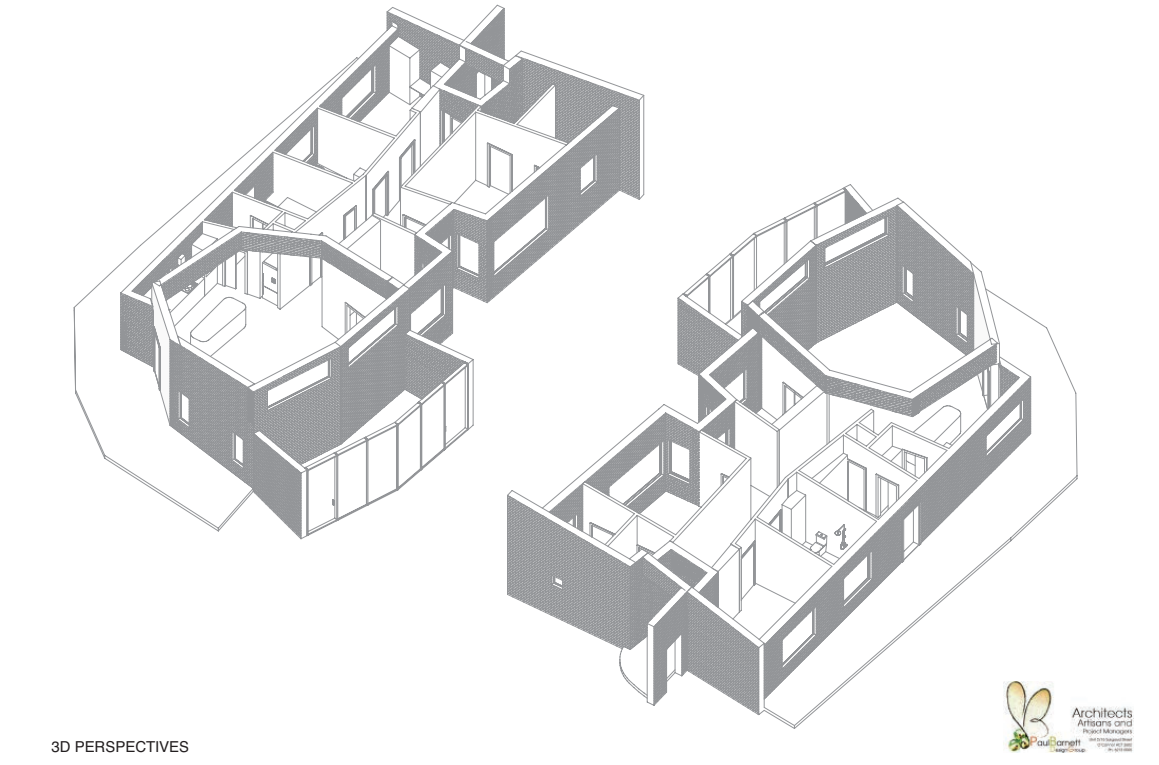


FIGURE 9. 3D Perspectives



5. Colours
   Colours are used to enhance mood and express geometry and form more clearly. Warm blue brown earth tones are in the brickwork both inside and outside. The intention was for the building to reflect the earth and the rocky outcrop setting. Timber, bamboo and plasterboard surfaces balance the warmth and robustness of the interior brickwork. This has provided a light-filled, cave-like peaceful quality.
6. Ornament
   Ornament is either integrated, applied or discrete. The idea of the building form as sculpture is the first expression of ornament. The brick sunburst and blade wall to the west are the second expression. Faceted internal geometry complemented by bamboo shelving (Figure 10) inspired by the artist Mondrian add another layer to the ornament of the building.

MANIFESTING HOME: HOW WE DESIGN TO BRIEF

Ann and Alison requested an energy efficient home for their rural property, where they could live off the land as much as possible. Manifesting the design was through the convergence of Micro-Village principles, design theory, sustainable technology and artisan construction. The bringing together of these practical and philosophical realms create environments that serve the planet, our culture and the diversity of our needs across our lifespan.

FIGURE 10. Carwoola House Bamboo Shelving

The Brief

Ann and Alison wanted to create a home for now and to serve them for the rest of their life. Their initial spatial requirements were interpreted in the design to respond to both current and future needs. The purpose of the brief is to clarify how people may live, particularly, how they are in contemplation and solitary work or rest, how they are during interaction with members of the household or family and how they receive friends, family and the local community during the range of social activities that occur through the seasons and through life. Essentially, the brief is a snapshot of peoples' view of the world through their eyes.

