Desert Rose

Project Manual

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SOLAR DECATHLON MIDDLE EAST DUBAI, UAE - 2018

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Introduction

The Solar Decathlon gives student teams the opportunity to design, build and operate a net zero energy solar powered house. The Solar Decathlon also provides the opportunity to challenge our current concepts of residential construction. Team UOW has used this opportunity to not only design for sustainability but for a global challenge that the world currently faces, an ageing population.

Our Vision: Team UOW Australia-Dubai is dedicated to creating an innovative and sustainable future that celebrates life.

Our Mission Through practical collaboration between students and industry, Team UOW Australia-Dubai in the Solar Decathlon Middle East 2018 endeavours to change the way the world views sustainable housing by building a home that is architecturally inspiring, innovative and adaptive to a person's needs as they continue to age, creating 'A House For Life'.

Dementia is the second leading cause of death in Australia, the leading cause of death for Australian women and the leading cause of disability for Australians over the age of 65. Dementia is not something unique only to Australia or western countries with over 370,000 people diagnosed with dementia in North Africa and the Middle East each year and a new person somewhere in the world diagnosed every 3.2 seconds. There is currently no cure in sight for dementia but the quality of lives and independence of people living with dementia can be improved through innovative architecture, interior design and integration of smart technologies.

Team UOW's idea for the Desert Rose is that someone approaching retirement age will move into a house able to adapt to their needs as they continue to age. Should the occupants develop a disability such as arthritis, mobility issues, or dementia then the Desert Rose is designed to be easily adapted to meet those needs so that the residents can enjoy the highest quality of life possible. Through this Project Manual you will learn how Team UOW's design principles have merged the Middle Eastern cultural influence with that of an Australian culture and have met the needs of someone living with dementia and aged related disabilities. The Desert Rose has been designed from the ground up with this goal in mind and almost every element and material within the Desert Rose has been selected based on research and considerations of how they would affect or improve the life of someone living with dementia or other aged related diseases.

With this endeavour Team UOW is committed to achieving engineering and construction excellence. We aim to go above and beyond traditional methods to achieve innovative, smart solutions to create a sustainable future. Team UOW have focused our engineering strategy on demonstrating unique solutions to housing functionality. This project manual explores our student innovations including our modularised light gauge steel frame, second skin wall, recycled vertical flow constructed wetland, PCM thermal storage tank and model predictive control. These innovations all student driven help to deliver an eco-friendly state of the art net zero energy house.

This manual will also demonstrate how Team UOW has shown innovation in our communications in the way that we have adopted new media technologies as tools to communicate with our audiences. Team UOWs mobile application with integrated AR, VR and 3D modelling is a way to leave a lasting impression on guests and increase Team UOW's educational potential. Our use of the HoloLens throughout the competition has enabled Team UOW to engage in a two-way dialogue around the design of the house.

Team UOW is dedicated to creating a safe work environment and has been innovative in developing our own safety campaign to ensure a safe and comfortable working environment for all team members and as a means to communicate the importance of safety to younger audiences. To achieve this, we have developed two safety mascots, Saferoo and Safe Clayton who are recognisable figures promoting safety and both wear our unique pink hi-visibility uniform. Saferoo is modelled off our primary team mascot Rosa the Kangaroo. She is a recognisable mascot for our team as an iconic Australian animal. Safe Clayton is modelled off Clayton our Health and Safety Coordinator. This manual details our safety culture and methods for maintaining a safe work environment.

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Contests Special Awards and Supportive Information

2.1 Architecture Concept and Design

The design philosophy that Team UOW has adopted for the Desert Rose is 'architecture that celebrates human life rather than itself'.

The Solar Decathlon gives student teams the opportunity to design, build and operate a net zero energy solar powered house. The Solar Decathlon also provides the opportunity to challenge our current concepts of residential construction. Team UOW has used this opportunity to not only design for sustainability but for a global challenge that the world currently faces, an ageing population. The design philosophy that Team UOW has adopted for the Desert Rose is 'architecture that celebrates human life rather than itself' with a motto of creating 'A House for Life'. Team UOW's vision for the Desert Rose is that someone approaching retirement age will move into a house able to adapt to their needs as they continue to age. Should the occupants develop a disability such as arthritis, mobility issues, or dementia then the Desert Rose is designed to be easily adapted to meet those needs so that the residents can enjoy the highest quality of life possible. Through this narrative you will learn how Team UOW's design principles have merged the Middle Eastern cultural influence with that of an Australian culture and have met the needs of someone living with dementia and aged related disabilities.

Design for an Ageing Population

Having committed to our vision, Team UOW's next step in designing a house for life was to conduct a "Day in the Life" exercise where all the different daily activities a person does in their home were examined. The team performed this exercise for a variety of occupants, namely individuals at different stages post-retirement. In addition, the way people from different cultural backgrounds use their home was considered, including those from Australia and from the Middle East. This explored daily activities associated with sleep, leisure, cooking and cleansing. From here, Team UOW looked into how best to design a space to cater to these different activities, while keeping within the 90 square metre footprint of the building.

A particular area of focus was designing for people living with dementia, with the following considered:

- One of the most important aspects to consider was the occupant's line of sight. In particular, visibility throughout the house helps to ensure occupants can navigate their home safely, and care for themselves with more ease. Desert Rose is designed to satisfy these requirements, with the main spaces within the house being visually accessible from different positions within the house. For instance, both the bedroom and dining room are visible from the main bathroom, providing a clear binary choice to someone living with dementia and allowing them to be guided throughout their daily activities. These simple visual cues provide easy choices for how the occupant would like to spend their time.
- Line of site from the bed to the toilet is very important, as research confirms people living with advanced dementia who can see the toilet when they wake up are up to eight times more likely to use the bathroom. This simple design element encourages the occupant to engage in necessary daily activities and maintain their human dignity.
- The doorways, hallways, and rooms are sized to accommodate the use of a wheelchair, walker or other mobility assistance. The main bedroom door has been specifically designed to enable a hospital bed to fit through, providing a pathway to the outdoor garden, allowing the occupant to remain in the comfort of their own home even when requiring medical attention or receiving palliative care.
- The structural wall frames have been designed with additional framework placed at a height where handrails can be fixed when needed. In line with the principles of sustainable architecture, this very simple design consideration and addition would allow occupants at retirement age to move into the house knowing that, when needed, supportive handrails can be directly installed throughout the home and in the bathroom, without the need for any further structural retrofits.
- The roof trusses have also been engineered to enable a hoist to be installed from the bedroom to the bathroom should one be required.
- Team UOW have also chosen timber flooring and custom-designed timber doors to enable a flush surface that avoids trip hazards in the home as well as any physical barriers for wheelchair users, limiting the potential causes of confusion

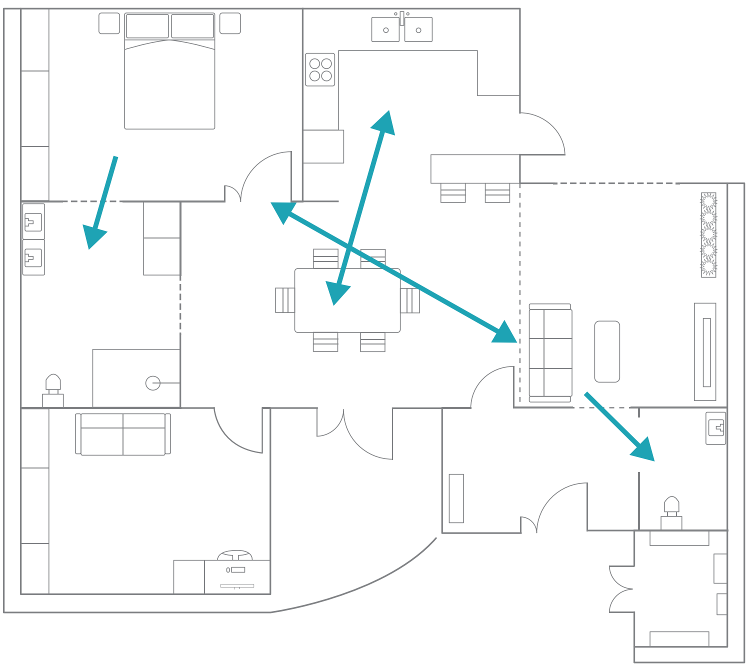


Figure 2.1 - Line of Sight Aspects of the Desert Rose

and apprehension for people living with dementia.

As an aesthetic feature supporting Desert Rose architecture and interior design, the doors also create unification and provide smooth transitions between internal areas and outside spaces. Top-hung sliding doors and internal cavity sliding doors within the house contribute to a sense of openness, while preventing further trip hazards.

The house has been designed to provide a visual connection to the outdoors in a climate where physical connection may be uncomfortable at times, with occupants having clear visibility of pleasant green walls from the spare room, living, kitchen and dining areas. This connection to the outdoors provides a sense of comfort and calm to the occupants, whilst providing fresh air and maintaining privacy and has been shown to assist in health and recovery benefits (REF 1).

Design Meeting Australian and Middle Eastern Contexts

While line-of-sight and openness are important aspects within the Desert Rose, Team UOW has also carefully designed the house to meet the Middle Eastern context. Respecting the Middle Eastern culture, the house has been divided to provide defined privacy zones. The first privacy zone is specifically designed for the guests of the home, with the front deck and foyer of the house acting as a formal, public meeting and welcoming area. Upon entering the foyer, guests are directed to the right-hand door to enter the living room. The living room can be closed off from the remainder of the house by the use of opaque glass sliding doors, giving appropriate privacy to the other household members. The living room was purposely placed in a location where guests would also have direct access to the second bathroom of the house, located adjacent to the entrance. With the option of closing off the living room and separating a guest area to the rest of the house, flexibility is given to the occupants, enhancing their comfort and privacy while guests are present.

The second zone is reserved for the family. This space is represented by the dining room and the kitchen space, with the dining room table being the heart of the house. It is physically in the centre of the space, but is also seen as the centre of social experiences between family. In Middle Eastern culture, food and hospitality are the focus of a homely environment, and the dining room in the heart of the house accentuates this consideration. In addition, this shared space is also essential for elderly people as it creates a place of joy and security.

The third privacy zone consists of the main bedroom and bathroom, and the study room / spare bedroom. These spaces are considered the most private area of the house, specifically placed the furthest away from the main entrance. The bed and toilets are designed and placed with particular attention to Middle Eastern religious cultural considerations, with them not directly facing the Kaaba and with the person sleeping not having their feet pointing towards the sacred Islamic site. The bathroom layout is also designed to be fully wheelchair accessible with the toilet positioned to enable the correct installation of grab rails in the future while maintaining direct line-of-site to other rooms in the house. The shower is similarly positioned to meet accessibility requirements, facilitates future grab rail installation, and creates a clear circulation space in front of the shower.

Responding to the Middle Eastern climate, a second-skin wall surrounding the Desert Rose provides an architectural feature and aims to reduce the solar heat gain. Using passive design strategies, and aiming to reflect the vernacular architecture of the UAE, this wall also provides a veil of privacy for the home and adds to the aesthetic design of the house with eye-catching back-lights illuminating the wall during the evening.

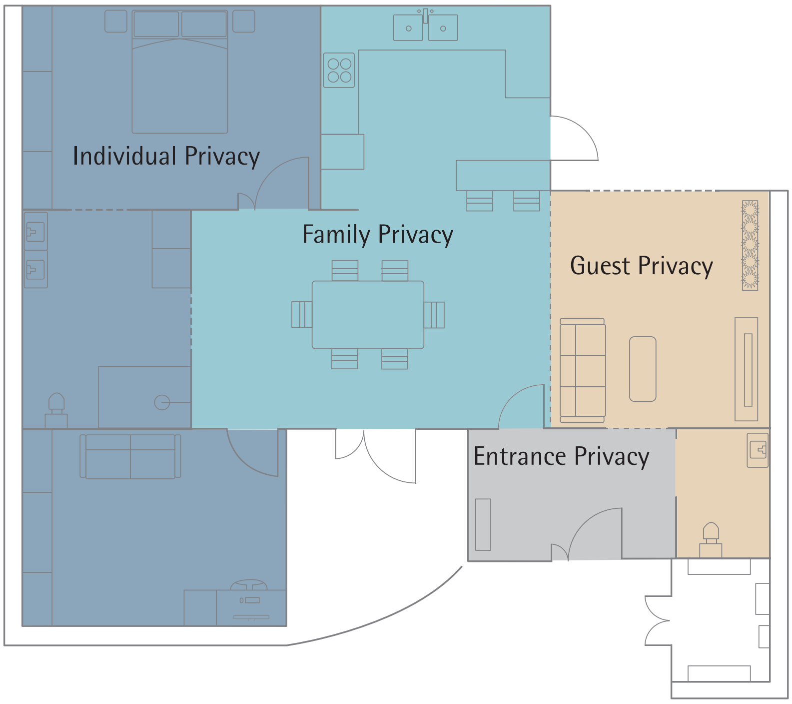


Figure 2.2 - Privacy zones in the Desert Rose

This innovative solution is student designed and manufactured with the goal of reducing the carbon footprint of traditional concrete. It is made of a foamed concrete incorporating recycled crushed glass as a cement replacement and carbon fibre mesh reinforcement as a substitute for conventional steel reinforcement. The holes in the wall are designed to allow air to pass through to cool the panels down at night and are positioned in a pattern to help guide guests towards the front door.

Spatial Quality and Flexibility

The Desert Rose has been designed to be aesthetically pleasing both internally and externally while providing residents and guests with both comfort and sensory delight. The front ramp and deck guide the guests towards the front door, where they would be welcomed before entering the premises. Upon entering the foyer, family members are able to access the main dining space or the living room, and guests can be guided directly into the living room which benefits from a view of the outdoors connecting them to nature. Sliding doors can divide the living area from the other areas of the house when guests are present. When the house is only occupied by family members, the space can be opened up to encourage shared space. This provides flexibility in the use of space. Family members can access the dining space to use the kitchen facilities and have access to both the back deck and the private courtyard, offering multiple choices for connection to nature and further adaptability in space. The open-plan design ensures occupants in the kitchen can still engage with other family members sitting in the dining room, making the occupant feel they are in a homely safe, environment. The high ceiling and clerestory windows in the dining room allow for natural light to flow deep within the room and provide a sense of space. Continuing towards the bedrooms, occupants have access to the main bathroom and most private spaces.

Entering deeper into the house, the spaces are designed to feel more personal and private, while still being connected to the outdoors by the internal courtyard. Contributing to adaptability within the Desert Rose architecture, the guest bedroom/study and the living area have both been designed as multi-use spaces. The guest bedroom can be used as a study and also to accommodate visiting family and friends. As the occupants age, they may need a carer to facilitate their daily activities. This room has been specifically designed to accommodate the long-term stay of an in-house carer by designing sufficient space for a double bed. The wardrobe can be used for general storage or personal items in longer stays and the desk can be utilised as a study space when needed. Similarly, the living room has been designed for hosting guests with additional seating available and direct access to the second bathroom of the house. Additionally, it has also been designed for leisure for the family, with a lounge and television in a comfortable space. The room is directly connected to the outdoor deck, with a green wall frame inside the house linking plant life to the outdoor adjacent green wall, giving the occupant a feeling of connection to nature. Biophilic design principles were followed to enhance spatial and living experiences of the house occupants, providing a healthy and safe environment.

Design Coherence

The Desert Rose architectural coherence is centred around a balance of simple and essential design principals that promote autonomy for the occupants, so that they remain empowered and comfortable within their own home creating 'A House For Life'. This is achieved through:

- Providing minimal transitions within the house, relying on subtle changes in colour, furniture style, and an open plan construction that allows the occupants to move easily between different rooms within the house. This is incorporated through the principle of line of sight, with the most important utilities of the home visible from the main space including access to food, water, and amenities.
- The interior open-plan design complements the privacy zones of the house, and smooths the transition between rooms by providing visually intriguing environments with colour palettes and furniture choices that do not over stimulate.
- As noted above, flexibility of space is also achieved by multi-purpose rooms, with opportunities to decorate and utilise space as desired.
- There are no steps or thresholds in the house, eliminating potential trip hazards and favouring smooth transitions between interior and exterior spaces for someone living in a wheelchair or with low mobility.
- Adaptability in design is also reinforced by additional support noggins installed on every wall of the house, allowing for direct handrail installation when needed, creating a living space that can change and evolve over time, like the lives of the occupants.

Figure 2.3 - Design Coherence in Action Through the Heart of the Desert Rose

The interior design, therefore, merges to a unified whole with the architecture of the house, creating a welcoming and healthy living space.

Biophilic design is further established by the defined connection of nature between internal and external zones, with plant life and natural light increasing the wellbeing of the occupants of the house. The landscaping around the Desert Rose has been designed to complement the house, using colours and features that continue the internal design concepts to the external environment. Plants native to the UAE that will appeal to those living in the region have been chosen, creating a feeling of familiarity and a connection to home. This supports the idea of a house for life, where the house itself lives through the plants surrounding it. A clear path delivers the occupant down the back ramp of the house into the landscaped area, providing them with a serene space that they can walk around, before being directed back to the front door. Occupants are never far from nature, with the courtyard and back deck providing private green spaces for relaxation.

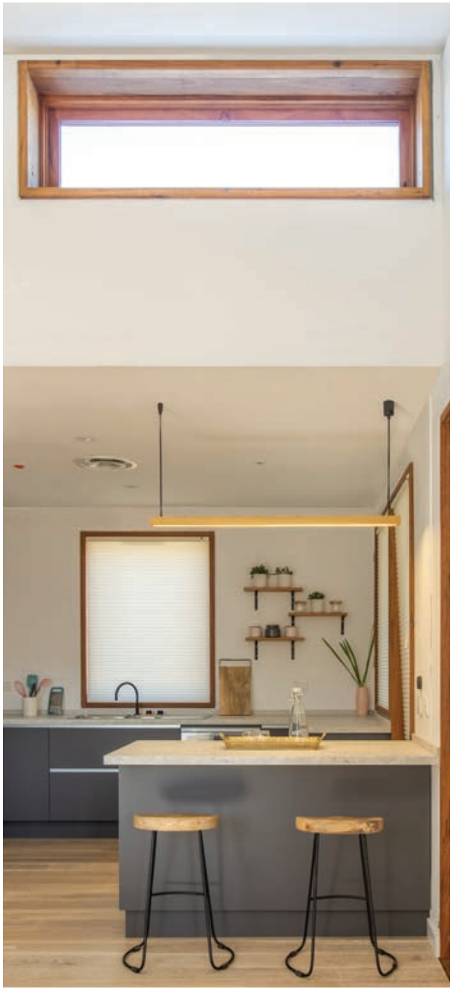
Its flexibility is also demonstrated from an overall design perspective, with the house designed and built to fit within a village arrangement as well as perform as a single living unit. This is achieved with no openings placed on either western or eastern sides of the house, allowing for the house to be potentially built in a side-by-side arrangement within a bigger village, where these walls would be shared with the neighbouring buildings. In an Australian context, this feature would allow the occupants to be part of a bigger community and contribute to a healthier, safer and more open environment for someone living with dementia.

At the same time, the second-skin wall allows for appropriate privacy, and increases the energy efficiency and architectural visual appeal of the house, remaining coherent with the vernacular architecture of the Middle East Middle Eastern residential features.

Lighting

The Desert Rose is designed to allow for maximum natural ambient lighting during the day whilst minimising direct solar heat gain and maintaining privacy. This is achieved by reducing glazing on areas facing the street and the southern façade and replacing them with windows on the northern façade. Clerestory windows allow light to penetrate deep within the living space providing a bright and spacious feel. The glazed surfaces located next to the southern courtyard are affected by direct sunlight. To address this Viridian's Microshade mesh has been installed on the internal surface of the external layer of glass. The Microshade consists of microscopic lamellas which shade the direct sun progressively. Microshade has the equivalent effectiveness of exterior shades, whilst maintaining natural lighting.

To supplement the natural lighting when required, indirect lighting from LED lights is used to add warmth and increase light intensity in general areas. LED task lighting provides the required illumination in areas such as the kitchen and study. The combination of natural



Left: Figure 2.4 - Clerestory Windows Above Kitchen and Dining Area
Above: Figure 2.5 - BIPV-T and Coolmax Sheeting on the Roof of the Desert Rose

and artificial lighting improves the comfort of the occupants by connecting them with the outside environment and providing illumination for daily tasks. While minimising additional artificial light sources will save energy and eliminate the direct heat from task lighting, artificial lights throughout the house can be adjusted to provide higher or lower intensities when required. This is crucial for ageing occupants with lowered sensory abilities – appropriate and adaptive lighting can improve comfort by transforming the indoor environment, improving comfort and better supporting daily habits. LED strips are installed on cornices throughout the bedrooms and lounge room and are adjustable to provide ambient lighting. This lighting can also be used to reduce agitation experienced by people living with dementia during sunset.

Technology Integration

Technology is seamlessly integrated throughout the Desert Rose design and include:

- Building Integrated Photovoltaic Thermal (BIPV-T) tiles replace the southern roof construction providing electricity and domestic hot water.
- Microshade mesh installed in windows affected by direct sunlight, reducing solar heat gains whilst maintaining vision to external spaces.
- LEDs integrated into cornices to provide ambient lighting and assist with reducing agitation of people living with dementia.
- Light up splashback provided task lighting or RGB mood lighting.
- Electronic taps that require low physical strength to operate, with LEDs that change colour with the water temperature.
- Automated windows for improved natural ventilation and ease of use for people with poor hand strength.
- Honeycomb shades that are automated or fitted with 'ultraglide' system operative mechanism for poor hand strength, providing privacy, improved insulation and allowing natural light to filter through. Creating well-lit private spaces where the occupant can still experience the natural progression of the sun's light during different times of the day.
- Innovative student designed and manufactured green wall connecting sustainable greenspaces in an otherwise harsh environment. Provides a feeling of comfort and connection to nature.
- Second skin wall providing a stunning architectural feature that reduces solar gains and provides privacy.

Innovative Solutions

There are innovative solutions integrated throughout the Desert Rose design. One key innovation is Team UOW's design philosophy, to create a house that celebrates life, rather than itself. Our Desert Rose is designed to be inspiring and support our ageing populations to live longer in the comfort of their own home. Features from the floorplan through to lighting and material selections all contribute to providing a supporting environment that encourages ageing in place and improving quality of life.

The second-skin wall is a striking architectural feature that provides external shading to the house, reducing solar heat gains, as well as an added privacy feature. The super thin wall is made of an innovative foamed lightweight concrete reinforced with carbon fibre. The concrete mixture is created by Team UOW students and uses crushed recycled glass dust as a partial cement replacement. This combined with the carbon fibre has significantly reduced the Desert Rose carbon footprint and promotes the use of recycled glass in major building development projects. The lighting behind the wall has an RGB colour system so that the house can be lit in a variety of colours to complement the environment and contribute to the occupants' experience.

The structure of the house uses an innovative light gauge steel framing system. Team UOW adopted EnduroFrame for the walls and roof of the house. This product is lightweight and uses a specially-

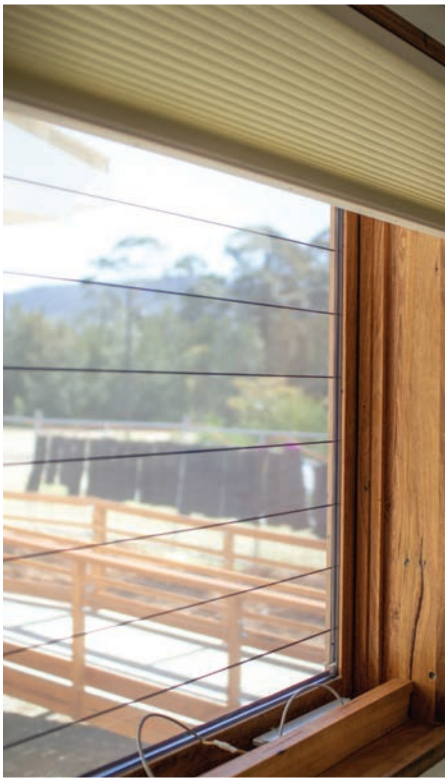


Figure 2.6 - Automated Windows

formulated software to design the structure so that it is manufactured exactly to specifications, eliminating waste. Additionally, the Desert Rose steel structure was built taking into consideration modular design, enabling each section of the house to be built individually before being added to the whole. This supported the team's need to dismantle the house for reassembly in Dubai, as well as shorter construction timeframes. The combination of lightweight concrete, with a density less than half normal concrete and light gauge steel reduces the overall weight of the building and hence the carbon footprint for transportation across the globe and back.