Design Theory Expressed

Our design theory is expressed uniquely in each project through the brief, site and specific project parameters.

For Ann and Alison, the combination of these principles has enabled them to live entirely as they wished, in a beautiful rural home with very low energy use. When we develop a brief, we are trying to understand the direct requirements and the implication of what our clients are asking. What they are wanting to create now and how this will serve them, as well as their extended family and local community over the decades of a lifespan.

When we design a micro-village system to resonate to a brief, we are marrying both clients' needs and the timeless aspects of site, sustainability, nature, cycle of seasons, and how this new environment serves the client through their lifespan and the changing needs during this time and the needs of others who follow. A building has a life beyond the lifespan of the current clients. We are considering timeless design principles when we apply a brief to allow

FIGURE 11. Carwoola House Interior

the building and environment to respond to change and to respond to the timeless aspects of nature and sustainability.

Micro-Village Master Planning

In our firm, we are now applying the theory of micro-villages to all our residential work. The masterplan for a micro-village responds to a residential brief and allows for a sustainable environment to be created over time. Each micro village masterplan will pick up the needs of the brief, in the particular site and embody living pods, greenhouses, and naturescapes. The masterplan is wholly or partially implemented at the initial stages and can be developed throughout the client's life and or those who follow.

Site Context

As Carwoola is a rural site, the limitations of micro-village are constrained by there being remote neighbours. On site however, there is more flexibility to enhance the Naturescape though applying the various zones as experienced with Permaculture Principles

Social Space and Private Space: Living Pod, Green House, Naturescape, Spatial Planning

We masterplan space by allocating the ideas of *journey*, *entrance*, *transition* and *habitat* to the site we are working on. With Carwoola, we have a single journey to the site from the main road. There are then two living pod precincts with a Guest Pod and a Main Living Pod. There is room for expansion of the Living Pods into a Micro-Village should the clients wish to expand their village population in the future. Social and private space is allocated both externally and internally as with utility and supportive spaces.

Solar Passive Orientation and Passive House Technology

Primary living space has been located to the northern face for effective solar gain in winter. Thermal mass has been applied through the concrete slab and internal brick walls. Passiv Haus standards have been applied in accordance with certification guidelines. These include airtightness, eliminating thermal bridging, high performance windows and doors and heat recovery ventilation.

Greenhouse Environmental Attenuation: Creating Greenhouse Zones

There are two Greenhouse Zones identified in our master planning work. One to the north of the Guest Pod and the other to the north of the living or connection point in the main living pod. These areas may be implemented in later stages to enhance the Living Pods and Micro Village concept.