Ref 1: Sempik, J., Aldridge, J. and Becker, S. (2002) Social and Therapeutic Horticulture: evidence and messages from research, Thrive (in association with the Centre for Child and Family Research): Reading.

2.2 Engineering and Construction Design Narrative

Team UOW is committed to achieving engineering and construction excellence. We aim to go above and beyond traditional methods to achieve innovative, smart solutions to create a sustainable future.

Team UOW is committed to achieving engineering and construction excellence. We aim to go above and beyond traditional methods to achieve innovative, smart solutions to create a sustainable future. As such, Team UOW have focused our engineering strategy on demonstrating unique solutions to housing functionality. In line with modern philosophies of construction we are committed to ensuring a safe construction environment and enforcing a strict health and safety plan.

Construction System and Assembly of House

The Desert Rose was transported to Dubai in closed shipping containers which creates unique challenges for construction and rapid on-site assembly. As such, the team used off-site fabrication methods with the aim of minimising the on-site work required to ensure the house is erected, finished and commissioned within the 15-day construction time limit. The pre-fabricated modules accompany house panels, and all house components are reduced to the appropriate size to fit within the shipping containers. Each section can therefore be pre-fabricated, flat-packed for shipping and then easily and quickly assembled in Dubai during competition.

Both construction and deconstruction phases of the project are dictated by the planned order of the containers arriving on site. Packing of the eight containers needed to fit in with the assembly and disassembly order while minimising double handling of components on site, and the transportation and shipping costs. Most roof modules were rotated on their side and tessellated together to maximise the vertical space and minimise horizontal space occupied in the containers. Creative space-saving measures had to be used. An example is a roof module was flipped completely upside down and tessellated on top of another roof module, saving significant space in a container and allowing for further material and house panels to fit into what would have otherwise been occupied space. The assembly on site begins with the placement of two volumetric pods that form the main bathroom. The bathroom pods remove the need to re-join walls and floors which allow waterproofing membrane and tile finishes to remain intact during shipping and re-assembly. These pods form the core structure which the remainder of the house is built off of. The house floor panels are then installed around these pods and kept aligned in position with bolted connections through the piers underneath. Bolted connections are also used between floors and walls, walls and roof, and roof modules. By replacing traditional nailed or screwed connections with bolted connections we can maintain the same connection strength when disassembled and assembled multiple times and ensure alignment is reached at every construction phase. Architectural features including the skirting boards and cornices have been designed specifically to cover the structural connection points. This method ensures a quick and efficient way of connecting the structural components together and obscuring them with an elegant and professional interior finish.

The building envelope consists of a second-skin wall (also referred to as a double-skin façade). Common in Middle Eastern architecture are concrete or masonry block walls surrounding homes as a modesty and privacy feature. The second-skin wall represents that common feature but is also used as a passive solution to improve energy efficiency and thermal comfort within the house. This innovative solution is student designed and manufactured,

Figure 2.7 - Pods and Floors Assembled

Figure 2.8 - Large HVAC Cage Being Lifted

it is made of a foamed concrete incorporating recycled crushed glass as a cement replacement and carbon fibre mesh reinforcement as a substitute for conventional steel reinforcement. The mix design was developed by UOW students and implemented for use in the Desert Rose to create the innovative and architecturally appealing wall. The foam concrete is half the weight of standard grade concrete and the carbon fibre enables us to reduce the wall thickness from 75mm to 50mm. This significantly reduces the weight and volume required for shipping. Additionally, the holes within the architectural pattern were also strategically placed to access connections between panels. These access holes were purposely designed to fit in with the pattern and be hidden in plain sight, creating an attractive architectural external feature during the day and when illuminated at night.

Intelligent Building Information Modelling (BIM) computing technologies also supported Team UOW's construction decisions throughout the whole duration of the project, from design to commissioning phases. This allowed for the generation of accurate panel and module configurations, as well as a precise bill of materials and schedules well before construction. The software packages adopted during the design phase provided Team UOW a testing platform to verify the effectiveness and feasibility of the entire house design, and better facilitate following construction efforts.

Figure 2.9 - Photo Taken of Structure

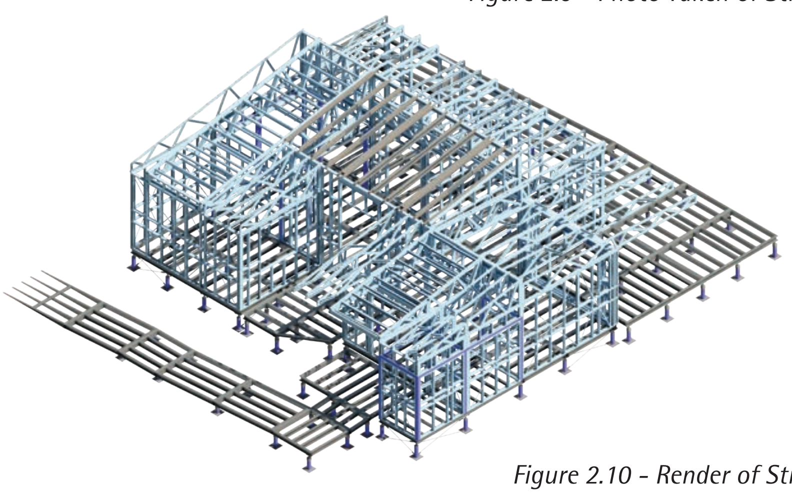


Figure 2.10 - Render of Structure

Structural Design

The Desert Rose adopted an effective steel structure solution to the complexity of the Solar Decathlon engineering challenge, with wall and roof structures made from locally manufactured light gauge steel. With the adoption of the EnduroFrame building system, light gauge steel represents a lighter alternative to timber framed houses. The weight reduction was also taken into consideration as an extremely beneficial factor for the purpose of creating a modular house where the structural elements must be shipped and eventually craned into place. This ensured lower shipping costs, reduced lifting requirements and easier installation on site. The house frame was designed by Team UOW students with technical assistance from EnduroFrame using their intelligent BIM software, ENDUROCADD. A key feature of this building system is the millimetre accuracy that the steel is rolled and cut to. As a result, no cutting was required during the assembly of the frames and trusses, which resulted in almost zero waste generated. Any off-cut material and waste steel is also 100% recyclable, which made it the ideal building product for the sustainability challenge of the Solar Decathlon project.

The Desert Rose frames feature pre-punched holes for connections, as well as pre-punched service holes. The bill of materials output from ENDUROCADD specified the exact number and type of screws to be placed in the pre-punched holes meaning exact quawntities of screws could be ordered. The assembly of the wall frames and trusses are analogous to a Lego or Meccano set being put together. Many Team UOW decathletes had the opportunity to get involved and assemble these main structural elements, and the assembly of all wall frames and trusses was finished in under three days. Once the frame was assembled, fit out of plumbing pipes and electrical cabling could begin immediately facilitated by the presence of precisely located pre-punched service holes.

The floor structure of the Desert Rose is also built from locally manufactured light gauge steel cee purlins. Using the steel purlins provided a similar benefit to that of the EnduroFrame building system, in that all steel members were delivered to site cut to length with millimetre accuracy resulting in minimal waste when constructing the floor frames. The structural design of the floor was also carried out by Team UOW students that used simple structural analysis methods on paper, finite element analysis software and manufacturers' span tables to size and design the floor structure.

The piers for the Desert Rose House were designed and fabricated by Team UOW students, with guidance from trade teachers. This hands-on experience upskilled many students of the team with not only skills in using metal work equipment such as MIG welders, grinders, bandsaws and drill presses but also training in the process of manufacturing right from ordering material to installation on the house. The influencing factors motivating the design were driven by the creation of a multi-functional pier that would allow the team to assemble a levelled, elevated floor and provide the flexibility to cater to the ground conditions at the Mohammed bin Rashid Al Maktoum Solar Park construction site in Dubai. This was achieved by using a simple mechanism consisting of a threaded rod and adjustment nut on the house piers where extremely fine vertical adjustments can be made until the floor is perfectly level.

The roof module housing most of the mechanical HVAC equipment demonstrated an innovative way of making the structural elements and mechanical equipment work together. With extensive collaboration among decathletes in respective teams, the idea was formulated to create a roof module slightly smaller than the container door opening, meeting transport requirements and featuring a completely open area to place all of the HVAC equipment and ducting. An innovative feature about this design is the safety benefits it provided, directly linked to the proven accuracy of extensive BIM adoption in Team UOW's design efforts. The design exercise saw many decathletes collaborating over a BIM model, running several clash detection simulations and design amendments as a result. Demonstrating the effectiveness of the BIM model, the full construction of the module and installation of the HVAC equipment was carried out on the ground at a separate construction location, increasing safety and efficiency during the instalment. Once fully fitted out, the HVAC roof module was then transported to site and craned into place, perfectly fitting within the overall structural frame of the house.

Mechanical System

Thermal comfort is extremely import for health and wellbeing. As the Desert Rose is a dementia friendly home, maintaining a comfortable and healthy home was one of the key goals from the beginning of the design phase of the project. However, maintaining a comfortable home in the hot Dubai climate requires a significant amount of energy, particularly during the middle of the day. It was therefore the goal of team UOW to develop an innovative and energy efficient HVAC system that is able to maintain strict thermal comfort conditions in the house while also being able to load shift to reduce peak demand contributions.

The Desert Rose HVAC system utilises an air-to-water heat pump as the primary source of cooling within the home. The heat pump is coupled to two fan coil units that supply cool air to the living spaces. Unlike traditional residential HVAC systems, the Desert Rose decouples its sensible and latent cooling in the home by utilising an innovative Daikin product called Desica, which uses desiccant crystals coupled with a heat pump to dehumidify the incoming air from the outdoor environment before it reaches the fan coil units. This means the fan coil units only need to reduce the sensible load which in turn requires less energy. By decoupling sensible and latent cooling the building management system can better control temperature and humidity in the home. The system also employs an energy recovery ventilator which recovers waste energy and precools fresh air into the building.

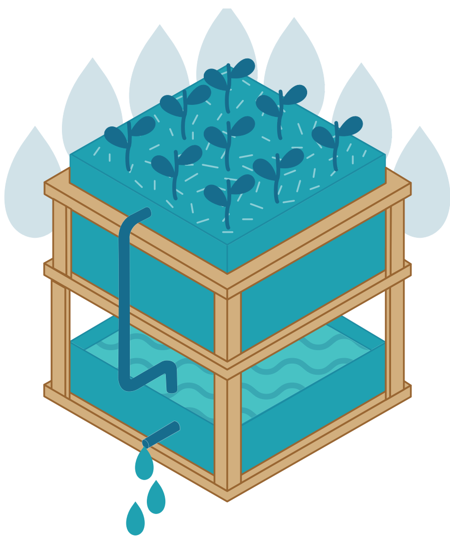


Figure 4211 - Greywater System

Finally, the most innovative component of the Desert Rose HVAC system is the phase change material (PCM) thermal storage tanks. Completely designed and manufactured by Team UOW, the PCM tanks act as a 35 kWh liquid thermal store that is cooled at night when the ambient temperature is cooler, increasing the coefficient of performance of the heat pump. The thermal store is then used during the middle of the day to drive the fan coil units instead of using the heat pump. This drastically reduces the amount of energy used by the HVAC system during peak load.

Plumbing System

For the Desert Rose to blossom during the harsh, arid periods of the Dubai climate it must have a unique and innovative relationship with its own internal water cycle. Like many parts of the world, Dubai will face issues of water security in the future. The Desert Rose will effectively treat and reuse greywater, which could offset up to 60% of its potable water consumption. The Desert Rose utilises a recycled vertical flow constructed wetland to treat the greywater produced and reuse the treated effluent for non-potable applications around the house, such as toilet flushing, clothes washing and irrigation of landscaping like the unique green wall on the back deck. The wetland was designed and constructed by Team UOW students using recycled hardwood and a recycled bulka container. The innovative design reduces typical wetland size by up to 90%, by recirculating the greywater multiple times through the system, making it more economically and socially attractive to the home owner.

All the water fixtures in the Desert Rose are fully electronic and monitored, this would put the Desert Rose's water management in a select handful of residential houses having such a system globally. Each water fixture has its own unique electronic thermostatic mixing valve which not only controls individual fixture temperature, but also controls flow and sends live water usage data to the building management system. The electronic water system not only excels in engineering aspects but also integrates into the dementia friendly nature of the house. The system includes features like; free spinning tapware and 'tap on and off' functionality whereby making it easy for someone with arthritis to use, removes heat shock as temperature set point can be pre-determined for aged sensitive skin and the tapware interface lights up easily displaying the expected temperature of the water.

The Desert Rose has also sought to minimise its impact on the environment by steering away from traditional plumbing materials, such as poly vinyl chloride (PVC) and associated harmful glues. Instead the Desert Rose utilises Raupiano drainage which is 100% recyclable, contains no toxic chemical and only uses non-toxic lubricant to interlock.

Hot water production is one of the major energy consumers in a residential household. The Desert Rose harnesses the intense solar radiation of the desert to produce hot water for the house by using a thermal exchange in our Tractile solar roof panels. The effect of passing cold water through the panels during the heat of the day will heat up our potable water for the house whilst having a cooling effect on the solar panels and thus increasing their efficiency. The Desert Rose creates synergy between two often separate systems which makes for an innovative solution and reduction in energy usage required for hot water production.

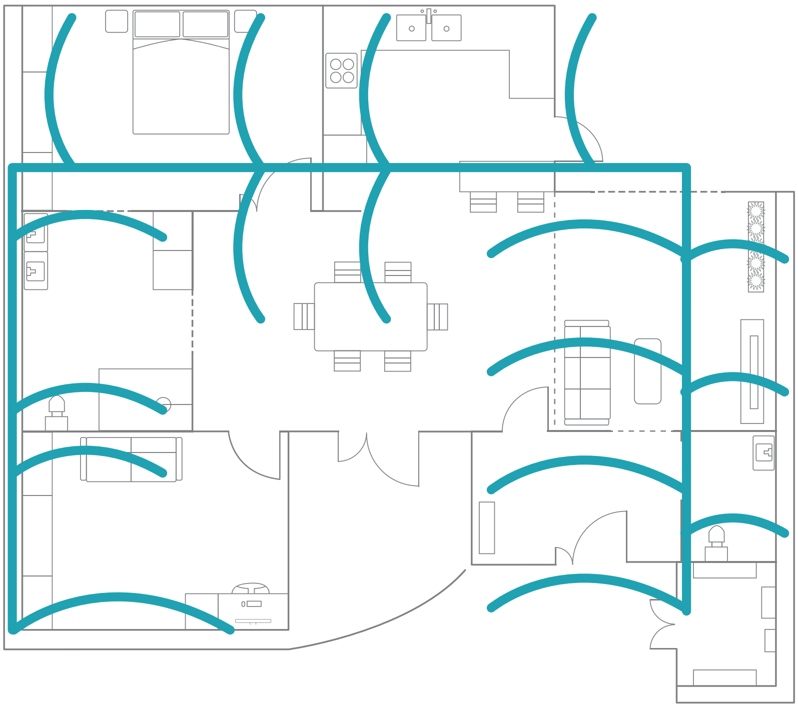


Figure 2.12 - Electrical System and Cables

Electrical System

The electrical system is key to the design of the dementia friendly, net-zero energy Desert Rose house. From its windows to its plumbing fixtures, many of the key components are connected electrically to allow its occupants to live and age comfortably in their homes for as long as they choose.

From the early design stage, the primary goal for Team UOW's electrical team was to create a plug-and-play electrical installation that minimised cabling and allowed fast connection and disconnection during the multiple assembly's/disassembly's of the house. To achieve this, the Desert Rose has a cable tray installed in the ceiling which runs around the perimeter of the whole house in an anti-clockwise direction from the electrical plant room to the guest bedroom. This cable tray acts like the spine of the Desert Rose, carrying power and information to the extremities of the house. At each section of the house where the roof splits, the power and lighting circuits have quick-connects that allow fast, safe and reliable electrical connections when the house is reassembled. These quick-connects can be thought of as being very similar to simply inserting a power plug into your wall socket. The same method is employed to make connections between the cable tray in the ceiling and conduit in the wall sections that connect to light switches, socket outlets and sensors. Finally, where possible the Desert Rose chose to use low smoke, halogen free, XLPE insulated cables as opposed to traditional PVC.

To minimise cabling within the house, DALI lighting is used. DALI lighting is an international standard for lighting control systems, where each individual lighting fixture is addressable and controllable. By using DALI lighting, the Desert Rose house only needs one lighting circuit that runs throughout the house connecting each lighting fixture. This reduces the number of lighting cables required in the Desert Rose by a factor of 10. The use of DALI also allows for control of the lights via wall switches, the graphical user interface and even voice control using the Amazon Echo.

Solar System

The Desert Rose has an extremely unique building integrated photovoltaic-thermal (BIPV-T) system installed on the southern facing roof. The system is made up of 104 solar tiles with a combined rated output of 10.4 kW from Australian company, Tractile Solar. The system will generate approximately 19,005 kWh of energy over the course of the year. With an expected annual energy consumption of 13,924 kWh, the Desert Rose will be a net-positive energy house, generating more energy than it consumes over the course of a year. Team UOW have been able to incorporate the solar tiles in the building construction to create a 5-in-1 system. The solar tiles not only produce all of the required electricity, but they also completely replace the roof construction on the southern facing portion of the house. The unique design means there is no need for roof sheeting. Instead, the interlocking tiles make up the entire roof and are able to withstand extreme weather conditions such as cyclonic winds and hail.

Along with producing electricity, the solar tiles also have water channels that run underneath the tiles which serve three purposes. Firstly, the water channels are connected to the hot water unit which pumps water through the tiles during the hottest parts of the day to produce our domestic hot water. Secondly, running water through the solar tiles creates a heat exchange effect, cooling the tiles down which significantly increases the solar PV efficiency. This is key in the hot Dubai climate. Finally, by cooling the tiles down, the roof construction is essentially cooled down which in turn cools down the building envelope, acting like an insulating element. Again, this feature is extremely beneficial for the hot Dubai climate.

The solar PV system is connected to two all-in-one energy storage/ inverter units. Each unit contains a 7 kW inverter along with 6.9 kWh of lithium ion energy storage. Using a student developed model predictive control algorithm, energy exchanges between the solar PV, batteries house and the grid are optimised, ensuring the maximum consumption of renewables in the home. These optimal energy exchanges are key to the overall Desert Rose energy strategy.

Control and Automation Systems

The Desert Rose building management system (BMS) acts as the brain of the house, constantly monitoring and controlling the home to ensure the optimal usage of renewable resources and maintaining of comfortable indoor conditions. The Desert Rose BMS is able to control and monitor lights, windows, HVAC systems, plumbing fixtures, EV charger, smart appliances and even the renewable energy systems. The key innovation of the Desert Rose BMS is the linking of all MEP systems into one IoT based BMS that can control the building holistically and have all systems work in conjunction with one another to ensure maximum energy efficiency.

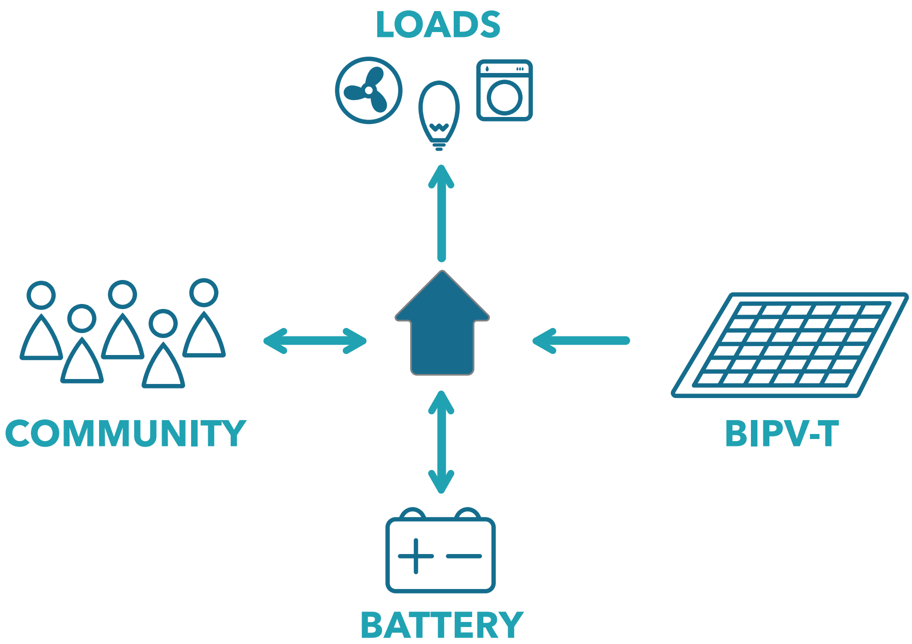


Figure 2.13- Control and Automation System Components

The Desert Rose utilises a student designed model predictive control (MPC) to maximise the amount of renewable energy used within the home. By predicating over the next 24 hours various factors such as the weather, the power output of the solar PV system, amount of charge in the battery and the occupants energy habits, the BMS can optimise the use of the energy within the home. For example, if the BMS predicts the weather to be very hot during the middle of the day, it will operate the HVAC system in the morning to pre-cool the building. Alternatively, the BMS may choose to run the HVAC system when solar PV output is high as this is free energy from the sun. This is an example of how often decoupled systems, such as HVAC and solar PV systems work together in the Desert Rose house. Another example is that if the BMS predicts the next day will be cloudy, it will choose to keep the battery fully charged until the peak period on the cloudy day to avoid high electricity costs.

Majority of the building controls communicate over KNX, MQTT (IoT protocol) and TCP/IP. The open source nature of KNX allows Team UOW to customise the building controls and have off the shelf devices work with student developed devices such as LED controllers, smart plumbing fixtures and smart power plugs. Using these three protocols allows Team UOW to bring all monitoring data and controls online into an IoT platform called Node Red. Node Red allows flow-based programming that connects all online systems in the house. Using Node Red, the Desert Rose can have solar PV, batteries, HVAC, EV charging and plumbing fixtures communicate and work in conjunction with one another which is particularly innovative for a residential house.

Innovative Solutions and Strategies

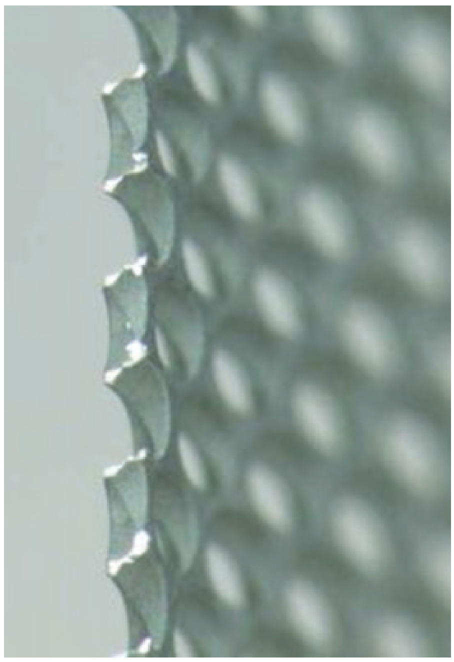
As mentioned in the above sections many innovative features have been designed and built by, or in collaboration with, Team UOW students in our endeavour to achieve engineering and construction excellence. These include;

- The EnduroFrame structure of the house which uses an innovative light gauge steel framing system. This construction system is manufactured locally to exact specifications, eliminating waste. Team UOW students were the first to modularise the EnduroFrame system so that the Desert Rose can be assembled and disassembled multiple times whilst maintaining its designed strength and fit within high cube shipping containers. The modularised HVAC module is also innovative in that the majority of the mechanical systems are self-contained within a roof module. This strategy enabled us to construct the HVAC module in a separate specialised workshop and proves that modularising complex components like this using residential light gauge steel construction is possible.

- The second skin wall was designed and constructed by Team UOW students. This wall is manufactured using an aerated concrete with recycled glass powder as a cement replacement and carbon fibre reinforcement as a steel replacement. Combining these two replacements we are able to reduce the overall thickness of the wall from 75mm to 50mm and reduce the carbon footprint by up to 40%. This wall acts as a shading element to the east, south and west facades reducing the solar heat gain on these sides.
- The overall HVAC system design and control was undertaken by Team UOW students. The innovative custom designed and manufactured PCM tanks can store approximately 35kWh of thermal energy. This enables the HVAC system to be operated during the night when the electricity price is cheaper, and the ambient temperature is lower, increasing the coefficient of performance (COP) of the heat pump. This stored energy is recovered during the day when the grid is experiencing peak load and the electricity price is higher. This smart solution can assist grid networks to better manage load requirements.
- The BMS has been designed and coded by Team UOW students. The innovative model predictive control enables the Desert Rose to better manage the electrical loads and maximises the overall energy efficiency of the house. The control system is capable of learning from past experiences and improves with time.
- The innovative grey water treatment system is a recycled, vertical flow constructed wetland, designed and constructed by Team UOW students. The size of this system has been reduced by up to 90% from a traditional wetland for this demand and works by recirculating the greywater multiple times through the wetland. The treated water can be used in irrigation, toilet flushing and the washing machine.

Other innovative engineering solutions that Team UOW have used in the construction of the Desert Rose include but are not limited to:

- Colorbond's Coolmax roof sheeting is manufactured less than 10km from the Desert Rose construction site and provides an innovative method for reducing solar heat gains. The high reflectance value of the sheeting can reflect up 77% of the sun's heat.
- Although not designed by Team UOW students, Viridians Microshade is an innovative product than enables access to natural lighting without compromising solar heat gains. This smart solution can significantly reduce cooling loads in hot climates.
- Tractile solar tiles are an Australian product that completely replaces the roof construction with an integrated solar and domestic hot water tile. These tiles enable Team UOW to take advantage of the water circuit beneath the solar cells to cool the tiles during the hottest parts of the day, increasing the cell efficiency, cooling the thermal envelope of the house and generating domestic hot water all at the same time.
- Daikin's Desica dehumidification system provides an innovative method for controlling humidity. The system uses two desiccant coated heat exchangers (DCHEs) which serve as the condenser and evaporator of the heat pump. The desiccant material traps moisture more effectively at a lower temperature, enabling the removal of the absorption heat during the air dehumidification process when it serves as an evaporator; this significantly improves the dehumidification performance. The desiccant can then be switched and regenerated by using the released heat when the DCHE serves as a condenser, which provides a reliable and energy-saving approach for regeneration. The COP of Desica can be over 5 during certain operating conditions.



Right: Figure 2.14 - Cross Section View of the Microshade Lamello

Above: Figure 2.15 - Close Up of Window with Microshade Installed

2.3 Energy Efficiency Measures

Team UOW are focused on a sustainable future by producing more energy than we use. In doing so we seek not only to maximise energy generation but to minimise energy consumption, hence the adoption of various energy efficiency measures.

Passive Design Strategies and House Envelope

Dubai is dominated by an extremely hot and humid climate with the majority of dwelling energy dedicated to cooling. To address this Team UOW have designed our building envelope and adopted several passive design strategies to reduce solar heat gains and increase the overall energy efficiency of the Desert Rose house.

Energy + was utilised to investigate the effect that varying insulation values of the walls, floor, ceiling and roof had on the overall energy consumption. As expected increasing the insulation values decreased the combined cooling and heating demands but diminishing returns were experienced for R values above 6, thus an R value of between 5 and 6 was targeted for the external surfaces of the envelope (refer to chapter 5). These values are achieved primarily through glasswool insulation in the cavities and extruded polystyrene (XPS) applied externally to the steel frames to increase the R value and reduce thermal bridging. A ventilated cavity has been designed between the external façade and the XPS layer, this is open at the base and top of the walls allowing built up hot air to escape.

The Desert Rose consists of a series of panelised wall, roof and floor modules with numerous joins throughout. To address the possibility of a high infiltration rate, the house is wrapped in an airtight membrane with the joins between panels sealed prior to installing the external façade / roof sheeting. Awning windows are fitted with seals and external doors have been custom designed to ensure a flush transition between inside and outside whilst achieving a airtight seal. These measures lower the overall infiltration rate of the envelope and improve energy efficiency.

The Desert Rose has been designed to meet the privacy needs of the middle east and to be suitable as both a standalone dwelling and for use in a higher density aged care village where the houses would be positioned in a line and share common western and eastern walls. This reduces the number of external walls and further decrease the energy lost to the outside. Following these concepts and to reduce solar heat gains, Team UOW's design minimises window openings on the eastern and western house façades whilst maximising windows on the northern façade for daylighting. Clearstory windows are provided in the living area enabling natural light to penetrate deep within the house whilst reducing direct solar heat gains.

Although Dubai's extreme climate rarely falls within a comfortable band the Desert Rose has been designed for natural ventilation when returned to Australia. The clerestory windows combined with the courtyard window allow for cross ventilation with a minor stack effect in the main living room.

Recycled hardwood timber frames and triple glazed, argon filled low e coated windows and doors are employed throughout the house to reduce heat gains throughout the day and heat loss on cooler nights. The glazed surfaces located next to the Southern courtyard are affected by direct sunlight. To address this Viridian's Microshade mesh has been installed on the internal surface of the external layer of glass. The Microshade consists of microscopic lamellas which shade the direct sun progressively. Microshade has the equivalent effectiveness of exterior shades, whilst maintaining natural lighting. In summer when the sun is high in the sky, the energy from the sunlight can be reduced by up to 90%. Honeycomb blinds are fitted to most windows and provide privacy and additional insulation when in the closed position.

Building Integrated Photovoltaic Thermal (BIPV-T) tiles are fitted to the south facing roof and provide a 5-in-1 combination of roof, insulation, electricity, solar PV cooling and hot water, and is engineered to withstand the extreme weather conditions, offering longevity with low maintenance. The north facing roof is sheeted in Colorbond's Coolmax steel which has a high reflective coating that achieves a Nominal Solar Reflectance1 = 0.77 and Solar Reflectance Index (SRI)1 =0 95, thus reducing solar heat gains. A ventilated cavity has been constructed beneath the BIPV-T tiles and Colorbond sheets to prevent pockets of hot air building up.

The Desert Rose's south, east and western facades are wrapped in an innovative lightweight second skin wall that was designed and built by Team UOW students. This concrete wall acts as a shading element, reducing direct solar heat gains (refer to chapter 5). The second skin wall has a series of holes and is open at the top and bottom to allow air to freely move around the wall, cooling the concrete at night.

Efficiency of Active Systems

The active systems in the Desert Rose

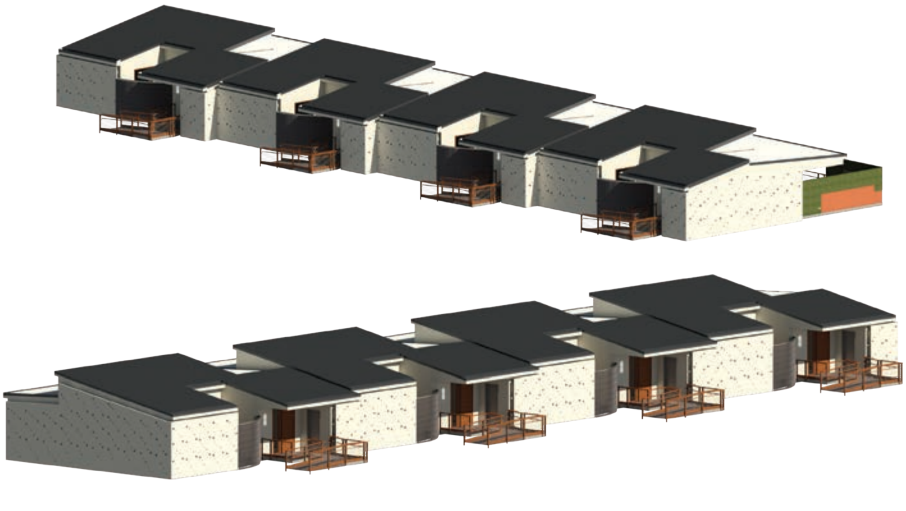


Figure 2.16 - Desert Rose Envisioned As A Side-By-Side Multi Complex

house play a vital role in ensuring the occupants live in a healthy and comfortable environment, however, they also actively contribute in reducing the total energy consumption of the building. These systems offer an efficient and elegant solution to Team UOW's engineering vision - to ensure the optimal balance between maximum thermal comfort and minimal energy usage.

To increase the efficiency of the Heating Ventilation and Air-conditioning (HVAC) system, Team UOW students developed a set of innovative cold thermal storage tanks that contain a salt hydrate phase change material (PCM) and water. The PCM tanks are able to store an equivalent of 17 kWh each and act like a thermal battery that can be charged during the night and used to cool the building during the hotter parts of the day. The air-to-water heat pump charges the PCM at night when the heat pump's efficiency can be greatly increased due to the cooler ambient temperature. The PCM tank also has the benefit of shifting the buildings peak HVAC load from the middle of the day to the night, which allows Team UOW to spread the electrical load more evenly throughout the day. This assists in maximising the self-consumption of renewable energy in the building, as the electrical energy storage can be used to run the heat pump late at night when the overall electrical load is small. The Desert Rose HVAC system also incorporates an energy recovery ventilator which pre-conditions incoming fresh air, reducing the amount of energy required to cool the fresh air down.

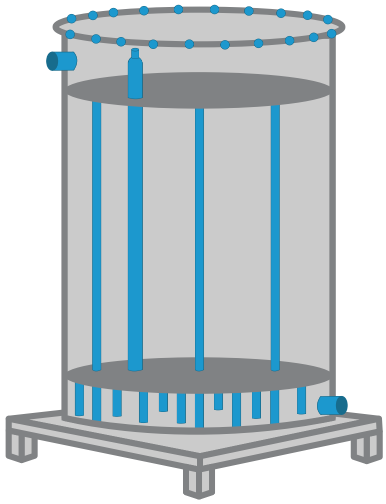


Figure 2.17 - Phase Change Materials Tank Photo and Diagram

Two radiant panels disguised as artworks are also located in the main living space. Chilled water can be pumped through these panels reducing the surface temperature and providing a radiative cooling effect to the occupants. Although these panels will not be used as a primary means for cooling the Desert Rose, they have been installed so that we can educate visitors on different mechanisms of how we as humans interpret temperature, and that we can achieve a comfortable state through radiative cooling rather than having to use excessive energy in cooling the entire air temperature.

The Desert Rose incorporates a smart DALI lighting control system in the house. Using DALI it is possible to dim individual downlights in the house to maintain optimal indoor lighting conditions. The DALI lighting is linked with the KNX building management system (BMS) that monitors indoor lighting and occupant levels in each room. If the BMS detects that no one is in the room, it can switch the lights off accordingly. The house also employs an 'All Off' switch at the entrance of the house which turns off all lights and standby power when the occupant leaves the home. This reduces the possibility of forgetting to turn lights off in the house which adds to the overall energy efficiency of the home. When the BMS detects that the occupant returns all active systems turn back on accordingly.

The Desert Rose utilises an innovative hot water system that is coupled to the BIPV-T system. The house incorporates

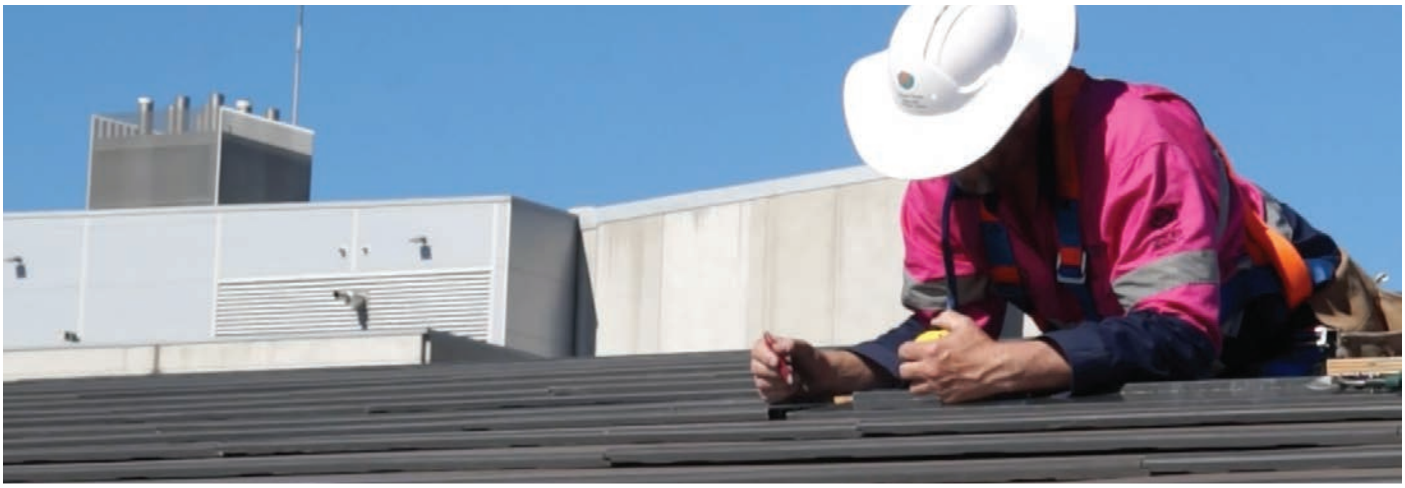


Figure 2.18- BIPV-T Being Installed

104 Tractile solar tiles that have water channels running underneath the solar PV. The hot water unit pump that takes cold water from the bottom of the tank up to the solar tiles where it is heated to around 45-50°C. The pre heated water then returns to the tank where it can be electrically boosted if required to provide domestic hot water to the home. This can save up to 50% of electrical energy that would be normally required to heat the domestic hot water with a conventional electric water heater. By running water through the solar tiles, it also has the added benefit of cooling the tiles down, which increases their efficiency and allows higher power output. During the summer months, cooling the solar tiles can increase the average energy production of the PV system over the course of a day by up to 10%. The electric booster for the hot water unit is also connected to a smart wifi controlled plug that is linked with the BMS. The electric boost will only turn on if there is sufficient solar energy to run the boosting element or if the cost of electricity is low. This ensures the maximum use of renewable energy and minimum cost to customers.

Efficiency of the Appliances

The Desert Rose house is designed for those living with age related diseases, such as dementia, Team UOW's goal was to not only incorporate energy efficient appliances in the home, but also appliances that are user friendly.

All appliances in the Desert Rose house have an Australian energy rating of at least 4/6 stars. One of Team UOW's unique appliances is the AEG L99699HWD combined washer/dryer that uses heat pump technology for the drying cycle with a 6 star energy rating. This is one of the first combined washer dyers with a heat pump in the world. Heat pump technology greatly reduces the energy required to dry clothes and unlike a conventional dryer it does not introduce moisture into the air. This further reduces internal heat gains and reduces the risk of mould developing.

The kitchen is fitted with a Miele KM 6363-1 induction cook top. Induction cooktops use electrical induction as opposed to conventional gas or electric heating. This leads to increased energy efficiency as cookware heats faster and heat losses in the system are reduced. The cooktop also contains mechanical knobs to control the heat which is more user friendly for those living with dementia who often do not recognise LED touch screens as a means to control the cooktop.

Finally, the electrical prediction model that is linked to the BMS provides feedback to the occupant such that if an appliance is operated at a certain time it will use: only renewable energy, partial renewable energy/ grid energy, or only grid energy. This allows the occupants to become more knowledgeable and actively contribute to maximising the self-consumption of renewables in the home.

Efficiency increases due to smart management

The Desert Rose incorporates an advanced BMS that couples all mechanical, electrical and plumbing systems to create a holistic building management solution that ensures the maximum self-consumption of renewables and maintains optimal thermal comfort and living conditions.

The heart of the Desert Rose smart energy management is the student developed, model predictive control (MPC) algorithm that optimises the use of the 13.8 kWh energy storage and 10.4 kW of solar PV. Using predicted solar irradiance, weather and occupant energy usage, the algorithm is able to maximise the amount of renewable energy used within the home, while minimising grid energy usage and subsequently electricity cost by creating optimal electrical exchanges between the renewable systems, home and the grid. This also allows for smart scheduling of major loads in the house including EV charging, hot water heating and HVAC. The prediction model is also able to provide feedback to the occupants on whether or not operating an appliance at a certain time will run solely off solar energy. Another added advantage of the MPC algorithm is that it is coupled with a learning algorithm that improves the prediction model. Therefore, the longer the occupants live in the house, the better the house is able to optimise

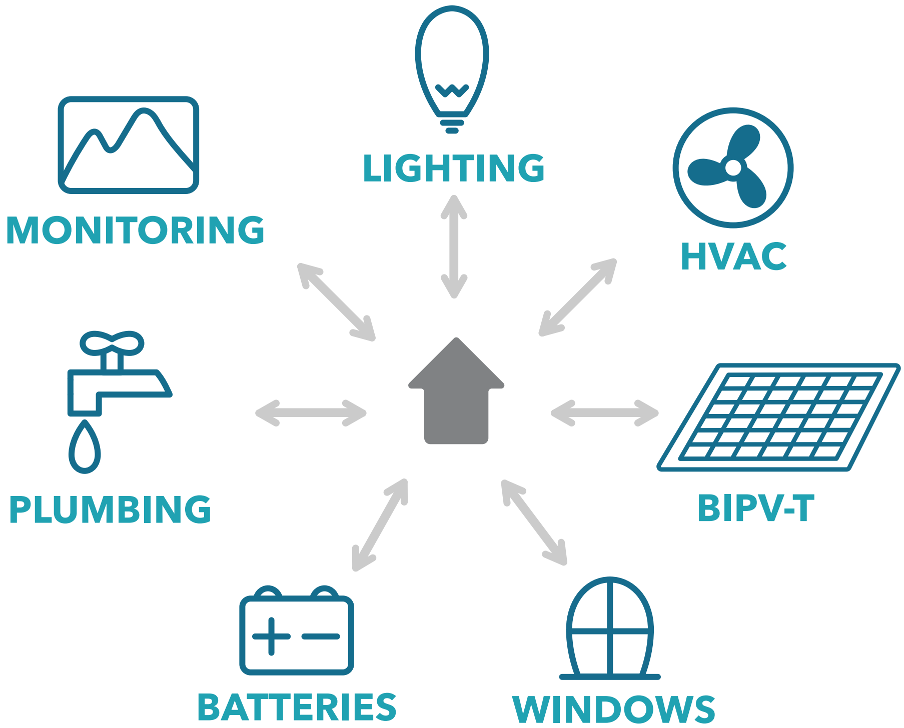


Figure 2.19 - Elements of the Desert Rose Work Together

the MEP systems around the way the occupants live.

All of the Desert Rose plumbing fixtures consist of electronic thermostatic mixing vales that are linked with the BMS. Smart plumbing fixtures allow the occupants to dynamically change the maximum temperature of each plumbing fixture along with setting automatic shut off times to conserve water. All water usage is monitored and fed back into the BMS to provide feedback to the occupants on their water usage.

Figure 2.20 - Glass Fines

Several of the internal electrical loads in the house such as the washing machine, dishwasher, TV, computer and microwave are connected to wifi controlled smart plugs. When there are no occupants in the house the BMS can turn off all stand by power, ensuring maximum energy savings.

Team UOW were able to create its advanced building automation system by using IoT programming platform Node Red. Using node red Team UOW are able to bring all of the MEP systems online into one location. This allows seamless interfacing of systems that are traditionally separate in buildings. For example, IoT has allowed the Desert Rose HVAC system to communicate with the solar PV and energy storage, it has also allowed Team UOW to incorporate smart load scheduling and occupant feedback to maximise renewable energy usage. It is Team UOW's belief that smart energy usage is the future of residential buildings, where building controls and occupant involvement ensure houses are as comfortable and energy efficient as possible.

Innovative Solutions

As mentioned in the above sections many innovative features have been designed and built by, or in collaboration with, Team UOW students to improve the overall energy efficiency of the Desert Rose, these include:

- A second skin wall designed and constructed by Team UOW students. This wall is manufactured using an aerated concrete with recycled glass powder as a cement replacement and carbon fibre reinforcement as a steel replacement. Combining these two replacements we are able to reduce the overall thickness of the wall from 75mm to 50mm and reduce the carbon footprint by up to 40%. This wall acts as a shading element to the east, south and west facades reducing the solar heat gain on these sides.
- Recycled timber door and window frames were developed in collaboration with Team UOW students. The innovative feature of these is the flush transition between the inside and outside of the doors to meet accessibility requirements. Many iterations in design were required to achieve a solution for air tightness, water management whilst maintaining this flush threshold.
- The overall HVAC system design and control was undertaken by Team UOW students. The innovative custom designed and manufactured PCM tanks can store approximately 35kWh of thermal energy. This enables the HVAC system to be operated during the night when the electricity price is cheaper, and the ambient temperature is lower, increasing the coefficient of performance (COP) of the heat pump. This stored energy is recovered during the day when the grid is experiencing peak load and the electricity price is higher. This smart solution can assist grid networks to better manage load requirements.
- The BMS has been designed and coded by Team UOW students. The innovative model predictive control enables the Desert Rose to better manage the electrical loads and maximises the overall energy efficiency of the house. The control system is capable of learning from past experiences and improves with time.

Other innovative solutions that Team UOW have used in the construction of the Desert Rose to improve energy

Figure 2.21 - Second Skin Wall Panels Freshly Painted

Figure 2.22 - Microshade Strips Visible on Doors on the South Facing Side of House

efficiencies include but are not limited to:

- Colorbond's Coolmax roof sheeting is manufactured less than 10km from the Desert Rose construction site and provides an innovative method for reducing solar heat gains. The high reflectance value of the sheeting can reflect up 77% of the sun's heat.
- Although not designed by Team UOW students, Viridians Microshade is an innovative product than enables access to natural lighting without compromising solar heat gains. This smart solution can significantly reduce cooling loads in hot climates.
- Tractile solar tiles are an Australian product that completely replaces the roof construction with an integrated solar and domestic hot water tile. These tiles enable Team UOW to take advantage of the water circuit beneath the solar cells to cool the tiles during the hottest parts of the day, increasing the cell efficiency, cooling the thermal envelope of the house and generating domestic hot water all at the same time.
- Daikin's Desica dehumidification system provides an innovative method for controlling humidity. The system uses two desiccant coated heat exchangers (DCHEs) which serve as the condenser and evaporator of the heat pump. The desiccant material traps moisture more effectively at a lower temperature, enabling the removal of the absorption heat during the air dehumidification process when it serves as an evaporator; this significantly improves the dehumidification performance. The desiccant can then be switched and regenerated by using the released heat when the DCHE serves as a condenser, which provides a reliable and energy-saving approach for regeneration. The COP of Desica can be over 5 during certain operating conditions.

Figure 2.23 - Second Skin Wall Illuminated at Dusk

2.4 Communications Strategy and Plan

Team UOW Australia-Dubai have carefully developed a strategic plan and communications strategy to engage, promote, educate and inspire the world about sustainability, innovation and the future of housing.

Participating in the Solar Decathlon provides teams with an opportunity to not only design, build and operate a solar powered house, but to communicate with the world about sustainable housing and make an impact. From the beginning, Team UOW Australia-Dubai have carefully developed a strategic plan and communications strategy to engage, promote, educate and inspire the world about sustainability, innovation and the future of housing. The strategic plan is an essential document used in internal Team UOW communications as a way of uniting the team towards achieving a shared vision, and our communications strategy has carried this through. We have successfully spread the word about the Desert Rose House and the Solar Decathlon Middle East to both a national and international audience, following the strategy and practices outlined in this report. We are very proud of the results we have accomplished and are excited to continue sharing our story throughout the SDME 2018 competition and beyond.