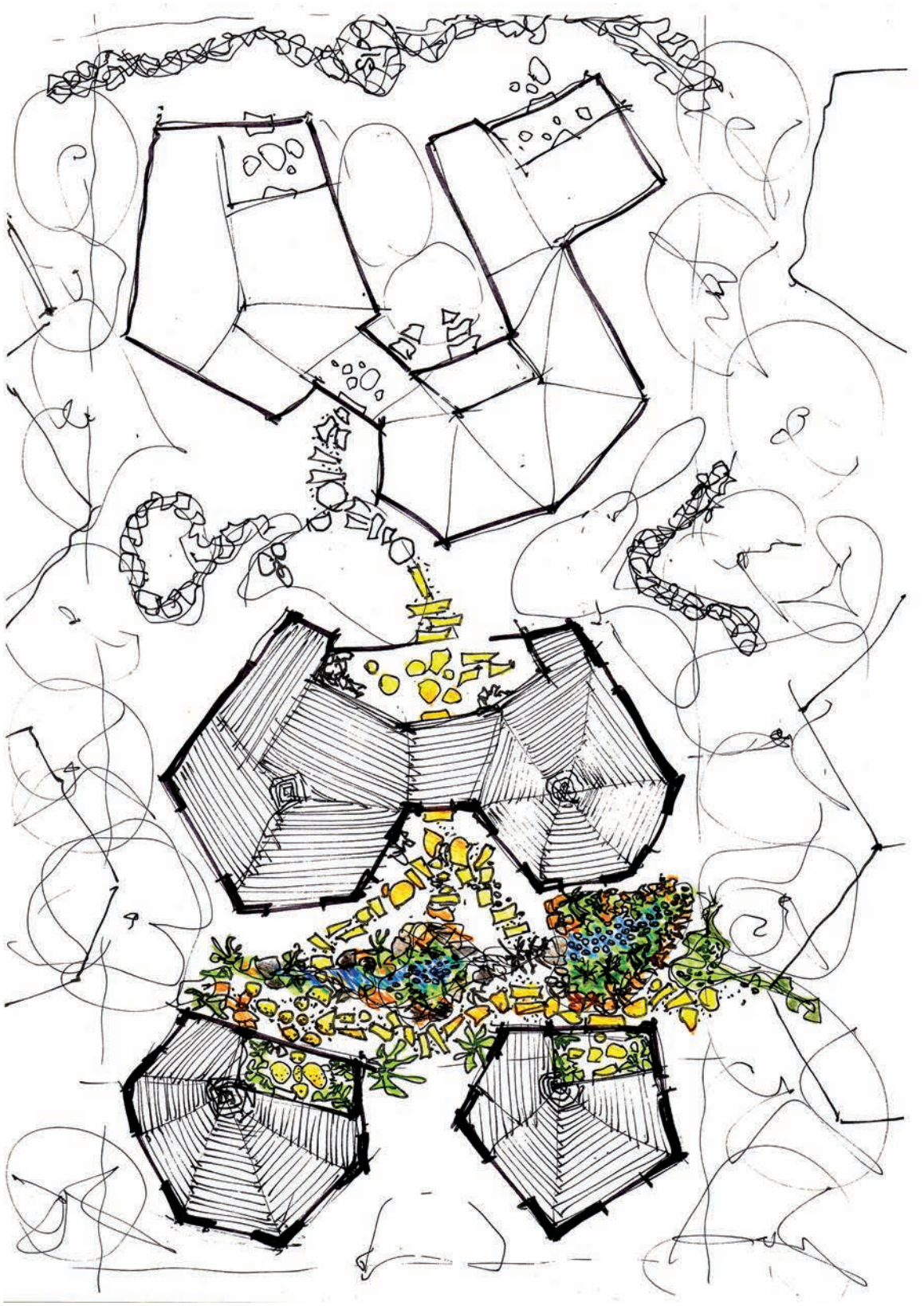
Naturescape Habitat

With more land in a rural setting than a residential setting Naturescape can be developed from close in with flowers, herbs, vegetable, shade, etc. to extend into hen runs, orchards and enhanced food production.

Sheltered Habitat: Wind and Fire Source Protection

Carwoola is situated in a bushfire prone area. Master planning located the main living pod nestled in below rock cutting some 2 metres high to the west of the pod, which provides protection from both fire source and prevailing western winds throughout the year.

FIGURE 12. Living Pod Cluster Plan



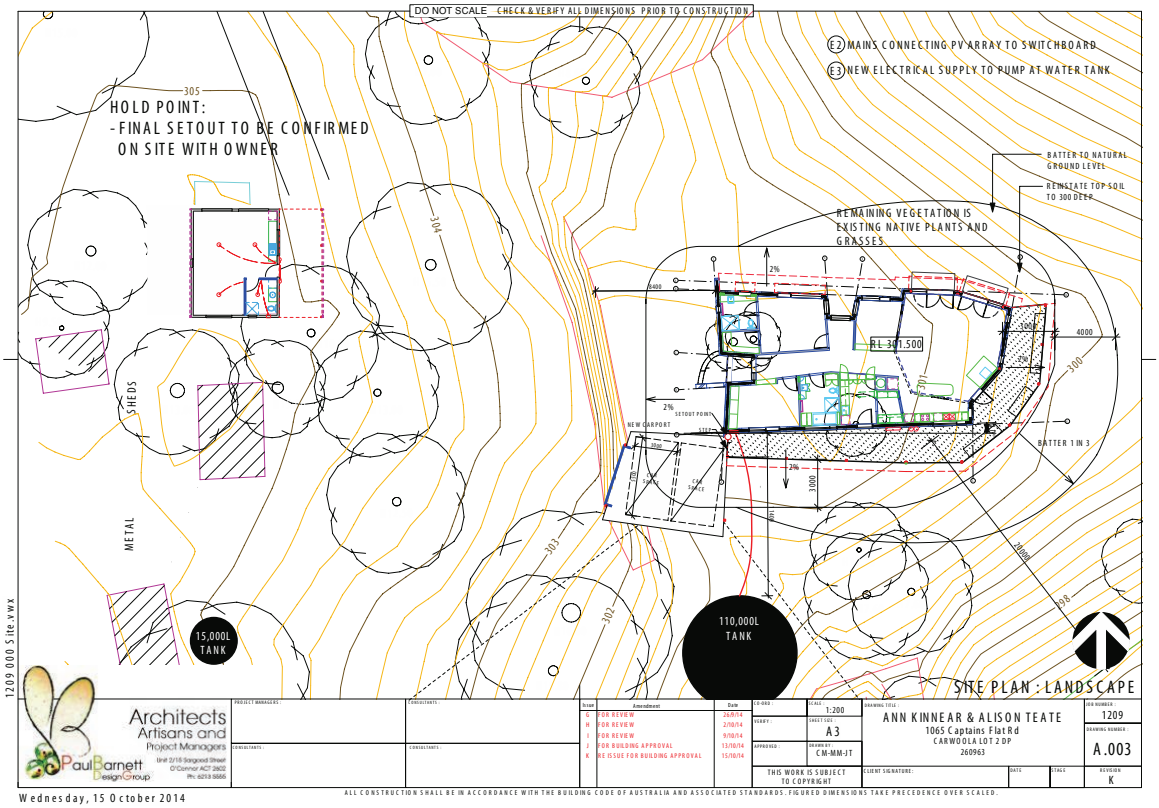
Biophilic Design

Biophilia and biomimicry have been expressed in the building planning, siting and through the expression of the Living Pod system. Floor plan geometry is referenced to both fractal and projective geometry to support the spatial planning. The use of natural materials, the interface through a greenhouse between inside and outside and the creation of a naturescape around the living pods is an expression and interpretation of biophilic design. The waterharvesting systems gather surface runoff water and rain water and filters it though the rocks, plants and subsoil as it journeys down the hill towards the contour swales and orchard.

TECHNOLOGY

When we design for low energy use and low embodied energy in construction, we are setting up a sustainable living precinct that aims at net zero energy and carbon. The rural setting at Carwoola provided an ideal opportunity to work with the natural setting and the timeless principles of solar passive design as well as current Passiv Haus technology. The existing site had been quarried and set up as a building site several decades ago. As part of touching the earth lightly, we were able to design a building footprint that sat within the existing terraced areas on the escarpment. The siting enabled full solar access during winter months to the main sleeping, study and living areas of the living pod.

FIGURE 13. Carwoola House Site Plan



Solar Passive Design

Micro-villages like Carwoola start with the principles of solar passive design:

- Orientation to let Winter sun in to living spaces and exclude sun in Summer.
- Well insulated to hold Winter heat and Summer coolth.
- Eaves that assist with sun access management.
- Southern verandas to cater for the interface between the land and the home.
- Thermal mass in the walls and floor to keep the temperature of the home interior more stable.
- Cross flow ventilation in the beautiful Spring and Autumn months.

At Carwoola House, the Summer sun is excluded with wide eastern eaves and solar shading to the north and virtually no windows to the west. The southern facade has a wide veranda to enable the activities of rural life to be sorted and cleaned before entering the living pod. The internal brickwork and concrete slab support thermal mass and there are high levels of insulation throughout the building.

Passiv Haus

Where Solar Passive deals with orientation, sun access, insulation and thermal mass, "Passiv Haus" deals with the technology of stabilising temperature.

The solar passive design principles are enhanced by Passiv Haus technology.

Passive House Standards require the following performance criteria are met:

- Maximum air leakage of 0.6 ac/hour at 50 Pa pressures.
- Delivers an average indoor air temperature of 21 degrees.
- Allows for internal temperatures to sit above 25 degrees for less than 10% of the time.
- Delivers an average internal surface temperature of greater than 17 degrees.
- Heat recovery ventilation providing fresh heat exchanged and filtered air around the clock.

The implications of meeting these standards have resulted in the following implementation:

- A complete building envelope with a membrane to prohibit air movement except through a filtered, heat exchange ventilation system in the extremes of Summer and Winter. This air tight building envelope uses a membrane system that allows moisture to move from inside to outside, thereby preventing condensation, but ensuring that the air is kept stable inside the home.
- Triple glazed, argon filled, thermally broken windows and doors that seal shut like a fridge door.
- A heat transfer system that retains coolth inside the house in Summer and heat inside the house in Winter and allows an exchange of filtered air that excludes dust and fog and allows the house and inhabitants to breathe.
- A high level of insulation has been installed with sub floor insulation R1, wall insulation R2.5, and ceiling insulation R6.
- Elimination of thermal bridging within the structure through carefully design detailing and use of thermal insulating bricks at the floor wall junction. This is achieved with a

thermal break beam that runs the perimeter of the house at the junction between the slab and the cavity brick wall insulation.