Our Vision

Team UOW Australia-Dubai is dedicated to creating and innovative and sustainable future that celebrates life.

Our Mission

Through practical collaboration between students and industry, Team UOW Australia-Dubai in the Solar Decathlon Middle East 2018 endeavours to change the way the world views sustainable housing by building a home that is architecturally inspiring, innovative and adaptive to a person's needs as they continue to age, creating 'A House For Life'.

Communication Strategy

Team UOW Australia-Dubai have developed our Communication Strategy to align with our overall strategic goals based on Competition Commitment, Housing Solutions, Team Enhancement, Institutional Reputation and Community Engagement. The last goal Community Engagement is the key premise of our Communications Strategy.

Figure 2.24 - State Deputy Premier Cutting The Ribbon

Communication Goals

Our communications plan defines 4 communications goals for Team UOW. These include:

To Educate - Educate our audiences about the innovative and sustainable smart solutions that Team UOW is generating through the Desert Rose House; using digestible and understandable content tailored to the audience.

To Promote – Promote Team UOW and the Desert Rose House to new audience groups to increase interest in the Desert Rose and the Solar Decathlon Middle East 2018.

To Engage - Engage consistently in two-way communication with our target audiences, sponsors, institutions and the SDME to keep them involved in the Desert Rose process and up to date on Team UOW's progress.

To Inspire - Use the Desert Rose as a proof of concept to encourage target industries and community groups to adopt sustainable technology and liveability focused design solutions.

Key Messages

We used these goals to devise four key messages that underpin our communications. These key messages are the foundation of Team UOW's purpose and objectives.

Sustainable housing design is achievable across all sections of the population.

Team UOW is investigating smart solutions to allow for the integration of sustainable technologies in the homes of the world's ageing population.

Vocational training and academic research must work hand in hand to make industry improvements.

Team UOW works under the guidance of the University of Wollongong in Australia and Dubai and TAFE NSW to bring together students and staff from all institutions in the design, construction and promotion of the Desert Rose House.

Considered design can lead to better quality of life for our ageing population.

The Desert Rose house is investigating innovative improvements to the design and technology integrated in homes for our ageing population to increase liveability within their homes prolonging independence, especially for those living with dementia.

The Desert Rose house is a proof of concept. Team UOW is designing the Desert Rose as proof of the innovative technologies that the building industry and retirement living industry can adopt in the near future to improve sustainability and liveability. Team UOW is dedicated to promoting the Desert Rose after the competition, in an effort to encourage long-term change in industry.

Target Audience

A vital aspect of the communications plan was defining our target audiences and determining which channels would be the most appropriate way of communicating with these target groups. Rather than looking at each target audience as a whole, we decided to devise a persona to represent each audience. This persona is a representation of the target audience based on their typical demographics, interests, behaviour patterns, motivations, and goals. Understanding who our target audiences are, helped us to identify the most appropriate methods of communications and most relevant messages. Our six key audiences are Sponsors, Staff, Government, Team UOW, the Community and Medical and Retirement Living.

Visual Identity, Uniform, Motto and Project Name

Visual communication students from UOW developed the Team UOW Australia-Dubai brand with advice from senior design academics within the university. A key aspect of our goal to promote Team UOW Australia-Dubai and the Desert Rose House was to create a recognisable and robust logo and visual identity that makes our team identifiable across the printed material, digital communications, events and within the SDME2018.

The name, Desert Rose and our corresponding logo was conceived with reference to Australia's flower the Sturt Desert Rose. This flower, which flourishes in the harsh, arid environment of the desert across central Australia. The shapes were created with reference to the shape of the flower petals and are representative of the five sub-teams of the Desert Rose. The colour palette was chosen for two reasons; first to reflect the vibrant blue and teal hues of the Australian landscape and the sand present in both Australia and Dubai. Secondly our research indicated the colours were a common theme in Middle Eastern logo design and are complimentary to each other.

To support our visual identity we have our team mascot Rosa the Kangaroo. She is a recognisable mascot for our team as an iconic Australian animal. Rosa is a fun way to appeal to a younger audience and is a key feature of our social media. In addition we have developed two safety mascots, Saferoo and Safe Clayton who are recognisable figures promoting safety, who both wear our unique pink hi-visibility uniform. These figures have been used on our construction site and have been turned into fun stickers that we give to children to promote the Solar Decathlon and encourage safety, a creative way to engage children through our communications.

Our team uniform uses the colour black, chosen to parallel the UAE flag which references strength of mind, as the Desert Rose promotes a healthy house that is a strong foundational haven for its occupants, especially those with dementia. The black also provides a solid base for our striking logo to appear. The eye-catching design appears on each of our uniform pieces, professionally designed for our formal dress shirt and polo shirt. We have designed two more casual t-shirts, one features our house design and our top tier sponsors who have supported our journey. The second t-shirt has been designed to recognise the Australian culture and our focus on safety, promoting our Saferoo mascot with our recognisable Australian 'G'day from Down Under'. Additionally, Team UOW has a pink high-visibility construction uniform, chosen to differentiate ourselves in Australia and in Dubai with our unique colour. Wearing this during our construction and public display in Australia has promoted Team UOW throughout our region, making us recognisable to industry and public.

The team motto of 'A House For Life' has been utilised alongside the primary Desert Rose logo as a succinct way of further conveying our mission and our vision for the project. 'A House for Life' is our focus of building a house that is comfortable and enjoyable to live in for your whole life.

Team UOW's visual language works as a key identifier of the team. Graphic materials are utilised at every point of contact across the communications plan. Having a strong visual identity has made us recognisable across the university campus and throughout the Illawarra, as it will in the Solar Hai and around Dubai.

Figure 2.25- Official Team Uniforms

Communications Plan and Communication Throughout the Project Duration

Team UOW developed an actionable communications plan that framed how we could convey our key messages efficiently to our target audiences. Team UOW developed our communications plan with guidance from a leading marketing business in the Illawarra, Waples Marketing Group and media specialists from the University of Wollongong's Strategic Marketing and Communications department. They supported our team of students in developing an effective communications strategy and plan suitable for the SDME2018. Throughout the execution of our communication activities, we constantly referred to our Communications Plan as a guide to whether the material being produced served the intended purpose based on our goals, objectives, key messages and audiences.

Team UOW carefully planned each of our communication actions, ensuring that each action met with our objectives. Along our journey, we received different suggestions from a variety of sources, recommending different communication actions that we could implement. We only enacted suggestions that aligned with our communication plan. This ensured we were staying true to our purpose and maintaining our brand.

Web and Social Media Content and Impact

Based on our key personas Team UOW pinpointed social media as a key channel to achieve our communication goals. Social media is a cost-effective resource that can yield a highly effective spread of communication to our audiences. This, in conjunction with our digital newsletter, became a vital method of delivering consistent updates to those that had already shown interest in the Desert Rose. The versatility of social media allows us to address our key communications goals to educate, promote, inspire and engage and target all six of our key audiences.

The primary platform we use is Facebook. Facebook allows us to communicate with the broadest segment of our audience. Currently, our Facebook page has almost 1500 followers. We also publish content on Instagram, Twitter, LinkedIn and YouTube. We tailor the content to each platform and design for the intended audience. Instagram primarily targets the Community, Team UOW, Sponsors, Medical and Retirement Living as well as SDME2018. Twitter is used to communicate with Government and the Medical and Retirement Living audience; LinkedIn targets our Sponsors and Staff; and YouTube connects to all our audiences.

Team UOW used social media to:

- Promote the Desert Rose to UOW students and staff to encourage new decathletes
- Promote the Desert Rose Reveal- Our week of Public Events promoting the Desert Rose House and the SDME2018 with a primary focus on Sustainability
- Educate our audience about the innovations and smart solutions in the Desert Rose House. We have established a weekly educational posting schedule across Facebook and Instagram, as well as weekly decathlete blogs to allow our audiences to get to know the individuals in the team and understand the innovative, smart solutions implemented in the Desert Rose House.
- Provide consistent engagement through design and construction updates
- Inspire audiences to adopt sustainable thinking through diverse and informative content.

Team UOW has developed and maintains our website (www.desertrosehouse.com.au) which provides a comprehensive guide to Team UOW. On the website we outline our goals, media appearances, sponsors and have a wide range of media including photos and videos. The site also contains a comprehensive guide to the sustainable technology, passive design and other innovations within the Desert Rose. As of September 2018 our website has had over 31,000 page views with visitors from over 90 different countries.

Team UOW is also passionate about sharing our story and involving all members of our team in our communications process. The communications team recognised the significance of human interest in communicating a message. We asked every student to write a blog that describes their experience in the team. Each week this blog is posted to our website and shared on Facebook. The blogs provide a timeline of our journey and introductions to all our fantastic team members. These posts typically reach over 1,000 people each week.

Team UOW's monthly newsletter is used to engage our audience by updating them on recent progress within the team as well as give an opportunity to promote upcoming events and our industry sponsors. The monthly newsletter also includes a decathlete profile, in which a decathlete provides an overview of their tasks within the team, and a little about themselves. Our monthly newsletter has over 1200 people signed up for it, with an average clickthrough rate of 27%, well above the industry average.

Audiovisuals

Videography is utilised across all mediums of Team UOW communications. Because of its educational, promotional and inspirational qualities we have made our videography material fundamental to our digital media, public media and events strategy. We have used a combination of timelapse and traditional video footage in our audiovisual material. All videos have been produced by our team members, including the audio recordings.

Throughout the project, the communications team has encouraged decathletes to collect an abundance

Figure 2.26 - Clayton McDowell Speaking at the Desert Rose Reveal Event

of footage which we have curated into purposeful and considered videos. This captures our design process, innovative features and events. These videos have been some of our most engaging content. We plan to produce a Desert Rose documentary of our journey and have captured documentary footage to communicate the SDME2018 journey to the community.

App

Team UOW's students have designed and developed an innovative mobile app to communicate with audiences about the Desert Rose House. Our app can be used anywhere in the world to see an augmented reality model of the Desert Rose House using only our logo. In conjunction with the tour plan and wayfinding system the app is an additional tool to educate audiences about the features of the Desert Rose House. The app utilises augmented reality technology to allow guests to scan icons around the house to access information, diagrams and animations on the related technology. The app also has information on the Team UOW solar decathlon journey and 3D model of the house. After the competition when the house is permanently on display in Australia, a fully-guided tour will be added to the app. We believe our mobile app is a highly innovative tool to engage and educate our younger and professional audiences due to its interactive nature. In consideration of our older and less technologically able target audiences we have designed the app with accessibility principles in mind.

Seminars and Conferences

Team UOW has presented to numerous audiences in numerous contexts. Decathletes from across Team UOW have presented and held information stands at many events including Sydney Build Expo, aged living conferences, university workshops, STEM festivals, Innovation Campus events, Engineering Australia Conference, UOW open days and pitch competitions. In total Team UOW has given 72 presentations and held 26 exhibition stalls and events throughout the Desert Rose's journey, reaching an audience of over 30,000 people. Team UOW have attended and held a variety of presentations and stalls to reach all six of our target audiences in a format/location to suit them.

Team UOW has incorporated the use of Augmented Reality as an innovative educational tool. Using the Microsoft HoloLens, we are able to give visitors a virtual tour of the Desert Rose House using augmented reality. We can also demonstrate the Desert Rose's age-related adaptability and passive design elements in any location using this technology. This tool also allowed Team UOW to demonstrate our design to industry professionals during the design phase to gain feedback on our design, an innovative approach to the building design process.

Appearances on Radio, TV, Press and Magazines

Team UOW acknowledged that not all our target audiences use social media. Therefore, it is essential to communicate with these audiences using an alternative communication method. We used tailored media releases to engage with traditional forms of media to spread our message at crucial milestones throughout the project. The media coverage commenced with our acceptance into the project which made local news in October 2016, local news headlines again with our Construction launch in December 2017, and our Public Open day in July 2018. We also had many stories published in different outlets over the duration of the project, ranging from local to national news stories covering various aspects of the project across newspapers, tv news, radio, internet, blogs and trade magazines. As of September 2018, Team UOW has had 133 media publications across Australia and the UAE.

In addition, Team UOW have agreed to feature in four additional magazines during the competition in Dubai. These include the Engineers Australia magazine Create which is sent to every single professional engineer in Australia; appear on the front cover of ReNew Magazine which is Australia's premier sustainability magazine; EcoLibium Magazine from Australia's peak body in HVAC&R; and UOW Outlook Magazine that is sent to all 70,000 UOW alumni.

Figure 2.27 - Desert Rose App Screens

Education and Social Awareness

TAFE educational space - As part of Team UOW's goal to create long-lasting change in the Australian building industry, as well as our collaboration with TAFE NSW, Team UOW established an educational space at our initial site of construction. This educational space included posters designed and printed by our graphic design students, focusing on sustainable engineering, team innovations, passive design elements, BIM and on-site safety culture. It also featured an architectural scale model, an augmented reality model; and materials from the Desert Rose House.

While the Desert Rose was being built at the TAFE campus, we invited schools, tertiary education students and the media, over 300 people, to visit and learn how Team UOW is using smart solutions and sustainable technologies to build the Desert Rose House. This exhibition was a crucial step in educating our vocational students about sustainable design excellence within the building industry. This space was used to engage with all six of our target audiences.

Major Events - Throughout the Desert Rose journey, Team UOW has organised and hosted events to promote the Desert Rose House and SDME2018. Some of our earlier events included The Desert Rose construction launch and our industry focused Trade Night. Team UOW events strategy culminated in the Desert Rose Public Reveal Week in July 2018. This series of events was planned by the communications team to engage with our key audiences. Our Sponsorship Evening and Industry Breakfast was designed to enable Team UOW decathletes to directly engage with the sponsors that have supplied some of the technologies and materials in the house as well as those from community organisations who have advised the direction of the Desert Rose. The Sunset Social was a partnership with UOW's Innovation Campus to engage academics and professionals across various industries; and to inspire some of the Illawarra's leading minds to work collaboratively to achieve a more sustainable future. Our public reveal weekend was open to the larger community. Our official unveiling the following week attracted local and state politicians, significant sponsors as well as local news coverage. Team UOW's active promotion of these events in social media, newspapers, promotional signage, fencewrap and newsletter distribution resulted in event attendance by over 1500 people. Our overall reach for these events is estimated to be over 50,000 people, almost 20% of our region's population.

We designed all these events to include specialised sustainability talks, house tours and access to printed material. The weekend display also involved stalls promoting sustainable practices such as organic gardening, recycled furniture and education on proper waste disposal practices, as well as all food vendors with zero single-use plastic. These events were also a chance for networking between industry leaders which operationalises our communications objective; to encourage a change in mindset across professional and public communities using the Desert Rose as the potential for sustainable, innovative and aged focused housing.

Youth Engagement - Team UOW strives to inspire and educate our younger generations on sustainability. We have engaged youth through kids colouring-in, family activities and our mascot photo frame at our reveal festival. Recently a local school has created a 'Desert Rose Garden' inspired by our project. We also tour school groups around the Desert Rose construction site (which was publicised on local TV news).

Dementia Australia - As a key contributor to the development of our Dementia focused solutions within the house, Team UOW has maintained a close working relationship with Dementia Australia. In turn Team UOW has been given many opportunities to promote the Desert Rose to Dementia Australia stakeholders as well as inspire and educate their already established audience. Two key activities included participation in the Illawarra Dementia Walk and taking photos of decathletes holding signs with #youthfordementia which were shown at an international conference. Our key message to the Medical and Retirement Living audience is that sustainability is important and achievable in their daily lives. Concluding the Solar Decathlon Middle East, Dementia Australia has asked to partner with us in developing a series of videos that educate their community on how to retrofit their homes to be more sustainable and supportive for people living with dementia.

Figure 2.28 - Touring the Desert Rose

Communication at the Solar Hai

To ensure that the innovative smart solutions in the Desert Rose House are highlighted during touring, Team UOW has developed a comprehensive tour plan. Our tours involve a single decathlete taking a group of approx. ten people through the house, making stops to point out and share the sustainable and innovative features of the Desert Rose House. The tour plan also contains all information needed to cover most questions that guests will have about the Desert Rose, so that extra information can be shared with inquisitive guests.

When touring guests around the Desert Rose in the competition, there will also be informational wayfinding signage. This signage will highlight critical points around the house to deliver more in-depth and visual information focused on the Team UOW journey, BIPV-T panels, second skin wall, greywater treatment system, HVAC, microshade windows and dementia considerations.

Team UOW will continue to carry on our communications objectives during the SDME2018 in Dubai by committing to a vigorous communications plan including daily blog posting, weekly newsletters, on-site video development and consistent social media posting to communicate with family, friends, sponsors and supporters in Australia and internationally. During the competition phase, we will promote our social media and newsletter to those that tour the house, so they can join Team UOW for the future of our journey. We will also be distributing information booklets and asking guests to download the app which will provide them with ample resources to learn more around the Desert Rose. The app informs visitors of the innovative and sustainable features of the house, including short videos, photos and fun facts.

Guests will be provided with a brochure that they can take home with them. This brochure has a unique swivel pin design that provides the reader with a variety of information in an easy-to-read, fun format. For young children, stickers will also be offered as a fun alternative. Our wayfinding signage and brochures are all printed in both English and Arabic to ensure we can communicate with all visitors.

Innovation

Team UOW has shown innovation in our communications in the way that we have adopted new media technologies as tools to communicate with our audiences. Team UOWs mobile application with integrated AR, VR and 3D modelling is a way to leave a lasting impression on guests and increase Team UOW's educational potential. Our use of the HoloLens throughout the competition has also been an innovative asset in the way that Team UOW engages in a two-way dialogue around the design of the house.

Results and the Future

Team UOW has planned and executed a communication plan that endeavored to deliver our four communications objectives; to educate, to inspire, to promote and to engage. In the vision of our strategic plan, we believe through our various methods of communication we have successfully delivered on our objectives and key messages.

The Desert Rose Reveal event had a reach of over 21,000 people on Facebook. During this keystone event we had a weekly average impression of 14,968, while our average weekly reach grew to 6,722 people. Team UOW have only spent $60AUD on Facebook promotions. We continue to have an average organic reach of over 1,000 people each week. More broadly, Team UOW can safely estimate that we have connected with 88,000 people since late 2016 through exhibitions, presentations and social media connections.

When the Desert Rose returns to Australia, it will be built on the sustainable housing precinct where it will sit alongside the Illawarra Flame House and the Sustainable Buildings Research Centre. Team UOW will continue to share the Solar Decathlon during future presentations and events. The Desert Rose will be open for tours regularly, including visits from international dignitaries, politicians, school groups and community groups. It will be open twice a year for public display during the national Sustainable Houses Day in September each year and the Sustainable Building's Research Centre's annual open day. It will feature on school student visits to the nearby Science Centre, continuing to promote sustainable futures to our youth. It will also become a Living Lab where guests will be able to stay in the house to experience sustainable living, while we gather more data to further improve the Desert Rose House.

Team UOW has energised so much excitement surrounding this project in the Illawarra that Wollongong City Council has reached out about the potential of hosting a Solar Decathlon Competition in the future.

Figure 2.29 - Team UOW Mascot Rosa The Roo and Safe Clayton

2.5 Sustainability

The Living Building Challenge has inspired Team UOW to exceed traditional building approaches by using non-toxic materials, recycling construction waste, conceptualising the building and its occupants in situ, and connecting the indoors with nature.

The Solar Decathlon offers a benchmark for sustainability, but Team UOW have chosen to go above and beyond this benchmark with a strategy that aims for Living Building Challenge certification. With our Desert Rose we have also aimed to encompass sustainability in creating a building that is able to grow and adapt to meet the needs of the occupants as they age, reducing the need for resource-intensive reconstruction. This narrative explores the solutions and materials that we have selected to make the Desert Rose sustainable and 'A House For Life'

Living Building Challenge

'Imagine a building designed and constructed to function as elegantly and efficiently as a flower: a building informed by its bioregion's characteristics, that generate all of its own energy with renewable resources, captures and treats all of its water, and that operates efficiently and for maximum beauty' (Living Building Challenge).

The Living Building Challenge is an international sustainability certification that encompasses a holistic approach to achieving sustainability through innovative design, smart solutions, minimal waste and connection to nature. The Living Building Challenge has inspired Team UOW to exceed traditional building approaches by using non-toxic materials, recycling construction waste, conceptualising the building and its occupants in situ, and connecting the indoors with nature.

The Living Building Challenge consists of 7 petals, Place, Water, Energy, Health and Happiness, Materials, Equity and Beauty. The Desert Rose has been designed and constructed with these concepts at the forefront driving sustainability in all aspects.

Team UOW is based out of the University of Wollongong's Sustainable Buildings Research Centre (SBRC) which is on track to become Australia's first fully certified Living Building Challenge building and join a list of less than 20 buildings to receive certification worldwide. Our vision in the future is to couple the Desert Rose with the SBRC to meet the Living Community Challenge.

Construction System

Team UOW's construction system uses light gauge steel that is manufactured specifically to our structural drawings with members cut to size with millimetre accuracy. Intelligent BIM software was adopted for the design of the overall house frame which resulted in there being no cutting required during the assembly of the frames and trusses, which resulted in almost zero waste. The steel is manufactured less than 10km from our construction site, and the frames themselves, along with any off-cut material and waste steel, is 100% recyclable, which made it the ideal building product for the sustainability challenge of the Solar Decathlon project. The adoption of light gauge steel was also driven by the convenience of the material manufacturing process and the reduction in weight when compared to a traditional timber frame construction. By selecting to use light gauge steel over traditional pine timber we were able to reduce the weight of each wall truss panel by approximately 35%, saving a total of 1,150 kg. This saves in shipping and assists in manual handling as the steel panels can easily be moved and assembled by only two people. Once ordered the frames can be rolled to size within a couple of days and took Team UOW students only 4 days to assemble all individual wall and truss panels and eliminated the need for hiring professionals to assemble our structural frame. Although timber takes in carbon from the atmosphere and stores it for the life of the building, steel is more durable, stable and termite proof, requiring little to no maintenance for the entirety of the building life. The Desert Rose is constructed to be comfortable and healthy to live in, with steel emitting no toxic emissions during the building's life, it was selected to be our primary structural component.

The Desert Rose has been designed with additional noggins placed at a handrail height, enabling the house to easily be retrofitted with handrails should the occupants in the future have mobility issues. This reduces the need for costly retrofits ensuring the building is sustainable for occupants for longer. Additional strong points have also been fitted in the roof trusses to allow for a hoist to be fitted between the master bedroom and bathroom should one be required.

Materials

Plasterboard: The internal wall and ceiling lining of the Desert Rose is Gyprock Sensitivity. A locally manufactured product that experiences zero growth in mould spores, eliminating mould growth and provides "long-term peace of mind for asthma and allergy sufferers". Gyprock Sensitive has VOC levels around 90% less than the maximum allowable levels set by the Green Building Council of Australia (GBCA).

Cladding: The external cladding of the Desert Rose is Weathertex Ecowall. This cladding is manufactured from 97% recycled hardwood timber and 3% wax, is termite resistant and has a 25-year warranty. The product claims to have a "Better than zero carbon footprint" and is accredited under the Living Building Challenge.

Glasswool Insulation: The cavity walls of the Desert Rose are filled with Bradford Black glasswool insulation. Australian made, it is manufactured with natural binders that are better for the environment and exhibit hypoallergenic properties. With a 70-year warranty, the product displays low odour characteristics, does not contain any VOC and uses no ozone depleting products for manufacturing. It is approved by the National Asthma Councils Sensitive Choice Program and contains on average 80% recycled glass content and renewable raw materials in the manufacturing process.

Roof Sheeting: Two different materials are used for the roof covering of the Desert Rose, Colorbond Coolmax for the northern sloped section and Tractile solar tiles for the southern sloped section. Colorbond Coolmax is a steel sheeting product manufactured less than 10km from the Desert Rose construction site. The sheeting is coated in a highly

Figure 2.30 - Weathertex Cladding

reflective material that has a nominal solar reflectance of 0.77, passively keeping the house cooler by reflecting up to 77% of the sun's rays. The Tractile solar system is covered below in the Solar System section.