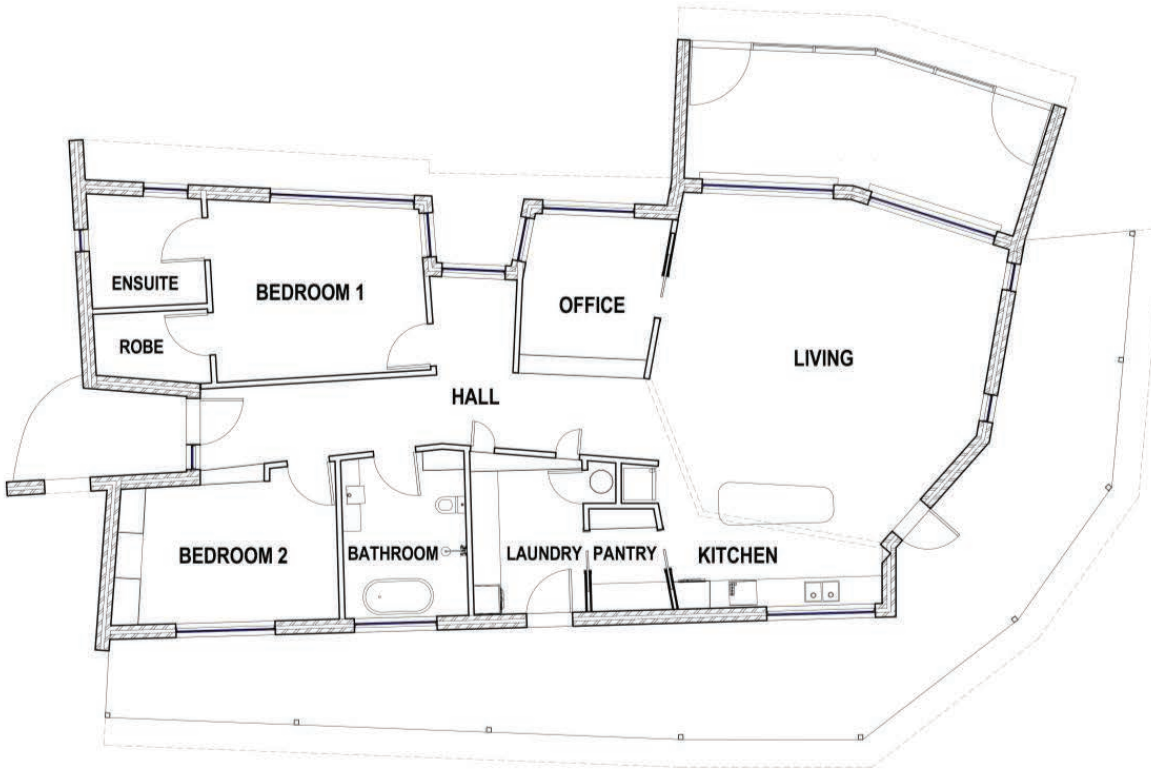
The effect of combining Solar Passive principles and Passiv Haus technologies has enabled the energy efficient rating to be extremely high. The current energy efficiency software used in Australia does not fully recognise the benefits of Passiv Haus technology and the actual energy efficiency rating of the building is likely higher than the 9.8 stars recognised by the current rating system. Power provided from the photovoltaics is also returned to the power grid. Large water tanks are used for fire management and use in the home with any surplus going to the naturescapes' waterharvesting system.

MATERIALS

The design of a micro-village setting looks at a vast range of issues, and we are constantly reviewing what we can achieve with highly sustainable materials. In out pallets of materials, we consider all aspects of the building envelope and fit out. Flooring options included rammed earth, linseed oil floors, recycled pavers and concrete with recycled fly ash.

Options for walls include hempcrete, earth, straw, plantation timber, plantation bamboo and more mainstream materials such as plantation pine and recycled bricks. Living walls and earth roofs, shingles roofs and sod roofs can be options depending on the siting and local material availability. Natural floor covering include linoleum, timber and bamboo and natural paints

FIGURE 14. Carwoola House Floor Plan



can be sourced locally and from overseas made from egg whites. Timber finishes included oils and waxes, one of which we have been using for over 15 years. These require very little maintenance and never require re-sanding.

For Carwoola House, the palette of materials selected was influenced by the fire-retardant qualities that the building envelope required for a bush fire zone. We specified a concrete insulated slab with fly ash option, thermal break insulating brick at the slab wall junction and cavity brick walls. Expanded foam insulation board was used in the cavities and plantation termite resistant trusses were used for the roof. Pro-Clima intello and Mento membranes were used inside and outside the roof framing and triple glazed aluminium timber composite windows were imported from Germany. Internally, the timber furniture and joinery were made from Bamboo, plantation and recycled timber and finished with natural oil wax. Linoleum and 100% wool carpet were used for floors and green choice certified paint

We chose locally kiln fired Bowral Blues bricks and at the time these were very economical at $500 per thousand. The bricklayers, both in their late sixties, had years of experience but found it challenging at first to be working with no cut bricks and no 90-degree corners and finger locking hinge joints. The bricklayers came to enjoy the expression of their craft as the project progressed. We asked them to put aside orange bricks as they came across them, so we could create a sunburst mural on the western wall with a tiny window at its centre. The bricklayers did a wonderful job interpreting this idea and by the time they had completed the work, they were extremely proud of what they had achieved.

CONSTRUCTION

The construction process is where the design and technology and materials combine to create living pods. Our experience is that you need a team dedicated to achieving the high standards of construction that a solar passive and Passiv Haus technology require to be as effective as the design modelling indicates.

Through an interview process a team was created who were interested in sustainable, careful selection; we had a great team on this project. The builders were committed to creating a well-insulated airtight, thermally bridge free construction. The joiner, Select Custom Joinery, only work in natural materials such as timber, plywood, bamboo and use all-natural oil wax finishes. The fit out has been beautifully crafted.

The performance of a 10-star building requires a high level of skill and quality control to achieve real effective performance outcomes. For our 9.8-star building work, we utilised a range of measures to achieve a high-quality outcome when working with Passive Haus technology and artistic details.

Specialist industry support for Passiv Haus materials and equipment supplied by Laros Technologies was provided to the Builder along with extensive detail review of all passive house technology. Samples were requested to show the construction understanding and to solve process and quality level understanding. Hold points were introduced into the program and covered such items as wall insulation tightness, membrane fit, sealing membranes, heat recovery ventilation supply and return air ducting, thermal breaks and brick jointing.

Shop drawings were prepared for joinery, windows and doors, as well as the HRV system duct layout and the truss system. The shop drawings were used to assist coordination of understanding and creating airtightness in the thermal envelope.

The concrete slabs needed to be level within tight tolerances and so a survey of the formwork and hold points was included to ensure that the formwork was within building tolerances on the quality checklist. Site preparation and keeping the surrounding soil was important for when the Naturescape work commenced. Naturescape are 50 % below the ground and acts like the arteries of the sub-soil. Site soils, topsoil spill, natural soil and excavated matter was kept separated from all construction materials. The waterharvesting trenches can be installed straight after the floors are in place and covered over so that the earthwork below ground along with serve trenching is complete before work above the floor commences.

Tolerances are quite tight with Passiv Haus technology. The fitting of windows and connections to the insulation board and membranes needs to ensure that the seals and tape used to connect membrane, windows and foil face insulation board is sound and kept airtight. Air testing is usually carried out at pre-sheet to ensure that the windows and doors and membrane systems are yielding the airtightness required. For Passiv Haus this is down to 0.6 air changes per hour at 50 Pa pressures.

Complex geometry was part of the design for this living pod. Radial lines start from the west and converge on an 8-sided heart shape around the living space. Surveys for the concrete slab ensured the plan geometry was achieved.

Cavity brick construction was used for thermal mass and for fire resistance and for the beautiful colours of the Boral Blue second bricks. To accommodate non-ninety-degree corners, knuckle joints were used where bricks pass behind the bend in both directions to create the impression of a hinge. This type of brickwork makes for an expressed joint and showcases more of the bricks qualities.