Timber and Door Frames: Recycled timber door and window frames were developed in collaboration with Team UOW students. The innovative feature of these is the flush transition between the inside and outside of the doors to meet accessibility requirements. Many iterations in design were required to achieve a solution for air tightness and water management whilst maintaining this flush threshold. The timber used in the manufacturing of these was reclaimed from demolition sites across our local area, manually de-nailed and given new life in a factory located less than 7km from the Desert Rose construction site. These frames are not just aesthetically beautiful but bring character to Desert Rose with each piece of timber having a story from its previous purpose.

Decking: The Desert Rose decking, and ramp material is ModWood, an ecofriendly plastic composite with 90% of the material used either recycled or reclaimed. Each linear metre contains approximately 37 recycled plastic milk bottles and 2 kilograms of reclaimed pine dust. The UAE does not have an abundance of raw materials suitable for construction, but like all metropolitan areas they generate waste including plastic. ModWood is an innovative solution showing how waste products can be transformed into a sustainable product. ModWood is Green Tag Certified with no formaldehydes used in production. After processing there are no noticeable Volatile Organic Compounds (VOC's) and contains no chemical that will leach out, thus are suitable for ecologically sensitive areas.

Second Skin Wall: This wall acts as a shading element to the east, south and west facades reducing the solar heat gain on these sides. This innovative solution is student designed and manufactured, it is made of a foamed concrete incorporating recycled crushed glass as a cement replacement and carbon fibre mesh reinforcement as a substitute for conventional steel reinforcement. The mix design was developed by UOW students and implemented for use in the Desert Rose to create the innovative and architecturally appealing wall. The foam concrete is half the weight of standard grade concrete and the carbon fibre enables us to reduce the wall thickness from 75mm to 50mm. Combining these two replacements we can reduce the carbon footprint by up to 40%. This again highlights how common waste materials can be used to lower our ecological footprint.

Passive Design Strategies

Dubai is dominated by an extremely hot and humid climate with the majority of dwelling energy dedicated to cooling. To address this Team UOW have designed our building envelope and adopted several passive design strategies to reduce solar heat gains and increase the overall energy efficiency of the Desert Rose house.

Energy + was utilised to investigate the effect that varying insulation values of the walls, floor, ceiling and roof had on the overall energy consumption. As expected increasing the insulation values decreased the combined cooling and heating demands but diminishing returns were experienced for R values above 6, thus an R value of between 5 and 6 was targeted for the external surfaces of the envelope (refer to Chapter 5). These values are achieved primarily through glasswool insulation in the cavities and extruded polystyrene (XPS) applied externally to the steel frames to increase the R value and reduce thermal bridging. A ventilated cavity has been designed between the external façade and the XPS layer, this is open at the base and top of the walls allowing built up hot air to escape.

The Desert Rose consists of a series of panelised wall, roof and floor modules with numerous joins throughout. To address the possibility of a high infiltration rate, the house is wrapped in an airtight membrane with the joins between panels sealed prior to installing the external façade / roof sheeting. Awning windows are fitted with seals and external doors have been custom designed to ensure a flush transition between inside and outside whilst achieving an airtight seal. These measures lower the overall infiltration rate of the

Figure 2.31 - Modwood Decking

envelope and improve energy efficiency.

The Desert Rose has been designed to meet the privacy needs of the Middle East and to be suitable as both a standalone dwelling and for use in a higher density aged care village where the houses would be positioned in a line and share common western and eastern walls. This reduces the number of external walls and further decrease the energy lost to the outside. Following these concepts and to reduce solar heat gains, Team UOW's design minimises window openings on the eastern and western house façades whilst maximising windows on the northern façade for daylighting. Clearstory windows are provided in the living area enabling natural light to penetrate deep within the house whilst reducing direct solar heat gains.

Although Dubai's extreme climate rarely falls within a comfortable band, the Desert Rose has been designed for natural ventilation when returned to Australia. The clerestory windows combined with the courtyard window allow for cross ventilation with a minor stack effect in the main living room.

Recycled hardwood timber frames and triple glazed, argon filled low e coated windows and doors are employed throughout the house to reduce heat gains throughout the day and heat loss on cooler nights. The glazed surfaces located next to the southern courtyard are affected by direct sunlight. To address this Viridian's Microshade mesh has been installed on the internal surface of the external layer of glass. The Microshade consists of microscopic lamellas which shade the direct sun progressively. Microshade has the equivalent effectiveness of exterior shades, whilst maintaining natural lighting. In summer when the sun is high in the sky, the energy from the sunlight can be reduced by up to 90%. Honeycomb blinds are fitted to most windows and provide privacy and additional insulation when in the closed position.

Building Integrated Photovoltaic Thermal (BIPV-T) tiles are fitted to the south facing roof and provide a 5-in-1 combination of roof, insulation, electricity, solar PV cooling and hot water, and is engineered

Figure 2.32 - Team UOW Assembling the BIPV-T on the Roof of the Desert Rose

to withstand the extreme weather conditions, offering longevity with low maintenance. The north facing roof is sheeted in Colorbond's Coolmax steel which has a high reflective coating that achieves a Nominal Solar Reflectance1 = 0.77 and Solar Reflectance Index (SRI)1 =0 95, thus reducing solar heat gains. A ventilated cavity has been constructed beneath the BIPV-T tiles and Colorbond sheets to prevent pockets of hot air building up.

The Desert Rose's south, east and western facades are wrapped in an innovative lightweight second skin wall that was designed and built by Team UOW students. This concrete wall acts as a shading element, reducing direct solar heat gains (refer to chapter 5). The second skin wall has a series of holes and is open at the top and bottom to allow air to freely move around the wall, cooling the concrete at night.

Active Systems

The Desert Rose house incorporates a state-of-the-art innovative HVAC system to maintain optimal thermal conditions within the home. The system was designed by Team UOW to ensure maximum comfort for the occupants year-round. An air-to-water heat pump is used in conjunction with two fan coil units as the primary source of cooling for the house. The system also consists of a dehumidifying heat pump to control humidity, and an energy recovery ventilator to maintain the C02 concentration at a reasonable level in the house. By intelligently controlling these devices, the Desert Rose house can achieve optimal thermal comfort while aiming to reduce the overall energy consumption of the system.

One of the key innovations at the core of the HVAC system is the on-site thermal storage tanks that contain a salt hydrate phase change material and can store an equivalent of 35kWh of thermal energy. These tanks act like a thermal battery that can be charged at night when the ambient temperature is cooler which reduces the amount of energy required to charge the PCM tank. The tanks can then be used during the day to drive the two fan coil units to cool the building. This not only reduces the houses overall energy consumption but shifts the peak HVAC load away from the middle of the day when typical peak load in Dubai occurs. Finally, the HVAC system can directly communicate with the energy management system to maximise the amount of renewable energy used by the HVAC system, thus, minimising energy used from the grid.

DALI lighting is used throughout the home to maintain sufficient light levels. DALI lighting makes each individual light intelligent with a unique address. Using presence/lux sensors located in every room, the smart lighting system is able to dim lights to maintain a specific lighting level, saving energy. Lights will also automatically turn off when no one is in the room. The Desert Rose also has an 'All Off' option at the entrance to turn off all active systems, lighting and standby power when leaving the home. When the house detects the occupants return, the active systems can turn back on accordingly. The use of DALI lighting also reduces the amount of cabling required as there is only one circuit that connects each downlight ballast. This approximately reduces the total amount of cabling required for lighting by a factor of 10.

Selection of Appliances

All of the appliances in the Desert Rose were chosen with two specific criteria in mind. First, all appliances must be extremely energy efficient, with an Australian energy rating of at least 4/6 stars. Secondly, they must be user friendly for those living with age related illnesses such as dementia. The Desert Rose incorporates a 6 star energy rated washer/dryer that utilises heat pump technology, one of the first of its kind in the world. Using heat pump technology for clothes drying means the dryer will not increase the temperature and humidity in the indoor environment as much as a conventional dryer, thus decreasing the overall house cooling load. The house also utilises an induction cooktop. Induction cooktops are significantly more energy efficient than regular electric cooktops as the pots and pans can heat up much quicker and there are reduced thermal losses, however, cooktops in general use significant electrical energy. To combat this, Team UOWs cooktop has a 'Booster' option that can be turned off to minimise the amount of electric energy used during cooking. This will help ensure the electrical energy storage units can provide all the power required for cooking at night when the solar PV system is not producing power.

Team UOW's innovative building management system incorporates a prediction model that informs the occupant on whether operating an appliance at a certain time will run purely off renewable energy. This assists the occupants in making decisions on when they run their appliances to maximise the amount of renewable energy in the home, adding to the houses overall sustainability and actively involving the occupants in recognising and adapting their energy consumption patterns.

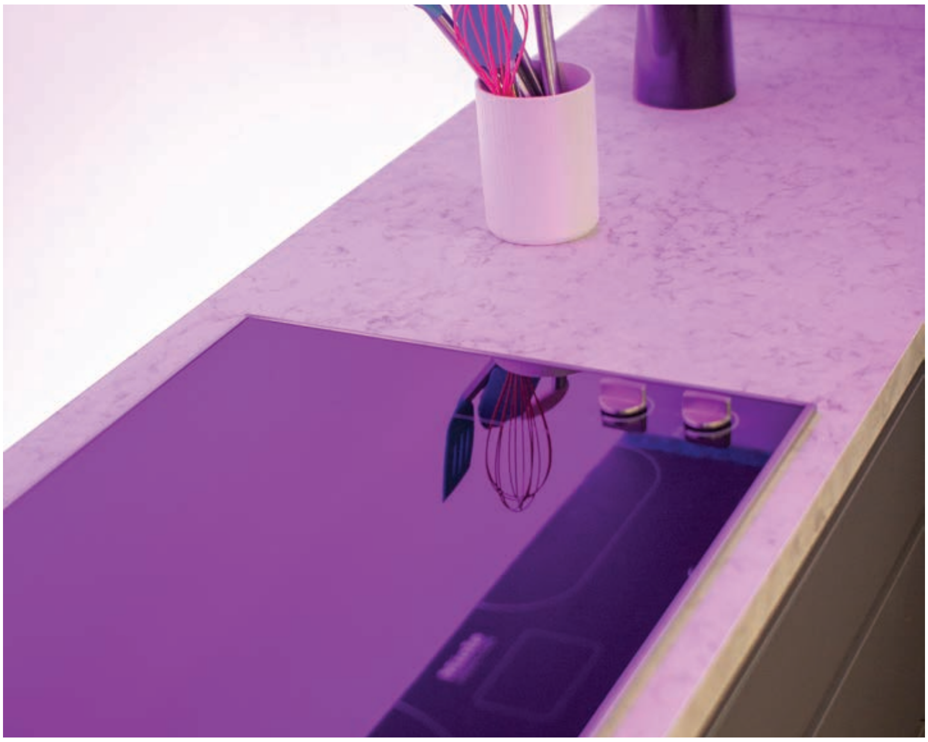


Figure 2.33 - Induction Cooktop with LED Backlight Changing Colour

Solar Systems

The Desert Rose has a state-of-the-art building integrated photovoltaic-thermal system. The system is made up of 104 solar tiles with a combined rated output of 10.4 kW from Australian company, Tractile Solar. Team UOW made the decision to incorporate the solar tiles in the building construction to create a 5-in-1 system. The solar tiles not only produce all of the house's electricity, but they also completely replace the roof construction on the southern facing portion of the house. The unique design means there is no need for roof sheeting. Instead, the interlocking tiles make up the entire roof and are able to withstand extreme weather conditions such as cyclonic winds and severe heat.

Along with producing electricity, the solar tiles also have water channels that run underneath the tiles which serve three purposes which are particularly relevant to local conditions in the UAE. Firstly, the water channels are connected to the hot water unit which pumps water through the tiles during the hottest parts of the day to pre-heat domestic hot water to 45-50°C. The water running through the tiles is a closed loop system, therefore no water is wasted in the process. Secondly, running water through the solar tiles creates a heat exchange effect, cooling the tiles which greatly increases the solar PV efficiency. Finally, the cooling of the solar tiles in turn cools down the building envelope, acting like an active insulating element.

This 5-in-1 system means that the Desert Rose is able to reduce its total construction materials. By using Tractile Solar tiles there is no need for roof sheeting on the southern facing portion of the house, no need for traditional solar thermal evacuated tubes and no need for bulky solar mounting equipment that is found on traditional roofs.

Team UOW's philosophy in regards to energy is to maximise the self-consumption of renewable energy in the home. This is achieved by optimal control of the 13.8 kWh energy storage system along with the major electrical loads. Team UOW students have developed a model predictive control algorithm that predicts weather, solar PV power output and occupant energy usage to optimise the charging and discharging of the energy storage unit. The overall goal being to maximise the amount of renewable energy used in the house. All major loads such as EV charging, hot water, HVAC and lighting are also fully controllable and linked with the Desert Rose building management system. Deferrable loads such as hot water heating and EV charging will only operate when sufficient renewable energy is available. Through smart control and energy management, the Desert Rose will become as grid independent and sustainable as possible. The Desert Rose also uses low smoke halogen free XLPE insulated cables where possible to again, avoid using PVC.

Vegetation: Plantings form the intersection between the ground plane and the building, with soft building edges allowing the Desert Rose to merge and mature with the landscape. The colours of the landscape materials form a neutral palette in harmony with the building allowing the planting to be the dominant feature of the site, working with the building, rather than being in competition with it. The splashes of colour that appear throughout the year and the native fauna attracted by flowering, mark the seasons and contrast beautifully with the timber and concrete of the house. In Australia native plants will adorn the landscape, while more durable local plants will be used in the Middle East context. Plant life in the form of green walls, potted plants and herbs found within the Desert Rose enhances sustainable living, aesthetic comfort and emotional wellbeing, connecting the interior and exterior of the house and supporting a healthy lifestyle.

Water

Like many parts of the world, Dubai will face issues of water security in the future. The Desert Rose will effectively treat and reuse greywater, which could offset up to 60% of its potable water consumption. The Desert Rose will utilise a recycled vertical flow constructed wetland to treat the greywater produced and reuse the treated effluent for non-potable applications around the house, such as toilet flushing, clothes washing and irrigation of landscaping like the vertical green wall on the back deck. The wetland was designed and constructed using recycled sustainable materials by Team UOW students. The innovative design reduces typical wetland size by up to 90%, by recirculating the greywater multiple times through the system, making it more economically and socially attractive to the home owner.

The Desert Rose has also sought to minimise its impact on the environment by steering away from traditional plumbing materials, such as poly vinyl chloride (PVC) and associated harmful glues. Instead the Desert Rose utilises Raupiano drainage which is 100% recyclable, contains no toxic chemical and only uses non-toxic lubricant to interlock.

Waste Management

As part of Team UOW's endeavour to meet the Living Building Challenge a stringent waste management plan was created that focused on reducing the creation of waste and recycling as much waste as possible. To achieve this Team UOW partnered with Remondis a world leader in recycling who provided us with a series of wheelie bins to separate and easily collect our recyclable waste materials, and Flagstaff who assisted us with recycling of plastic and extruded polystyrene ridged insulation. This meant that almost all our waste products were able to be separated and recycled. Additionally, Building Information Modelling was undertaken for all items within the Desert Rose house, this enables an accurate bill of materials to be produced for ordering, reducing wastage.

Figure 2.34 - Green Wall

Figure 2.35 - Waste Management

2.6 Innovative Solutions and Elements

Being built using visionary principles, cutting edge design and engineering tools, the Desert Rose house is, of itself, a major innovative solution containing a variety of innovative elements.

With the aim to change the way the world views homes for the elderly, and the desire to provide occupants with age-related disabilities including dementia with independent living, Team UOW decided to envisage, develop and offer the innovative Desert Rose. Being built using visionary principles, cutting edge design and engineering tools, the Desert Rose house is, of itself, a major innovative solution containing a variety of innovative elements to meet this aim. Team UOW's focus on creating A House for Life addresses an issue that many countries around the world do, or soon will, face. The Desert Rose is innovative in this approach by developing a house that is able to adapt to an occupants needs as they age. Throughout this narrative we will detail the process we used for managing and developing innovation along with innovations that Team UOW have developed to make the Desert Rose more sustainable and aged friendly.

Fostering Innovation

Team UOW developed a solution for the management of innovative ideas within the Solar Decathlon competition. Team UOW took a systematic approach to innovation, starting from capturing innovative ideas and solutions and continued by filtering, analysing and monitoring these innovative concepts until their implementation within the Desert Rose. In order to be able to capture innovative ideas, process and monitor them as innovative solutions through their life cycle within the project, the innovation framework (Figure 1) was developed. This framework although tailored to Team UOW and the Desert Rose project is flexible and able to be adaptable to suit future Solar Decathlon teams in their endeavour to generate innovations. Sections that are specific to Team UOW and the Desert Rose are indicated by the dotted format outline.

Dementia Friendly Residential Architecture and Interior Design

Dementia is the second leading cause of death in Australia, the leading cause of death for Australian women and the leading cause of disability for Australians over the age of 65. Dementia is not something unique only to Australia or western countries with over 370,000 people diagnosed with dementia in North Africa and the Middle East each year and a new person somewhere in the world diagnosed every 3.2 seconds. There is currently no cure in sight for dementia but the quality of lives and independence of people living with dementia can be improved through innovative architecture and interior design.

The Desert Rose has been designed from the ground up with this goal in mind and almost every element and material within the Desert Rose has been selected based on research and considerations of how they would affect or improve the life of someone living with dementia or other aged related diseases.

One of the most important aspects to consider in the design of the Desert Rose floor plan was the occupant's line of sight. In particular, visibility throughout the house helps to ensure occupants can navigate their home safely, and care for themselves with more ease. Desert Rose is designed to satisfy these requirements, with the main spaces within the house being visually accessible from different positions within the house. For instance, both the bedroom and dining room are visible from the main bathroom, providing a clear binary choice to someone living with dementia and allowing them to be guided throughout their daily activities. These simple visual cues provide easy choices for how the occupant would like to spend their time.

Line of site from the bed to the toilet is very important, as research confirms people living with advanced dementia who can see the toilet when they wake up are up to eight times more likely to use the bathroom. This simple design element encourages the occupant to engage in necessary daily activities and maintain their human dignity.

The doorways, hallways, and rooms are sized to accommodate the use of a wheelchair, walker or other mobility assistance. The main bedroom door has been specifically designed to enable a hospital bed to fit through, providing a pathway to the outdoor garden, allowing the occupant to remain in the comfort of their own home even when requiring medical attention or receiving palliative care.

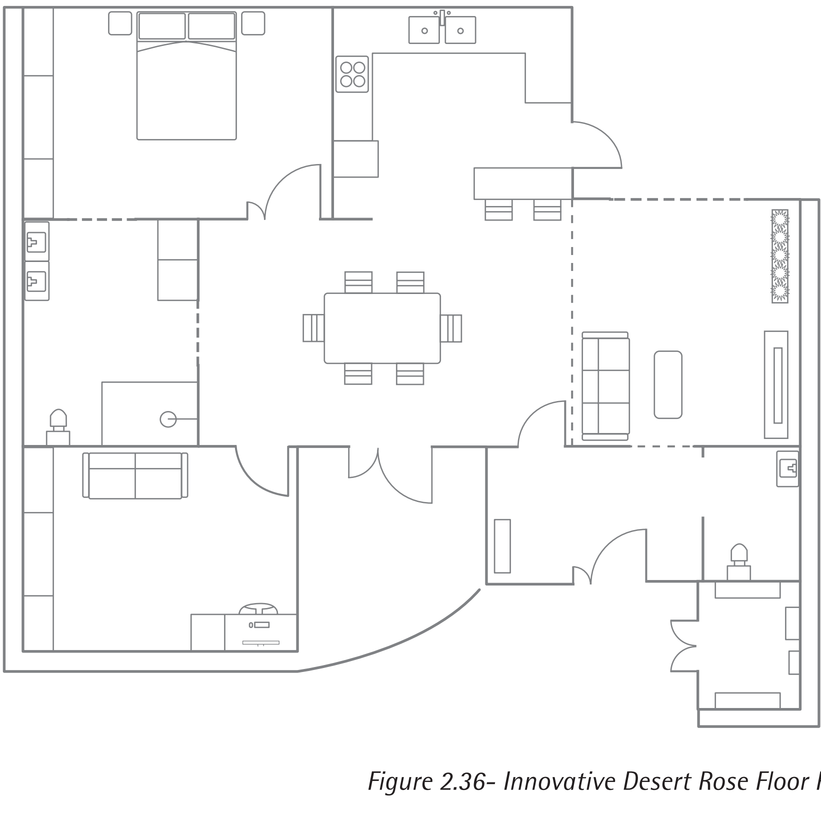
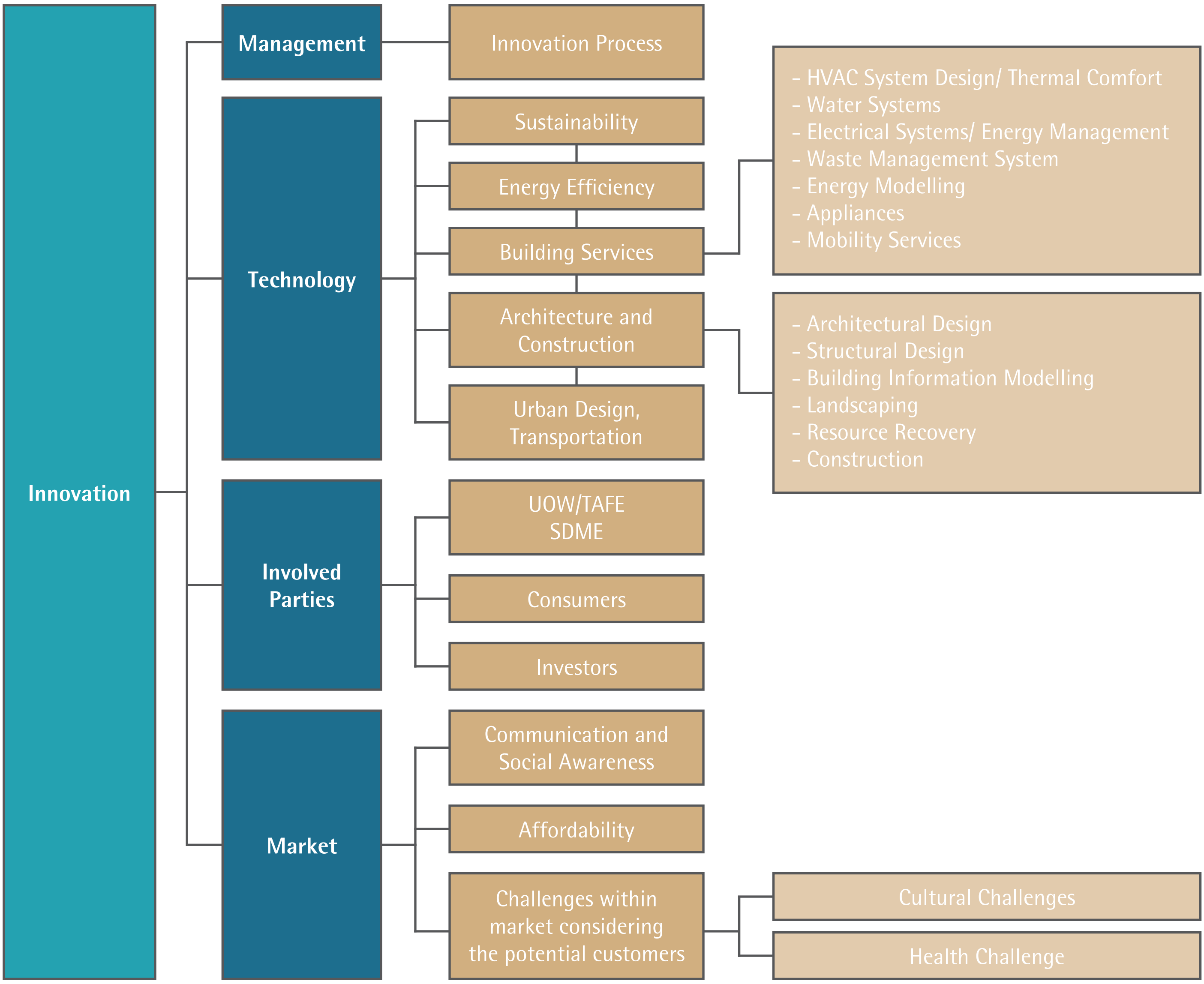


Figure 2.36- Innovative Desert Rose Floor Plan

Table 2.1- Innovation Management Flowchart



The structural wall frames have been designed with additional framework placed at a height where handrails can be fixed when needed. In line with the principles of sustainable architecture, this very simple design consideration and addition would allow occupants at retirement age to move into the house knowing that, when needed, supportive handrails can be directly installed throughout the home and in the bathroom, without the need for any further structural retrofits.

The roof trusses have also been engineered to enable a hoist to be installed from the bedroom to the bathroom should one be required.

Team UOW have also worked with local manufacturers to custom-design timber doors to enable a flush surface that avoids trip hazards in the home as well as any physical barriers for wheelchair users, limiting the potential causes of confusion and apprehension for people living with dementia.

From an interior perspective Team UOW has endeavoured to provide where possible a Light Reflectance Value (LRV) of up to 62, and a minimum of 30 LRV between different surfaces to assist those with vision impairment to distinguish different elements. Sources of light have been placed away from users' line of sight to minimise direct glare, as well as providing separate lighting for task work at minimum 300 lumens.

Keeping flooring colour consistent and reducing reflection throughout the house can improve the quality of life for elderly residents living with dementia. Shiny surfaces – especially in regards to the flooring – have been avoided as the floor can be mistaken as a wet surface and create places within the home where residents will not venture, discontinuing their living activities. The colour selection for the interior has been completed to be aesthetically pleasing but also designed to provide high contrast for occupants and guests with sight concerns, so they are able to easily discern different features around the house without becoming confused or disoriented.

The selection of detailed items such as door fixtures, tap handles, and light switches blend aesthetics with improved useability for elderly occupants (including those with poor grip strength) by ensuring correct grip and clearance for hands and fingers. Additionally, the heights of door fixtures, light switches, and power points, are placed to enable occupants with limited mobility to reach whilst minimising strain.

All of the taps used throughout the Desert Rose are prototypes and are designed with accessibility in mind. The tap handles are electronically controlled and thus provide no resistance when turning, this assists occupants with poor hand strength to still be able to access water. They can also be operated via a "tap on – tap off" feature or connected to Amazon echo for occupants unable to perform a rotating motion with their hands. Dual tap handles have been provided to enable occupants living with dementia to still recognise them as a place to access water and the handles can easily be replaced to mimic handles iconic to the occupant's younger years to improve usage. The handles light up around the base to help occupants recognise the temperature of the water flowing from the tap.

Each of these design considerations on their own is not especially innovative but combined we have created a house that aims to promote a comfortable and healthy lifestyle and a home that can adapt and grow with people as they age. This innovative concept has grabbed attention from many national and international aged care providers and support networks including Dementia Australia. Team UOW have spoken of our design concepts at national aged care summits and have been requested to assist in the production of an online video series to educate people on how they can design or renovate their homes to be more supportive of people living with dementia. Concluding the Solar Decathlon students from Team UOW have been requested to assist in a design review of a new $500 million health precinct to be constructed on our Innovation Campus with the goal of implementing Desert Rose design concepts in a series of independent living units for future research.

Modularised Light Gauge Steel Frame

The Desert Rose adopted an effective steel structure solution to the complexity of the Solar Decathlon engineering challenge, with wall and roof structures made from locally manufactured light gauge steel. The house frame was designed by Team UOW students with technical assistance from EnduroFrame using their intelligent BIM software, ENDUROCADD. Team UOW students were the first to modularise the EnduroFrame system so that the Desert Rose can be assembled and disassembled multiple times whilst maintaining its designed strength and fit within high cube shipping containers. The modularised HVAC module is also innovative in that the majority of the mechanical systems are self-contained within a roof module. This strategy enabled us to construct and fit out the HVAC module in a separate specialised workshop. Team UOW have received a great amount of interest in how we solved this complex problem from Australia's leading property developers and from our Defence Force.

Second Skin Wall

The second-skin wall is a striking architectural feature that provides external shading to the house, reducing solar heat gains, as well as an added privacy feature. Common in Middle Eastern architecture are concrete or masonry block walls surrounding homes as a modesty and privacy feature. This innovative solution is entirely student designed and manufactured, it is made of a foamed concrete incorporating recycled crushed glass as a cement replacement and carbon fibre mesh reinforcement as a substitute for conventional steel reinforcement. The mix design was developed by UOW students and underwent months of experiments and testing until suitable properties were obtained. The foam concrete is half the weight of standard grade concrete and replacing the steel reinforcement with carbon fibre enables us to reduce the wall thickness from 75mm to 50mm. This significantly reduces the weight and volume required for shipping. Substituting these two replacements enables us to reduce the carbon footprint by up to 40% when compared to conditional concrete. The UAE lacks many natural resources and construction is dominated by use of concrete. Team UOW through our second-skin wall wanted to demonstrate how using every day waste materials like glass, can have a large impact on our carbon footprint.

Recycled Vertical Flow Constructed Wetland

In many parts of the world, especially the Australia and the Middle East water scarcity is a prevalent issue. By sufficiently treating and reusing greywater at a domestic level, the Desert Rose creates an innovative solution to the issue at hand. Literature shows that in some cases the recycling of grey water can save up to 60% of potable water consumption. The use of a recycled vertical flow constructed wetland increases the sustainability of the Desert Rose as the demand for precious potable water will be minimised, thus reducing the various adverse environmental, economic and social flow on effects of water overconsumption. This system has been designed by Team UOW students and offers innovation in its ability to recirculate the greywater multiple times through the wetland, reducing the required area by up to 90% when compared to traditional wetland systems, making it more economically and socially attractive to the home owner. The treated effluent for non-potable applications around the house, such as toilet flushing, clothes washing and irrigation of landscaping like the unique green wall on the back deck.

PCM Thermal Storage Tank

The overall Heating Ventilation and Air-conditioning (HVAC) design and control system has been designed by Team UOW students, but of particular note is the Phase Change Material (PCM) thermal storage tanks and how these integrate with the HVAC system to create an innovative and sustainable solution to Dubai's climatic condition. The PCM tanks are designed and manufactured by Team UOW students and consist of two tanks filled with water and 169 salt hydrate PCM tubes that can store 0.102 kWh of thermal energy. The PCM tanks combined have an effective storage capacity of 35 kWh, or 2.5 times more than our electrical storage capacity. The air-to-water heat pump chills water to 10°C and charges the PCM tanks at night when the heat pump's efficiency can be greatly increased due to the cooler ambient temperature. During the day when cooling is required, a pump circulates water through the PCM tanks to two fan coils suppling cool air to the living spaces. This enables Team UOW to shift the buildings peak HVAC load from the middle of the day to the night, which allows Team UOW to spread the electrical load more evenly throughout the day and access off-peak electricity prices. This assists in maximising the self-consumption of renewable energy in the building, as the electrical energy storage can be used to run the heat pump late at night when the overall electrical load is small. This innovative solution not saves the occupant energy and thus money but also assists in lower peak load on the grid by shifting energy use to off-peak times.

Model Predictive Control

The Desert Rose incorporates an advanced BMS that couples all mechanical, electrical and plumbing systems to create a holistic building management solution that ensures the maximum self-consumption of renewables and maintains optimal thermal comfort and living conditions.

The heart of the Desert Rose smart energy management is the student developed, model predictive control (MPC) algorithm that optimises the use of the 13.8 kWh energy storage and 10.4 kW of solar PV. Using predicted solar irradiance, weather and occupant energy usage, the algorithm is able to maximise the amount of renewable energy used within the home, while minimising grid energy usage and subsequently electricity cost by creating optimal electrical exchanges between the renewable systems, home and the grid. This also allows for smart scheduling of major loads in the house including EV charging, hot water heating and HVAC. For example, if the BMS predicts the weather to be very hot during the middle of the day, it will operate the HVAC system in the morning to pre-cool the building. Alternatively, the BMS may choose to run the HVAC system when solar PV output is high as this is free energy from the sun. This is an example of how often decoupled systems, such as HVAC and solar PV systems work together in the Desert Rose house. Another example is that if the BMS predicts the next day will be cloudy, it will choose to keep the battery fully charged until the peak period on the cloudy day to avoid high electricity costs.

Figure 2.37 - Close-up of PCM Tubes

The prediction model is also able to provide feedback to the occupants on whether or not operating an appliance at a certain time will run solely off solar energy. Another added advantage of the MPC algorithm is that it is coupled with a learning algorithm that improves the prediction model. Therefore, the longer the occupants live in the house, the better the house is able to optimise the MEP systems around the way the occupants live.

All of the Desert Rose plumbing fixtures consist of electronic thermostatic mixing vales that are linked with the BMS. Smart plumbing fixtures allow the occupants to dynamically change the maximum temperature of each plumbing fixture along with setting automatic shut off times to conserve water. All water usage is monitored and fed back into the BMS to provide feedback to the occupants on their water usage.

Several of the internal electrical loads in the house such as the washing machine, dishwasher, TV, computer and microwave are connected to wifi controlled smart plugs. When there are no occupants in the house the BMS can turn off all stand by power, ensuring maximum energy savings.

Team UOW were able to create its advanced building automation system by using IoT programming platform Node Red. Using node red Team UOW are able to bring all of the MEP systems online into one location. This allows seamless interfacing of systems that are traditionally separate in buildings. For example, IoT has allowed the Desert Rose HVAC system to communicate with the solar PV and energy storage, it has also allowed Team UOW to incorporate smart load scheduling and occupant feedback to maximise renewable energy usage. It is Team UOW's belief that smart energy usage is the future of residential buildings, where building controls and occupant involvement ensure houses are as comfortable and energy efficient as possible.

Educational App

Team UOW's students have designed and developed an innovative mobile app to communicate with audiences about the Desert Rose House. Our app can be used anywhere in the world to see an augmented reality model of the Desert Rose House using only our logo. In conjunction with the tour plan and wayfinding system the app is an additional tool to educate audiences about the features of the Desert Rose House. The app utilises augmented reality technology to allow guests to scan icons around the house to access information, diagrams and animations on the related technology. The app also has information on the Team UOW solar decathlon journey and a 3D model of the house. After the competition when the house is permanently on display in Australia, a fully-guided tour will be added to the app. We believe our mobile app is a highly innovative tool to engage and educate our younger and professional audiences due to its interactive nature. In consideration of our older and less technologically able target audiences we have designed the app with accessibility principles in mind.

Safety Campaign

Team UOW has also been innovative in developing our own safety campaign to ensure a safe and comfortable working environment for all team members and as a means to communicate the importance of safety to younger audiences. To achieve this, we have developed two safety mascots, Saferoo and Safe Clayton who are recognisable figures promoting safety and both wear our unique pink hi-visibility uniform. Saferoo is modelled off our primary team mascot Rosa the Kangaroo. She is a recognisable mascot for our team as an iconic Australian animal. Safe Clayton is modelled off Clayton our Health and Safety Coordinator whose stories of safety from his professional experience help to educate our team to be safer in their practices. These figures have been used on our construction site through the use of posters promoting how to stay safe around specific hazards such as electrical hazards, and Safe Clayton Says signs that are distributed in high risk areas and are found in our health and safety manual. These mascots have also been turned into fun stickers that we give to children to promote the Solar Decathlon and encourage safety, a creative way to engage children through our communications. During our public open week in Australia we also created a mascot photo frame that enabled children and adults alike to place their face in place of Saferoo or Safe Clayton and have their photo taken. This campaign is Australia-specific and caters to the context. Therefore, this campaign has the potential to be adopted throughout different construction projects Australia-wide. If in the future Team UOW commercialises the Desert Rose, this safety campaign will be followed through in all projects.

Figure 2.38 - On Site Safety Campaign Featuring Rosa and Safe Clayton

2.7 Building Intergrated Photovoltaics

This combination of technologies and form factor allows for a more efficient and aesthetically pleasing product than traditional solar PV installations.

The Desert Rose has an extremely unique building integrated photovoltaic-thermal (BIPV-T) system installed on the southern facing roof. The system is made up of 104 solar tiles with a combined rated output of 10.4 kW from Australian company, Tractile Solar. Team UOW have been able to incorporate the solar tiles in the building construction to create a 5-in-1 system. The solar tiles not only produce all of the required electricity, but they also completely replace the roof construction on the southern facing portion of the house. The unique design means there is no need for roof sheeting. Instead, the interlocking tiles make up the entire roof and are able to withstand extreme weather conditions such as cyclonic winds and hail.

Traditionally tiled roofs are limited to a minimum of 15 degrees. However, Tractile can be installed with a roof pitch of 10 degrees in its standard configuration. This allows for the Desert Rose House to maximise use of the solar envelope with minimal compromise to the solar efficiency of the project. Tractile tiles can be installed at such a low angle due to the unique interlocking mechanism of the panels. The tiles incorporate diverting channels in the interlocking mechanism to channel water down towards the runoff. This channel is designed to work against winds pushing water up underneath tiles, one of the main limitations of roofing pitch.

Using the Tractile system simplifies the construction process through a number of related parameters. The tiles have size of 1100mm by 690mm, and an effective size of 1050mm by 560mm. These tiles are much larger than traditional tiles, while the materials used in construction keep the weight of the tile to a manageable 19.56kg for the Solar PV panel. The increased size reduces the construction materials required for battens and speeds up the installation times. Due to the integrated nature of the system fewer materials are also used for the supporting frame, reducing fatigue on the housing structure through both weight and the 'sail effect' of traditionally mounted solar panels.

The Tractile Solar PV Panel is based on proven monocrystalline PV technology with an efficiency circa 20%. As the temperature rises silicon PV panels are known to lose efficiency (this is called the solar collector efficiency coefficient), the Tractile PV panels mitigate this effect by incorporating water channels that run underneath the tiles which serve three purposes. Firstly, the water channels are connected to the hot water unit which pumps water through the tiles during the hottest parts of the day to produce our domestic hot water. Secondly, running water through the solar tiles creates a heat exchange effect, cooling the tiles down which significantly increases the solar PV efficiency. This is key in the hot Dubai climate. Finally, by cooling the tiles down, the roof construction is essentially cooled down which in turn cools down the building envelope, acting like an insulating element. Again, this feature is extremely beneficial for the hot Dubai climate. There is a trade-off in this process that can be controlled by adjusting the flow rate of the circulating liquid. Optimising the flow rate for more efficient electrical power output results in efficiency gains of 7-12% but lowers the resulting water temperature.

This combination of technologies and form factor allows for a more efficient and aesthetically pleasing product than traditional solar PV installations.

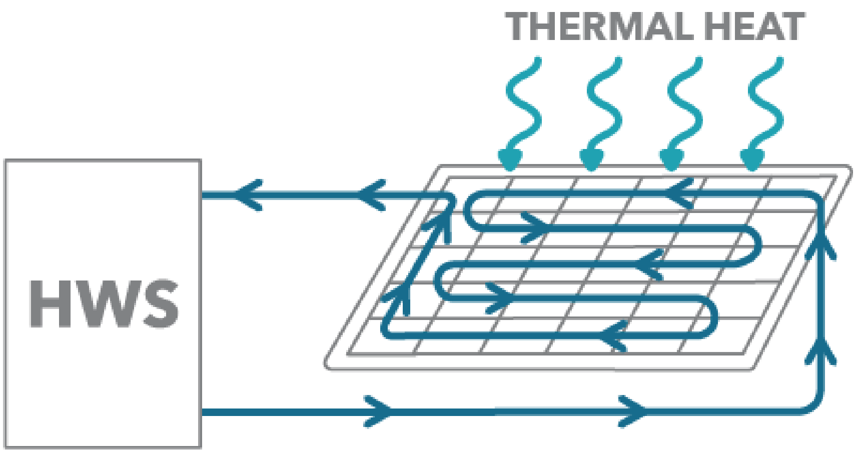


Figure 2.39 - BIPV-T and Hot Water System

Figure 2.40 - BIPV-T Installed on Desert Rose Roof

2.8 Interior Concept and Design

The Desert Rose was conceptualised to incorporate contemporary residential construction innovations that provide maximum comfort, elegance and privacy backed by a design that complements the needs of sustainable living in the Middle East.

The Desert Rose was conceptualised to incorporate contemporary residential construction innovations that provide maximum comfort, elegance and privacy backed by a design that complements the needs of sustainable living in the Middle East. The interior design integrates both Middle Eastern and European design concepts to produce a house that combines features sought by both mainstream Australian and traditional Islamic cultures.

To accomplish this, the interior scheme adopts a neutral pallet which allows aspects of both cultures to be seamlessly intertwined throughout the living spaces. The concept of the interior is to provide a relaxing, open and homely feel that accentuates the liveability features including line of sight and age-appropriate details such as high contrast bathroom details, wheelchair accessible spaces, appliances that are easily accessible and operable, and access to green spaces.

Strong weighting has been placed upon the colours chosen to combine the Australian coastal aesthetic that compliments Middle Eastern design. Cool colours such as blues and greys have been chosen as they can make rooms appear larger – blue has the added benefit of inducing feelings of calm, safety, protection and spirituality. This is an important feature as the home is known as a place of safety and family unity.

Given the strict solar envelope and architectural requirements, clever use of colour and light were incorporated into the design to help maximise the feeling of a light and open spaces. Natural lighting is used to promote health and wellbeing with artificial lighting used in work spaces to ensure safety and comfort.

Ageing Occupants

The Desert Rose is architecturally designed to grow with the ageing population and special considerations have been incorporated into the design of the house interior. Team UOW have endeavoured to provide where possible a Light Reflectance Value (LRV) of up to 62, and a minimum of 30 LRV between different surfaces to assist those with vision impairment to distinguish different elements. Team UOW has also endeavoured to provide sources of light placed away from users' line of sight to minimise direct glare, as well as providing separate lighting for task work at minimum 300 lumens. Keeping flooring colour consistent and reducing reflection throughout the house can improve the quality of life for elderly residents living with dementia. Shiny surfaces – especially in regards to the flooring – have been avoided as the floor can be mistaken as a wet surface and create places within the home where residents will not venture, discontinuing their living activities. The colour selection for the interior has been completed to be aesthetically pleasing but also designed to provide high contrast for occupants and guests with sight concerns, so they are able to easily discern different features around the house without becoming confused or disoriented. An example is line of sight is provided from the master bed and the toilet bowl in the bathroom, the toilet is a white ceramic and is backed by a dark grey tile. This line of sight and colour contrast can increase the use of the bathroom by someone living with dementia by up to eight times.

The features of the interior design are chosen to add value to the occupants staying in the house. Ensuring a stable flooring system that is without trip hazards inherently improves the likelihood of moving about the house without injury. Door thresholds have been custom designed in collaboration with Team UOW students to ensure a smooth transition between outdoors and indoors whilst providing an air tight seal. While some mats have been included to accommodate the Middle Eastern culture and weather conditions, they can be easily removed if they begin to become tripping hazards for residents. The selection of detailed items such as door fixtures, tap handles, and light switches blend aesthetics with improved useability for elderly occupants (including those with poor grip strength) by ensuring correct grip and clearance for hands and fingers. Additionally, the heights of door fixtures, light switches, and power points, are placed to enable occupants with limited mobility to reach whilst minimising strain.

All of the taps used throughout the Desert Rose are prototypes and are designed with accessibility in mind. The tap handles are electronically controlled and thus provide no resistance when turning, this assists occupants with poor hand strength to still be able to access water. They can also be operated via a "tap on – tap off" feature or connected to Amazon echo for occupants unable to perform a rotating motion with their hands. Dual tap handles have been provided to enable occupants living with dementia to still recognise them as a place to access water and the handles can easily be replaced to mimic handles iconic to the occupant's younger years to improve usage. The handles light up around the base to help occupants recognise the temperature of the water flowing from the tap.

The style of the Desert Rose best fits into the mid-century modern interior design theme, this features the use of natural materials, including accents of timber throughout the house. The Desert Rose utilises biophylic design, with a seamless flow between indoors and outdoors, this is seen by the use of plant life indoors, including the extension of the green wall into the living room. The house utilises statement furniture with striking, functional form and stand out colours, including the gold lounge and deep blue dining chairs, this furniture also acts as a centrepiece for the simple rooms, with little clutter. The mid-century modern theme is also seen through the use of natural light throughout the house as well as highlight colours to add warmth and interest, these include greens and maroons, as small pops of colour through the house. The statement lighting featured in the house adds class and connects the rooms of the house together, this is also a feature of mid-century modern homes. The simple paint colours of a mid-century modern house are seen in the Desert Rose, with plain, white ceilings and walls paired with light stained timber flooring.

Figure 2.41 - Kitchen

Privacy

Islamic culture places an emphasis on modesty, privacy, personal space and hospitality within the comfort of one's home. Given these cultural customs, special consideration has been taken while developing the house layout. To maintain privacy the architecture has been designed so that the only window that faces the street is the small window adjacent to the front door. The entry is designed in such a way that it does not give immediate access to domestic quarters, but leads to a vestibule/ lobby, which will obscure the interior from being exposed to the outside world when the front door is opened. The entrance lobby acts as a welcoming space for guests to the home and is equipped with a renovated shoe cabinet that sits flat against the wall. This has been re-decorated with blue and white hexagonal tiles and gold décor, hinting at the timeless interior design of the house. The entrance door also acts as a bold statement, reflecting the reclaimed and locally sourced timber aspect that is found throughout the house in both window and external door frames.

To continue the aspects of privacy coupled with hospitality, the Desert Rose house facilitates an unobstructed movement of people within the house, and from inside the house to its outside and vice versa, without putting the 'awrah', privacy and peace of any user of a house at stake. This helps to keep certain spaces of the house private whilst entertaining guests and being hospitable on occasions. Our understanding of the cultural sensitivities around gender and the interaction with men who are not a close relative by the female residents of the household has inspired the design and construction of a partitioned living or multipurpose room. While the dining room represents the heart of the home with a custom designed sophisticated recycled hardwood timber dining table that is able to expand for additional seats is located in the centre of the space, essential for entertaining family, the dining and living spaces of the house can be separated by opaque glass sliding doors, creating an adaptable and flexible home environment able to change depending on the circumstances. Two doors are provided from the entry that enable guests to privately enter the lounge room and residents to enter the other living spaces.

Privacy considerations were also taken into the design of the blinds for the windows and external doors of the house. Honeycomb shades were chosen for the Desert Rose House to ensure an elegant window covering that keeps the house warm in winter and cool in summer. The blinds are opaque and maintain privacy and thermal comfort as well allowing natural light to filter through. The blinds were chosen in a light cream colour which compliments the white walls and the timber of the doors and windows. The 'ultraglide' system was selected as the operative mechanism for most blinds, this features a click and walk away mechanism using a retractable wand to raise and lower the shades. This is aesthetically pleasing and easy to operate with an aging hand or from a wheel chair. The blinds in the kitchen and above the small courtyard door are automatic, using a cordless battery-operated control, this ensures the safety of resident preventing them from having to extend their reach.

Kitchen

In the kitchen, designs have been implemented which are modern, stylish, and embedded with features that aid the use of residents who are bound by a lack of physical ability. Many aspects of the kitchen are designed to be easily accessible to a resident in a wheelchair or with other age related diseases, maximising functionality and flow. The design incorporates appliances that are user-friendly along with automated above-head cupboards in a kitchen layout that makes it a safer place for aged and disabled occupants and those living with dementia.

The space has been utilised to its maximum potential, with compact storage units in all cupboards and enough room to support ease of movement and adaptation around the kitchen. The kitchen work triangle has been obtained to create the perfect layout for the modern home, streamlining workspace efficiency by connecting the three fundamental tasks performed in a kitchen: cooking, food preparation and food storage. This design allows the reduction of the effort required and distance travelled whilst cooking in the kitchen and is extremely beneficial for an ageing house occupant. Ease of movement is also supported by a minimum of 1550mm clearance in front of fixed benches and appliances, creating a flexible, easily accessible space with wheelchair access.