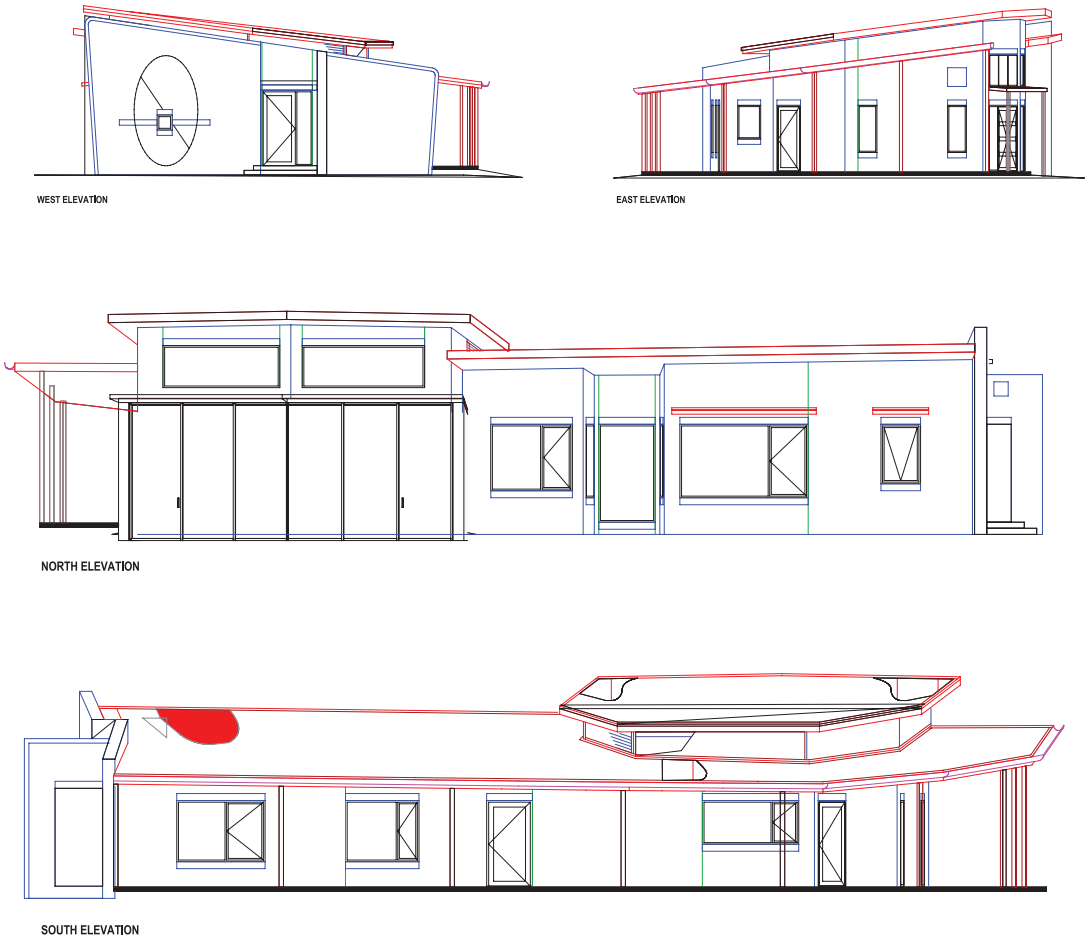
The construction systems called on the bricklayers to explore their trade craft which included a sunburst image from selected orange bricks selected from the Bowral Blue bricks and is featured in the western wall with a small square window at its centre. This is the wall you see as you arrive over the hill and the Living Pod emerges into view and observe the sunburst highlight of the western wall. The bricklayers in their late 60's and early 70's had a wealth of experience and went on to build a house for themselves using the same bricks and similar detailing. The 'young' 68-year-old bricklayer said, "it was the best thing we have ever done."

Thermal envelope was made up of sub-floor insulation boards taped and sealed to a Novomur insulation brick imported from Germany at the wall slab junction. The brick cavity was then filled with 55mm thick Kooltherm rigid board insulation which was taped and glued to the edge of the slab and taped throughout the cavity to adjoining boards and to windows and doors. The board was then taped to the ceiling membranes using Pro-Clima tape and Intello Membranes internally and Mento Membrane above the roof.

Roof trusses were engaged for the single slop roof. They were designed to have 3 ceiling levels from north to south, 2700mm, 2550mm and 2400mm over the southern services area. This minimised the timber required and created appropriate volumes of air and sunlight levels in from the north. Timber was also used where possible to provide sustainable material structure and to eliminate thermal bridging for the rafters extending over the thermal envelope to support the eaves.

A single steel column required to stabilise the north wall of the heart shaped living space has been housed within the thermal envelope to the north of the living space where the ceilings are 4500mm and also eliminate thermal bridging.