The fridge is located on the outer-most part of the kitchen providing the easiest point of access for an elderly person who is no longer cooking for themselves and who is then able to access food without entering the kitchen. An induction cooktop with onset controls allows an elderly person to recognise familiar features from their cooking past (i.e. rotary dial control operation) and link them to modern technology and performance, and a side-opening oven provides ease of use for wheelchair bound occupants.

The drawers do not feature handles, they are sleek and modern, mitigate risk of injury from brushing past or catching of objects, provide a soft-close mechanism reducing pinch-points, while also providing enough room underneath for wheelchair footplates. The drawers under the sink have been specifically designed to ensure a functional waste and recycling system, while corner solutions have also been adopted with LeMans pull-out and 2-tier revolving unit corner storage systems to efficiently maximise storage in commonly problematic corner locations.

Additional design considerations were taken in selecting all kitchen materials, for example shatterproof materials enable us to further mitigate any possible risk of injury to disabled occupants. The light-coloured benchtop maximises the distribution of light, adding a spacious feel to the kitchen, as well as ensure enough lighting for taskwork. The benchtop's material is laminate and was chosen as a measure to lower potential hazards and allow for less maintenance than stone. The cabinet colour adds a stylish, sophisticated feel to the kitchen, ensuring visibility with a high contrast to the flooring and the benchtop, and connecting to the colour palette of the bathrooms within the house.

The island bench allows for entertaining and appropriate utilisation of space, separating the kitchen from the dining room, it also ensures a line of sight for parent-child oversight and encourages communication with family and guests whilst preparing food. The experience of the occupants is further enhanced by ease of access to the outdoor area, with direct connection to the deck and therefore beautiful green spaces. This greenery is extended indoors through the interior green wall, pot plants and easy access herb garden. The lighting design includes an optionally-lit splashback of which colour can be controlled and adapted depending on design and mood intentions, task lighting installed above workspaces and LED strips installed around the cornices which contribute to the ease of use for the kitchen occupants and the lighting effect of the overall home. Appliances can be tucked away and stored whilst not in use and easy-use appliances such as the toaster and kettle can remain on the bench top to encourage independent kitchen use. The external door leading from the kitchen to the back deck and ramp is designed to enable occupants utilising a scooter to drive their scooter into the kitchen for ease of unloading groceries.

Master Bedroom

The master bedroom is accessible from the dining area and is connected to the bathroom via an internal door. The bedroom is equipped with bedside tables and a queen size bed. A series of built-in cupboards are installed to be wheelchair friendly with shelves that can be accessed easily from a sitting position. Sliding wardrobe doors were chosen to minimise space taken up and remove any unnecessary distractions in the room. The position of the bed is appropriate relative to the direction of Mecca. The bed and the windows have also been positioned to allow for a clear pathway from the bed to the bathroom for occupants with mobility issues.

The primary colour of the master bedroom is blue, chosen due to its importance as a psychological colour, causing a sense of serenity, safety and peace whilst acting as a soothing colour. It provides a tranquil atmosphere and brings down blood pressure, slows respiration and heart rate and prepares the resident for sleep,(Calkins 2002).

The deep blue velvet bed sheets

Figure 2.42 - Master Bedroom

contrast the light floor boards and ensure easy navigation around the bedroom. Symmetry has been utilised in the master bedroom in the form of matching bed side tables to create a sense of unison and calm, the bedside table, bed head and wall have a high contrast through their different colour tones. The bed-frame and mattress are 53cm high, according to the Disability Rights Education and Defense Fund beds should be 50.8 to 58.4cm high (Rest 2018). The bed frame is easily accessed with minimal strain and the padded head board minimises additional potential self-damage. The bed frame is grey, acting as a canvas for the accents of colour throughout the room. The mattress features a removable, washable cover and zero disturbance technology. The pillows on the bed are gold in colour, gold is used throughout the house as a connecting colour that weaves the rooms together, it is a colour of paradise in Islamic culture as it is associated with quality of life and success.

Sizing of the bedroom space enables easy navigation by occupants with a wheelchair or a walking frame. The door leading to the bedroom is wide enough to enable access for an emergency stretcher and facilitate the installation of a hospital bed, enabling occupants to receive palliative care in the comfort of their own home should they wish to.

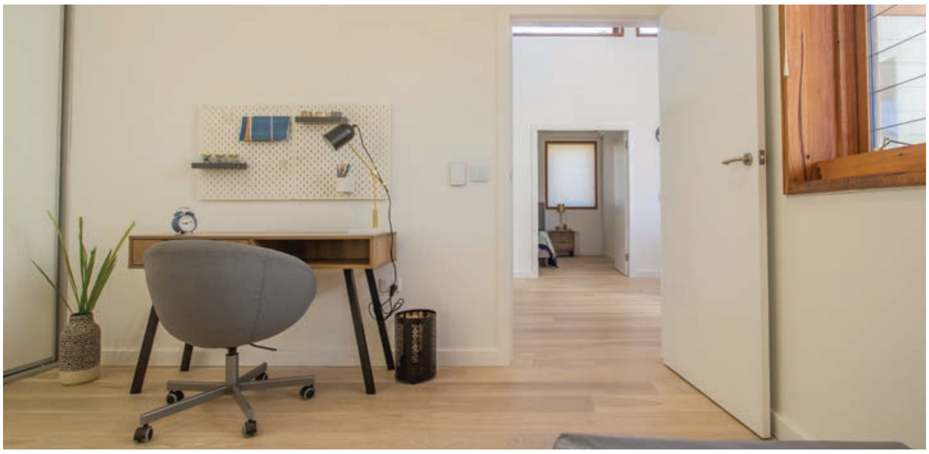


Figure 2.43- Spare Bedroom

Bathroom

The main bathroom has been designed to be fully accessible, and specific considerations were taken to create a space that is luxurious, modern, sustainable and comfortable for healthy occupants, as well as residents living with dementia or other age-related illnesses.

With their matte finish, the floor and wall tiles in the bathroom were chosen specifically to decrease slipping and eliminate their wet appearance, which can lead to uncertainty and falls for someone with late-stage dementia. The Belga Charcoal tiles for the flooring and feature wall were chosen as they are a locally made product, manufactured only 185km from our construction site in Wollongong. These elegant charcoal tiles run up the wall behind the toilet in both the main bathroom and the water closet. This ensures a high contrast between the toilet and the wall and floor, allowing higher visibility and identification of the toilet for someone living with dementia. The toilet has a soft close seat to minimise loud noises in the toilet and are positioned at a height to avoid straining occupant's joints – particularly those with poor mobility.

Satin white matte tiles were chosen for the walls as a neutral tone, making the bathrooms look more spacious. These tiles were selected in the 600x300mm size, ratio that continues the floor tile sizing.

Black matte taps were used against the matte white tiles and chrome shower head and taps were used against the charcoal tiles to ensure maximum contrast and visibility. For visual pleasure and continuity in design black matte was chosen for the kitchen and bathroom taps, bathroom handrails and toilet-roll holder.

The double vanity was chosen for the main bathroom for a number of reasons, including an increased storage and personal space. The vanities in both bathrooms are in the form of floating shelves, beneficial for ease of access with a wheelchair. Their sleek, stylish

Figure 2.44 - Flexibility of Space in the Spare Bedroom

and modern look connects to the kitchen design, and is complemented by beautifully reclaimed hardwood timber vanity tops, sourced and manufactured locally, this timber top was chosen to add the timber accent seen throughout the house into the bathrooms and produce design continuity.

The cupboard in the main bathroom acts as a laundry and further storage unit. It houses the washer/dryer combo and has a pull-out drying rack, allowing for an integrated alternative passive drying system. The cupboard also allows direct access to HVAC and electrical equipment, creating easy maintenance access.

Artificial lighting plays a critical role in both bathrooms, as windows were not installed on the eastern and western façades in order reduce thermal heat gains and enable the Desert Rose to be constructed in a higher density aged care village where the eastern and western walls will be shared with neighbouring buildings. To overcome this situation, an artificial skylight is installed on both ceilings among other lighting features. The skylight can be controlled to allow changes in light intensity and colour based on intentions or time of the day– such as increasing the lighting intensity to 1000lx for bright light therapy - establishing a comfortable and adaptable atmosphere that connects directly to the outdoor environment.

Figure 2.45 - Desert Rose Open Plan Living, From Dining Room

Figure 2.46 - Lounge Room Looking Out To Back Decking

Sustainability and Innovative Spaces and Elements with Student Collaboration

Creating a house that is true to the health and wellbeing of occupant is of utmost importance to the Desert Rose. The word 'true' shares an etymological ancestor with the word 'tree', once being the same word in Old English associated with the "uprightness of an oak, steadiness of a silver birch, and the fidelity of an orchard baring fruit year after year". Team UOW wanted to honour the act of planting a conceptual seed, to see houses grow to be more accessible in the future, solid, and real like a tree. Thus the house features wood architecturally throughout, an homage to meeting the needs of the present without compromising the sustainable growth of knowledge in the future. Sustainability is integrated into all aspects of the house, with the adoption of locally manufactured, locally sourced locally reclaimed and healthy materials all throughout the house.

All window and external door frames, including the main entrance door, are made of recycled hardwood timber that is manufactured in the local area with timber sourced from local house demolition sites. Significant attention was given to the door frame designs, having students collaborating directly with the manufacturer ensuring that a smooth transition between spaces was obtained with no steps or thresholds to cross. Each door well exceeds the Dubai and Australian standards of effective clear width for ease movement of occupants with mobility issues.

The dining room table, being the heart of the home, was specifically designed in collaboration with students and a local manufacturer. The students visited multiple demolition sites in the local area and worked with the demolition workers to rescue hardwood from waste disposal and give it a second chance at life. Together with the manufacturer, the students designed the extendable table that utilises space and evoke memories of homely-ness through this personal touch. Similarly, the floating tv shelf was also designed by students, who sourced materials locally and worked with a manufacturer to hand build the shelf out of local reclaimed hardwood timber. The kitchen, bathroom, vanity and laundry unit were designed by students and revised with the assistance of professional cabinet makers, and the overall interior design was worked on and finalised by the students. Having personal furniture and memorabilia with historic memories is crucial in a dementia-friendly home as it can stir thoughts of happy moments in life and give the occupants something to talk about.

All rooms have timber accents, this can be seen through the hardwood door and window frames, hand crafted table, vanity and TV shelf as well as upcycled furniture. This timber is a design principle in the Desert Rose as it links the house to the Earth through biophilic design, enhances the sustainable 'feel', improves health and wellbeing of the occupant whilst promoting sensory engagement and is a key aspect of a mid-century modern home.

The living room couch was originally a second-hand couch that was headed for the waste disposal. This kind donation has been recovered giving the lounge a new life in the Desert Rose House. Leftover timber off-cuts were utilised by students as shelving throughout the house, seen in both the kitchen and office, adding authenticity to the rooms and reducing construction waste.

Team UOW wanted to create spaces that were aesthetically pleasing and enjoyable to be in. To complement the furniture we decided to engage with the UOW Art Collection to find some pieces of art to complete our interiors. Students worked with the art curators to find pieces by Indigenous Australian artists to connect the Middle East and Australian design. In the main entryway is a piece called Yams that was developed in 1995, a piece that immediately welcomes the visitor into the Australian designed and built house. The Australian connection is continued in the guest room with a piece called the Sydney Harbour Bridge. In the living room, a small piece displays flowers and leaves, adding complementary colours to the interior style. The final piece takes centre space over the bed in the main bedroom, with creates a stunning feature that completes the space.

Further enhancing sustainable living, the interior and exterior of the house are inextricably connected through the use of plant life. Contributing to human health and productivity, and connecting people and nature within the modern built environment, biophilic design was at the centre of the Desert Rose architecture and interior design. Plant life throughout the house aims to assist the occupants through allowing for lower levels of stress, quicker recovery times from illness and increased energy. As a result, the Desert Rose House features two outdoor student-made green walls that provide a sense of purpose for residents, and foster wellbeing. The green features are extended indoors through a second student-designed and made interior green wall, pot plants and herb garden. This plant life features a variety of flowers, and offers functionality with fast-growing, edible plants, encouraging sensory experience for the occupants.

Calkins, M. P. (2002). "How Colour Throws Light On Design In Dementia Care." Journal of Dementia Care 10(4): 20-23.

Rest, E. (2018). "Bedroom Safety Tips." 12 Bedroom safety tips for seniors. Retrieved 01/09, 2018.

Figure 2.47 - Interior Styling

Figure 2.48 - Living Room Showing Sliding Wall Panel Track On Floor

Simulation Analysis and Discussion Reports

3

3.1 Simulation Report Introduction

The following simulation report is split into two sections, a comprehensive house performance report and an electrical energy balance report. The house performance report provides a detailed climatic analysis of the Mohammed bin Rashid Al Maktoum Solar Park competition site, the Desert Rose construction specifications, energy efficiency measure employed by Team UOW and both active and passive analyses on the Desert Rose and its associated HVAC system. These results flow into the energy balance report where the solar PV system is sized and modelled based on the loads modelled in the house performance report. An estimation is provided on the competition energy profiles and provides the estimated payback period for implementing the innovative BIPV-T system.

3.2 Comprehensive House Performance Report

3.2.1 Introduction

This section aims at assessing the Dessert Rose with different operation schedules (NatHERS protocol and SDME competition requirements), HVAC operation modes (free running and conditioned house) and envelope design parameters so as to a) understand the building energy performance and comfort conditions and b) ensure that the net-zero energy target in Dubai can be achieved, which entails maximising the energy production and minimising the energy consumption whilst maintaining the house regular functionality during the competition period.

This section is divided as follows: firstly, the objectives and methodology are introduced. Then, the climatic conditions are assessed. Thereafter, a house overview is provided including i) the envelope materials' thermal properties, ii) glazing optical properties, iii) passive design strategies and iv) HVAC system description. Then, the software packages employed to undertake the building performance simulation (BPS) analysis and the BPS inputs assumptions are presented. Finally, the results of the Desert Rose are presented for passive (i.e. free-running) and active (i.e. including the HVAC) conditions for the full year and during the competition period.

3.2.2 Energy Analysis Objectives and Methodology

Objectives:

• Explore the climatic conditions of the Mohammed bin Rashid Al Maktoum Solar Park and identify possible passive design strategies.

• Identify the best performing building envelope and active energy system to provide constant thermal comfort using the least amount of energy.

• Identify the temperature and humidity distributions of both passive and active analyses during the competition period.

Methodology:

Team UOW integrated with two of University of Wollongong's energy simulation courses ENGG447/947 Advanced Building Design for Energy Efficiency and Sustainability, and MECH442/918 Sustainable Energy in Buildings to trial and simulate various design considerations. These classes consisted of approximately 70 students each and the students were given the task of creating an Open Studio and a Design Builder model of the Desert Rose respectively. They performed several energy analyses on the models and modified various building elements including geometry, glazing, envelope materials, shading etc. to understand the effects on thermal performance and lighting requirements. These subjects helped to influence the early design decisions of the Desert Rose.

Following this several undergraduate theses were completed investigating natural ventilation and controls, detailed building envelope analyses and HVAC component simulations. These outputs further shaped the direction of the Desert Rose and assisted the leadership team in determining a base point in which to focus all future simulations.

With these inputs a detailed energy + model was created in Design Builder to simulate the annual and competition thermal loads and free running performance of the Desert Rose. Simultaneously a TRNSYS model was created to simulate and guide the HVAC design. These models were compared to one another to check for errors.

3.2.3 Climate Data and Weather Analysis

A detailed weather analysis was undertaken on the DEWA provided Mohammed bin Rashid Al Maktoum Solar Park weather data. Data ranges from 10/10/2013 to 05/11/2016 and include Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI), Global Horizontal Irradiance (GHI), Ambient Temperature, Wind Speed, Wind Direction, Relative Humidity and Hourly Rainfall. It should be noted that the timestep of the data varied with a mean time step of 1 hour, 8 minutes and 38 seconds and a standard deviation of 1 minute and 16 seconds. As such the graphs displayed in this climate analysis display time in approximately 21 time-steps rather than 24 hours. Also, the data for the sensors were not always consistent with some obvious recordings being beyond what is naturally possible or simply missing, these records were averaged based on the nearest recorded time step or emitted in some cases.

Table 3.1 - Dubai Geographical Data

Dubai	
Climate	Desert, hot and arid
Orientation	Northern hemisphere
Latitude (NS)	24.89
Longitude (EW)	55.17
Elevation	19
Time zone	4.0

Temperature and Humidity

Annual Analysis: The ambient temperature of the MBR Solar Park was plotted across the year and is displayed in Figure 3 1. During summer the ambient temperatures approach 50°C with a maximum between 48-49°C experienced in both years 2014 and 2015. In the winter months temperatures can reach as low 7°C but still reach maximums above 30°C for years 2014 and 2015. The annual distribution of the ambient temperature was also analysed for years 2014 and 2015, as shown in Figure 4 2 The distribution of temperature peaked at around 28°C and 30°C for years 2015 and 2014 respectively. As shown it is likely that the ambient temperature will be higher than 25°C, even though the distribution varies over a wide range from around 10°C to 50°C. The comfort bandwidth of 23-25°C is shaded in blue for clarity and a summary table of the results is provided in Table 3 2. The ambient temperature falls within this band for only 11.14% and 10.97% for years 2014 and 2015 respectively with an average of 62.5% of the time spent above 25°C and 26.4% spent below 23°C. This illustrates a need for active cooling measures to remain within the temperature band.

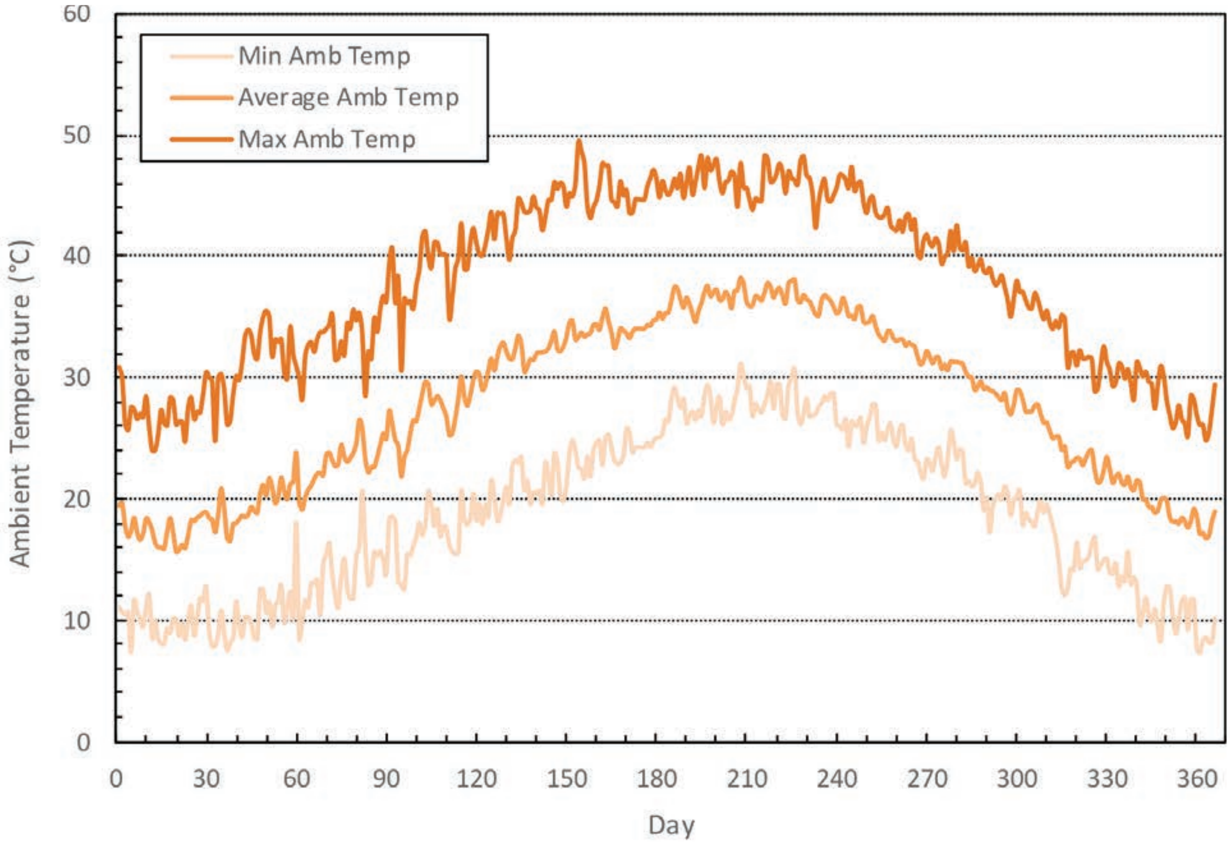


Figure 3.1 - MBR Solar Park Annual Temperature

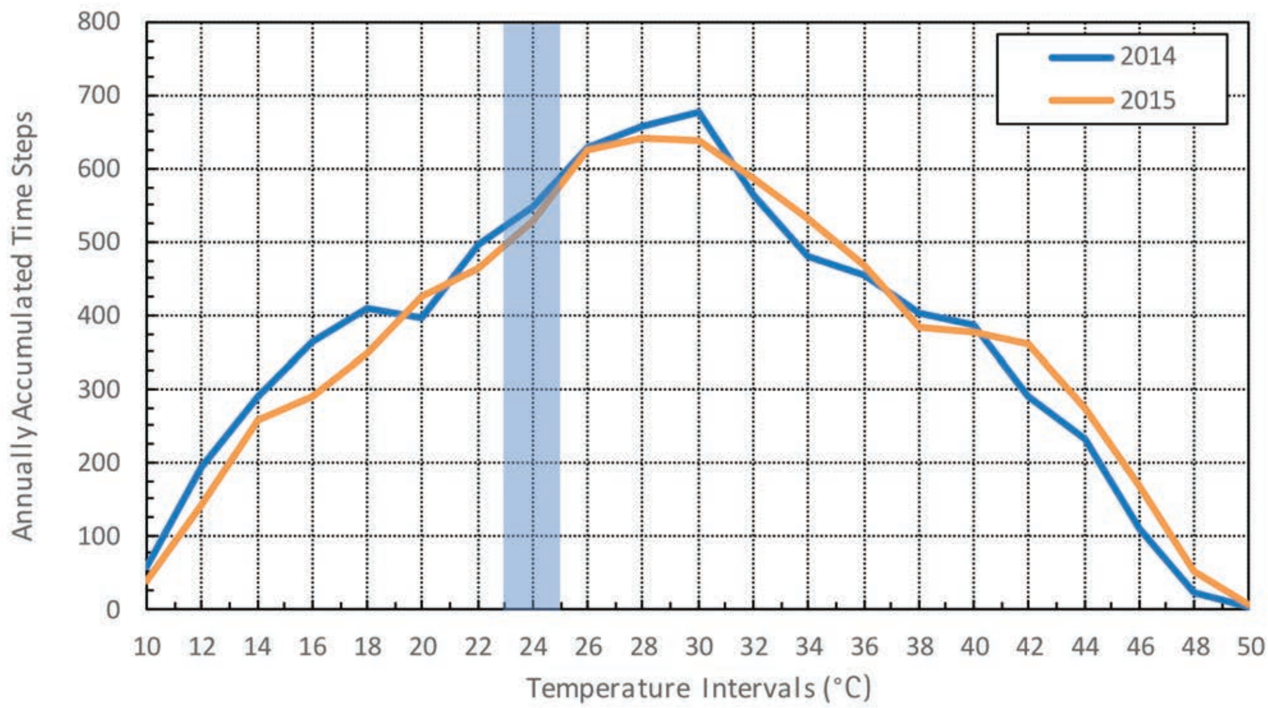


Figure 3.2 - MBR Solar Park Annual Distribution of Temperature

Similar to above the relative humidity of the MBR Solar Park was plotted across the year and the relative humidity annual distribution, these are displayed in Figure 5.3 and Figure 5.4 respectively. The relative humidity percentage fluctuates significantly between 100% and 0% but averages between 75% and18%. There is relatively even spread of time within the comfort band with an average of 32.2% of time within the band and 33.1% and 34.7% above and below respectively. This highlights a need for dehumidification and possible humidification to remain within the comfort bands.