FIGURE 15. Carwoola House Elevations



The HRV System (Heat Recovery and Ventilation System) was designed to suit the 165m^2 floor area and air volume of the living pod. A Stebel Eltron HRV System along with Doepfner Triple Glazed windows and Novomur thermal blocks, Pro-Clima Mento, Intello and Pro-Clima tapes were all sourced from LAROS Technologies Canberra, Australia. The HRV system was located in the Laundry Service room centrally in the house.

The built Living Pod is a testament to the team approach and the continuing reach for high quality work. Ann and Alison were on site everyday as their Guest Living Pod overlooked the main Living Pod construction area and were always available to check that quality was maintained As Architects we inspected the site for critical items and with the Builder's commitment to quality and embracing the level of Technology and artisanship required, the result was a beautifully crafted building.

OUTCOMES

From the beginning of the Carwoola House project, there were four key areas identified for integration:

1. Energy: the facility runs primarily on the electricity generated by solar panels.
2. Water: the facility captures rainwater, filters and uses it through the naturescape water-harvesting system and returns it to the catchment system as clean as when it arrived as rain.
3. Place: the facility is uniquely rooted in its place, reflecting the natural landscapes that surround it.
4. Beauty: the facility provides delight and wonder, inspiring all who visit it and reinvigorating visitors' and occupants' connection to the natural world.

We worked through several spatial planning options and arrived at a suitable spatial planning arrangement that covered, arrival, access, protection from the westerly winds and fire source, solar orientation, connection to the Naturescape areas, and the most magnificent views.

Passiv Haus technology was adopted for energy efficiency and thermal comfort. Ann and Alison had intended to install a traditional boiler and hydronic heating in the concrete slab. The enhanced technology of Passiv Haus enabled the elimination of wood fired radiant heating and in slab gas fired hydronic heating with the creation of a more energy-efficient and thermally advanced building envelope.

> "We wanted a house that would keep us warm because we knew how cold the winters were here, so obviously the house faces north. The use of high levels of insulation, increased air tightness through advanced building membrane, triple glazing and eliminating thermal bridging meant that we didn't need to spend money on the boiler or underfloor heating that has ongoing running costs."
>
> Client, Alison

The house is also fully wrapped in a building membrane to eliminate condensation, while a heat exchange ventilation system brings in filtered fresh air. In spring and autumn, you can open all the doors and windows: it only gets sealed up when it's really cold or really hot or really dusty. The house performs well beyond most sustainable housing in Australia. Its design and construction is at the cutting edge of sustainability.

Local builder Wayne Torres of Torres Builders is a great supporter of energy efficient design and construction and shared the project team's enthusiasm to realise this ambitious project; it was his first Passivhaus build.

> "In winter, as long as we don't have more than two days in a row that are cloudy and overcast, the temperature inside the house does not drop below 16.5 degrees even with the overnight temperature down to minus 9 (degrees Celsius). We have a slow combustion wood heater that we really wanted for the beautiful atmosphere it creates but we can't use it because the house is so well insulated and airtight. The 1.7 kW reverse-cycle air conditioner in the living space has been used only a few days after many hot days in summer and only 2 days in winter after several days of rain and cold days"
>
> Client, Alison

The couple installed a 2.4 kW solar photovoltaic system that has reduced their quarterly energy consumption bill to around $100. "We are keeping an eye on Tesla batteries for installation in future," Alison says. Being in a rural area, the house has its own traditional septic waste system that connects to the waterharvested naturescape area and 110,000 litres of water

FIGURE 16. Carwoola House

storage for indoor and outdoor use, and for firefighting. The build also meets the requirements of the high fire danger index mandated by the local council (FDI 100), with all external building products being brick, colorbond or fire-resistant glass. The threat of bushfires was brought home in February 2017, when the couple were lucky to escape the devastating Carwoola blaze that destroyed more than a dozen nearby homes and damaged 15 others. "Most afternoons we get a south to south-easterly sea breeze come through, but it didn't arrive that day, and that's the only thing that saved us," Alison says.

If you intend to live in a house like this for a long time, as Ann and Alison do, you'll have more chance of seeing that payback. The main thing we do as architects is promote small buildings, because we argue that a sustainable house isn't sustainable if it's big: there is so much embodied energy in a building. But this project goes a lot further in the right direction, and it's encouraging to see people investing in their homes in this way.

Paul and his team currently have two more Micro-Villages in planning and one in construction and are finding more and more people who are seeking the flexibility, comfort and sustainable qualities of the Microvillage Living Pod approach.