It was found that only 4.24% and 3.31% of the annual time for years 2014 and 2015 respectively were spent within both ambient temperature and relative humidity comfort bands. Further analysis of a building model is required but this highlights that the use of natural ventilation as a method of remaining within the comfort is unlikely.

Competition Period Analysis:

The climate conditions were further analysed for the MBR Solar Park during the November contest period for years 2014 and 2015, year 2013 was excluded due to variance in the number of time steps when compared to 2014 and 2015. Figure 5.5 illustrates that the ambient temperature fluctuates approximately 15°C on average per day with a range between 35°C and 12°C. The temperature distribution shown in Figure 5.6 shows a peak distribution in the comfort band for 2015 but with 2014 being more spread. Table 5.3 provides a summary of these results and as displayed an average of only 17.8% of time is spent within the comfort band but there is a relatively even split of 42.5% and 39.7% of time spent above and below the comfort band respectively. The daily temperature profile is plotted in Figure 3.7, an illustrates that variance between the maximum and minimum of approximately 10°C for each time step. Ignoring humidity, night time cooling may be possible to keep the dwelling within the comfort band for longer but active cooling will be required for the middle of the day.

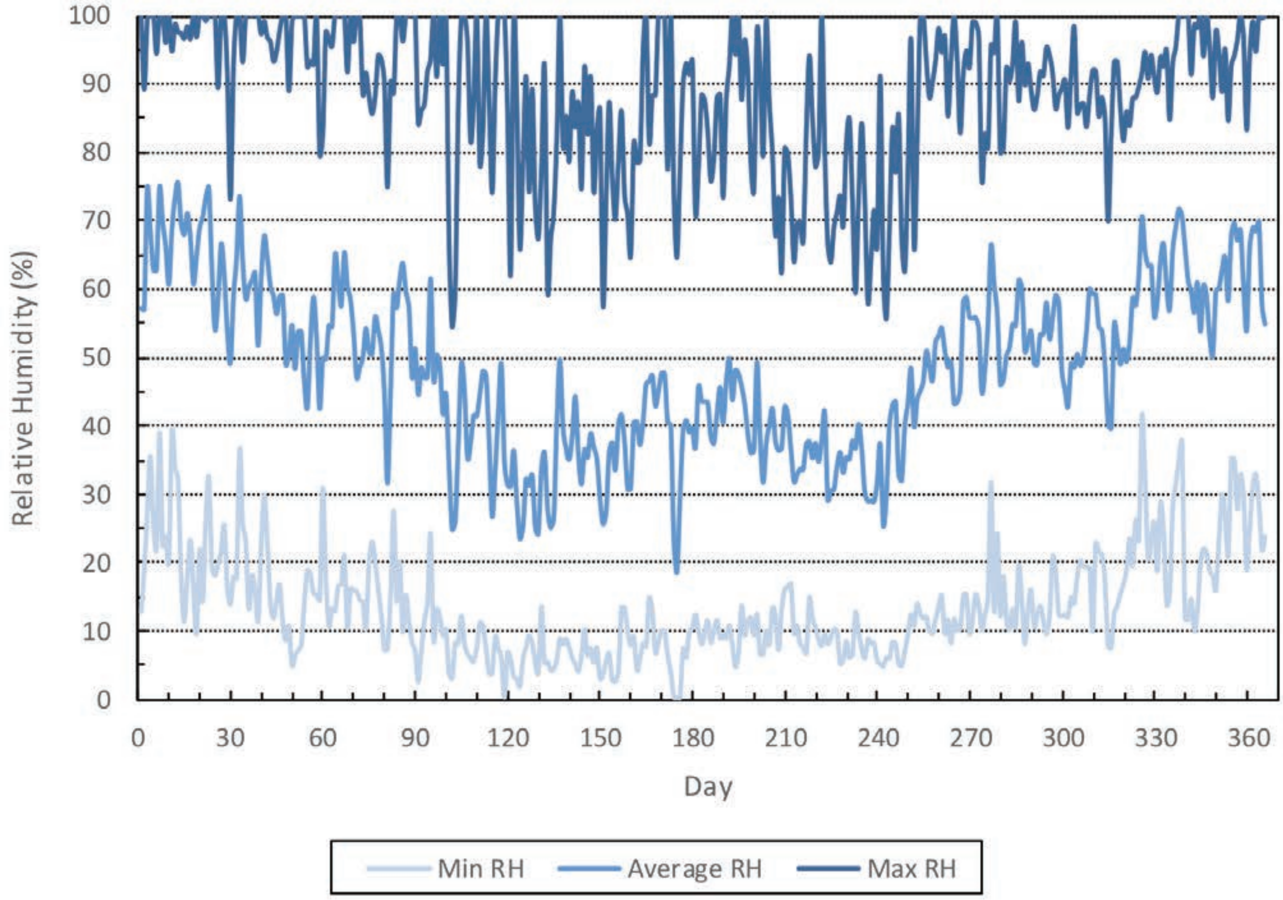


Figure 3.3 - MBR Solar Park Annual Humidity

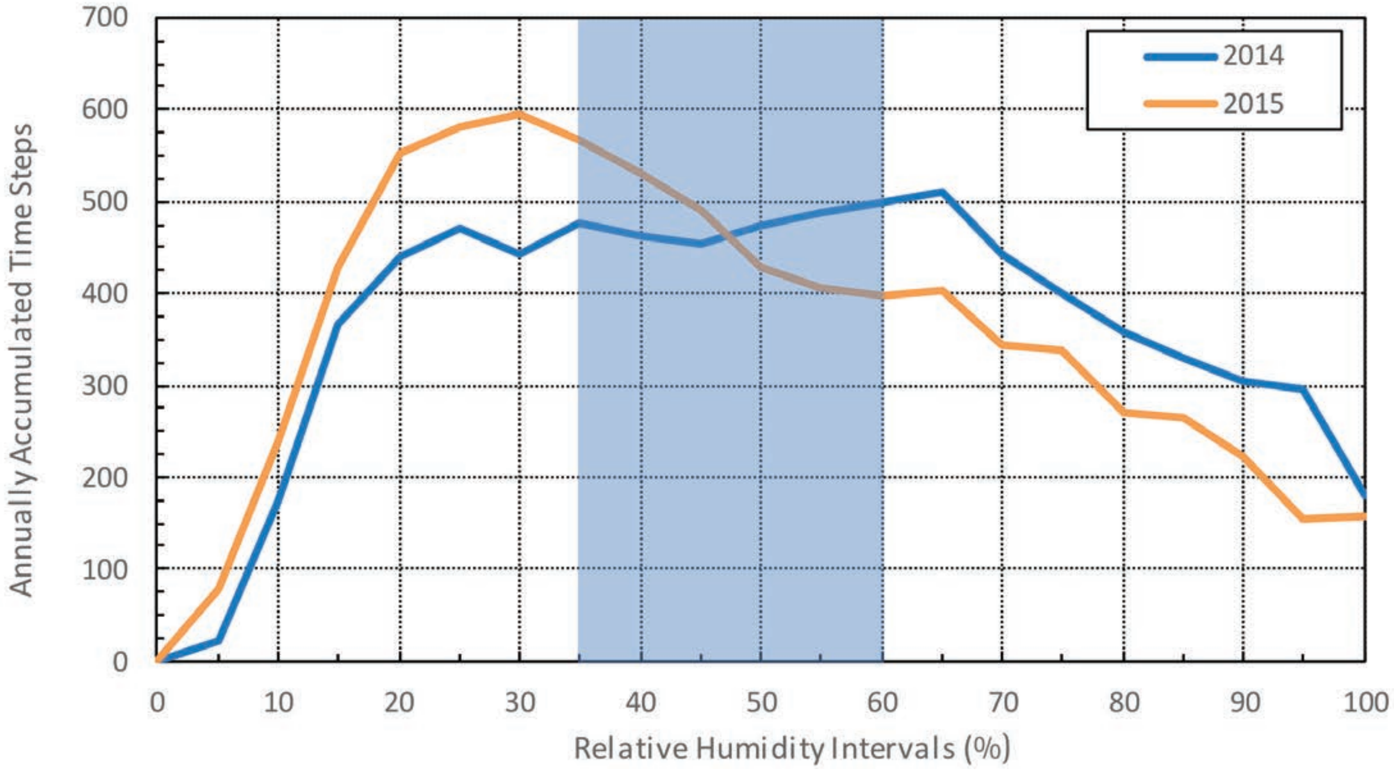


Figure 3.4 - MBR Solar Park Annual Distribution of Relative Humidity

Table 3.2 - Air Temperature and Relative Humidity Boundaries For Annual Mbr Solar Park Weather Data

		2014	2015
Temperature (°C)	maximum	48.23	49.43
	minimum	7.32	8.00
Relative Humidity (%)	maximum	100.00	100.00
	minimum	3.00	0.20
% of time within comfort T		11.14	10.97
% of time above comfort T		60.43	64.58
% of time below comfort T		28.42	24.46
% of time within comfort H		32.49	31.96
% of time above comfort H		37.1707	28.98
% of time below comfort H		30.3346	39.02
% of time within comfort T & H		4.24	3.31

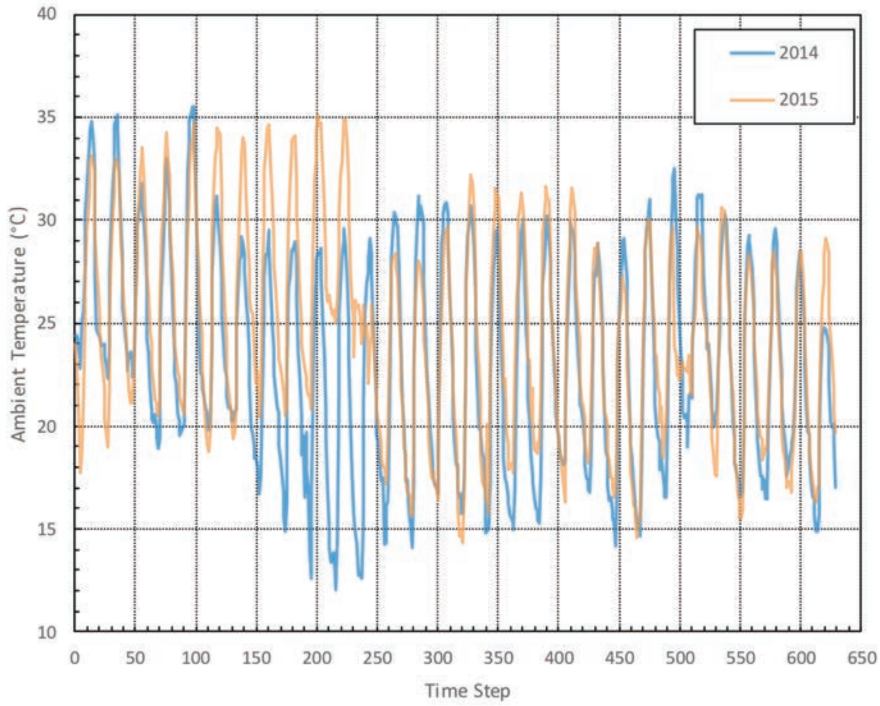


Figure 3.5 - MBR Solar Park Temperature Profile - November

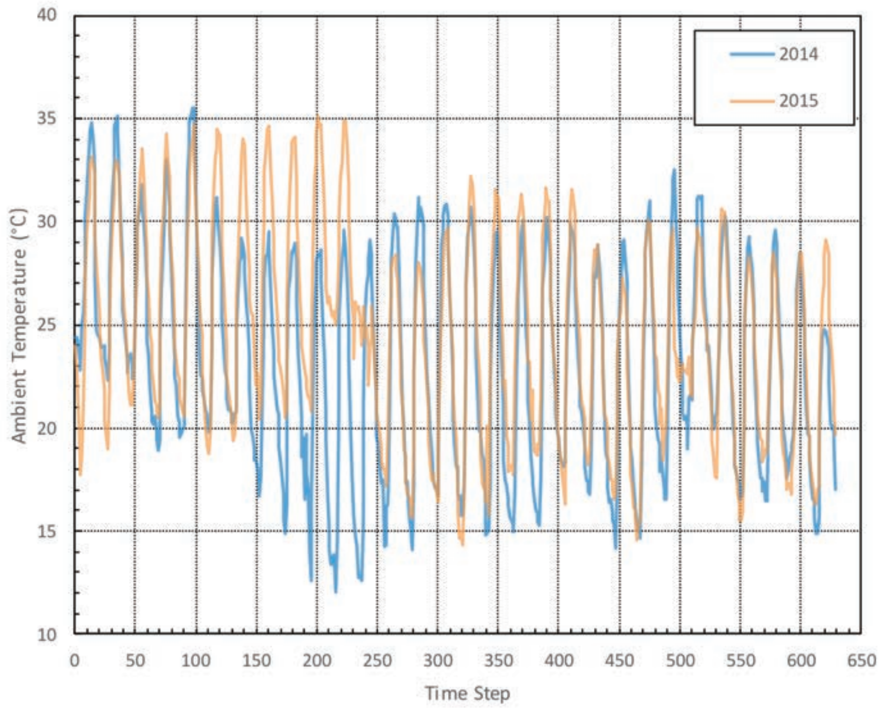


Figure 3.6 - MBR Solar Park November Distribution of Ambient Temperature

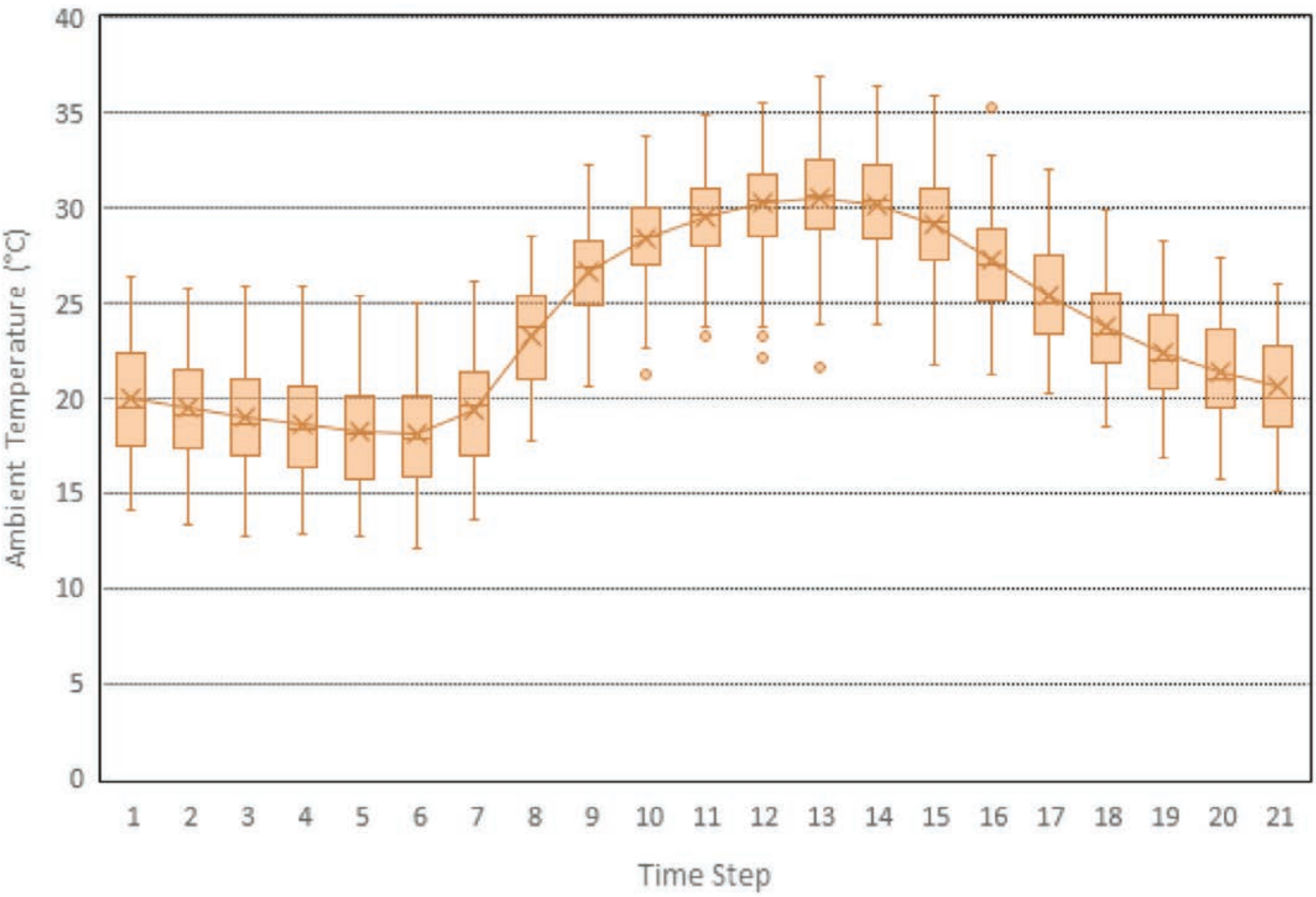


Figure 3.7 - MBR Solar Park Daily Temperature Profile - November (2018, 2014, 2015)

Similar to above the relative humidity and relative humidity distribution of the MBR Solar Park for years 2014 and 2015 was plotted for November, these are displayed in Figure 3.8 and Figure 3.9 respectively. From the distribution it is observed that the humidity ratio falls within the comfort zone for an average of 40% with 42.6% spent above this band and only 17.4% below. This highlights a high need for dehumidification if the building is to remain within the solar decathlon comfort band. The daily humidity profile is further explored in Figure 3.10 and illustrates how the humidity is above the comfort band overnight and within the band for much of the day. When looked at in comparison to Figure 3.7 it is observed that the when the temperature is within the comfort boundaries during the evening that the humidity is above the boundary and similarly when the humidity is within the band during the day that the temperature is above. This equates to only 6.2% and 5.7% of the time spent within both the temperature and humidity boundaries for years 2014 and 2015 respectively. This gives further evidence that the prospect of natural ventilation as a reliable means of remaining within the band is unlikely to be achievable.

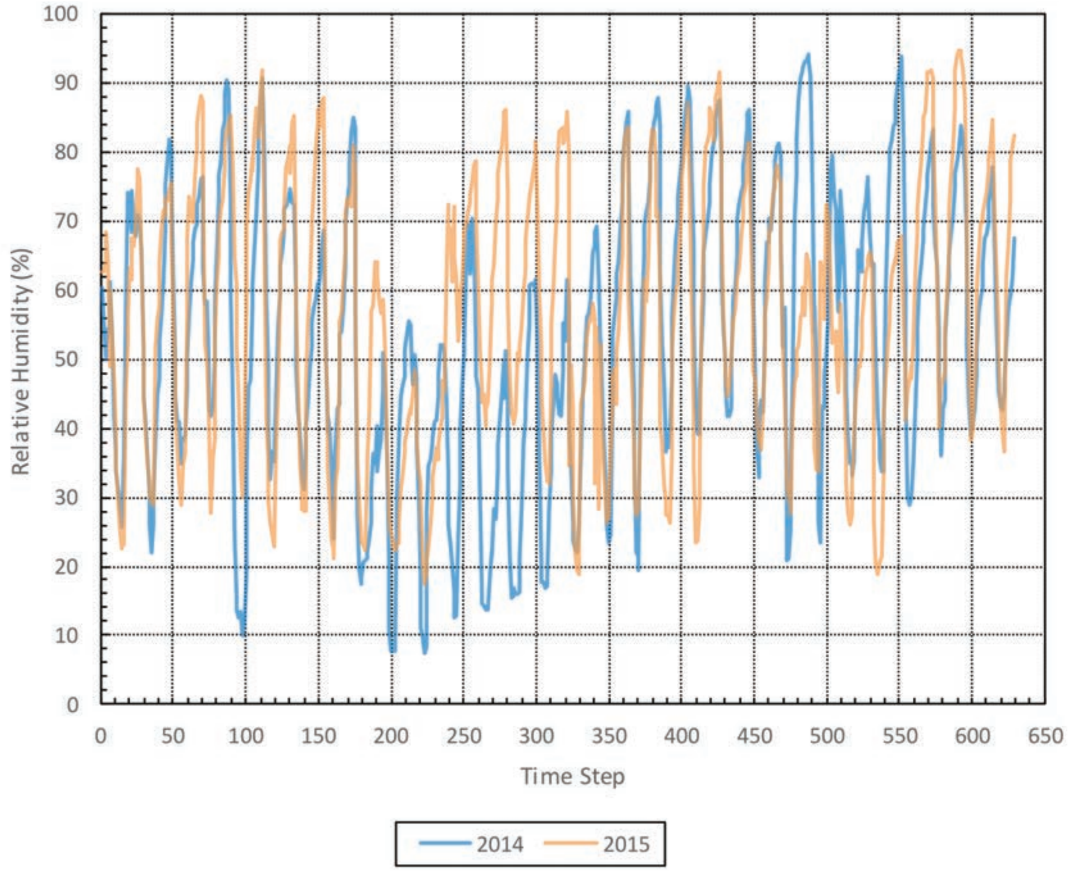


Figure 3.8 - MBR Solar Park Relative Humidity Profile

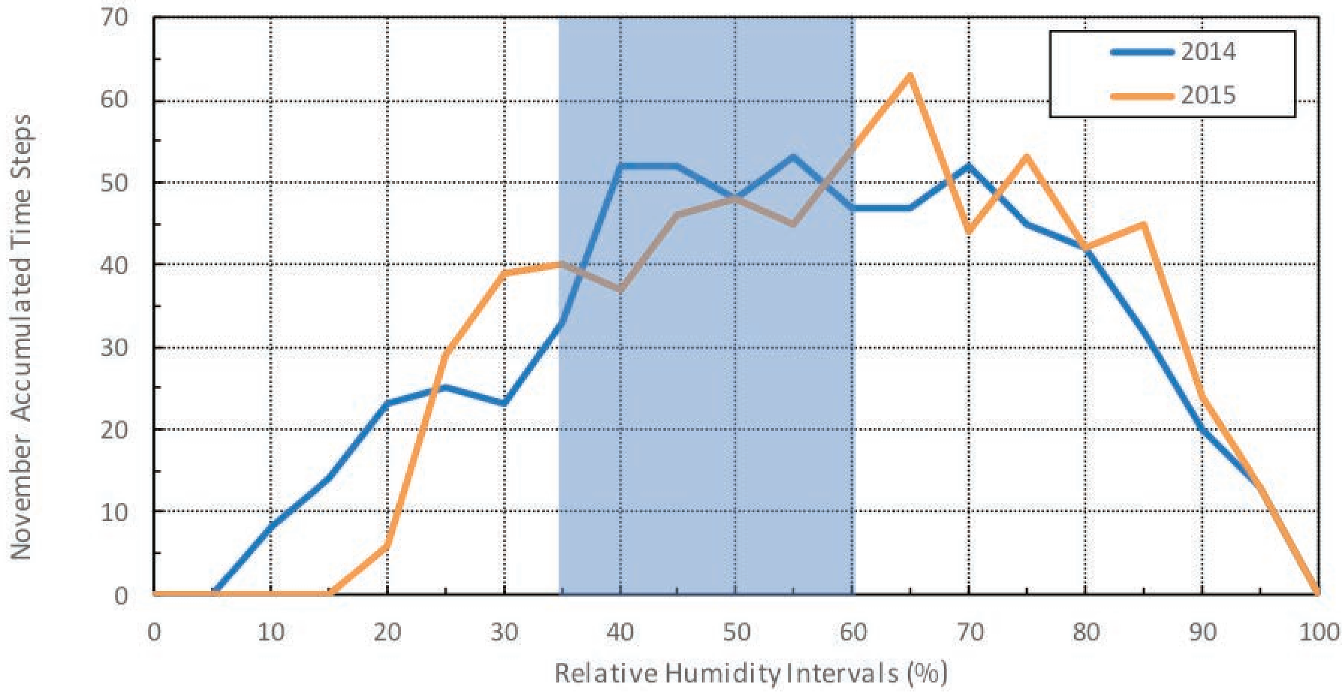


Figure 3.9 - MBR Solar Park Daily Distribution of Relative Humidity

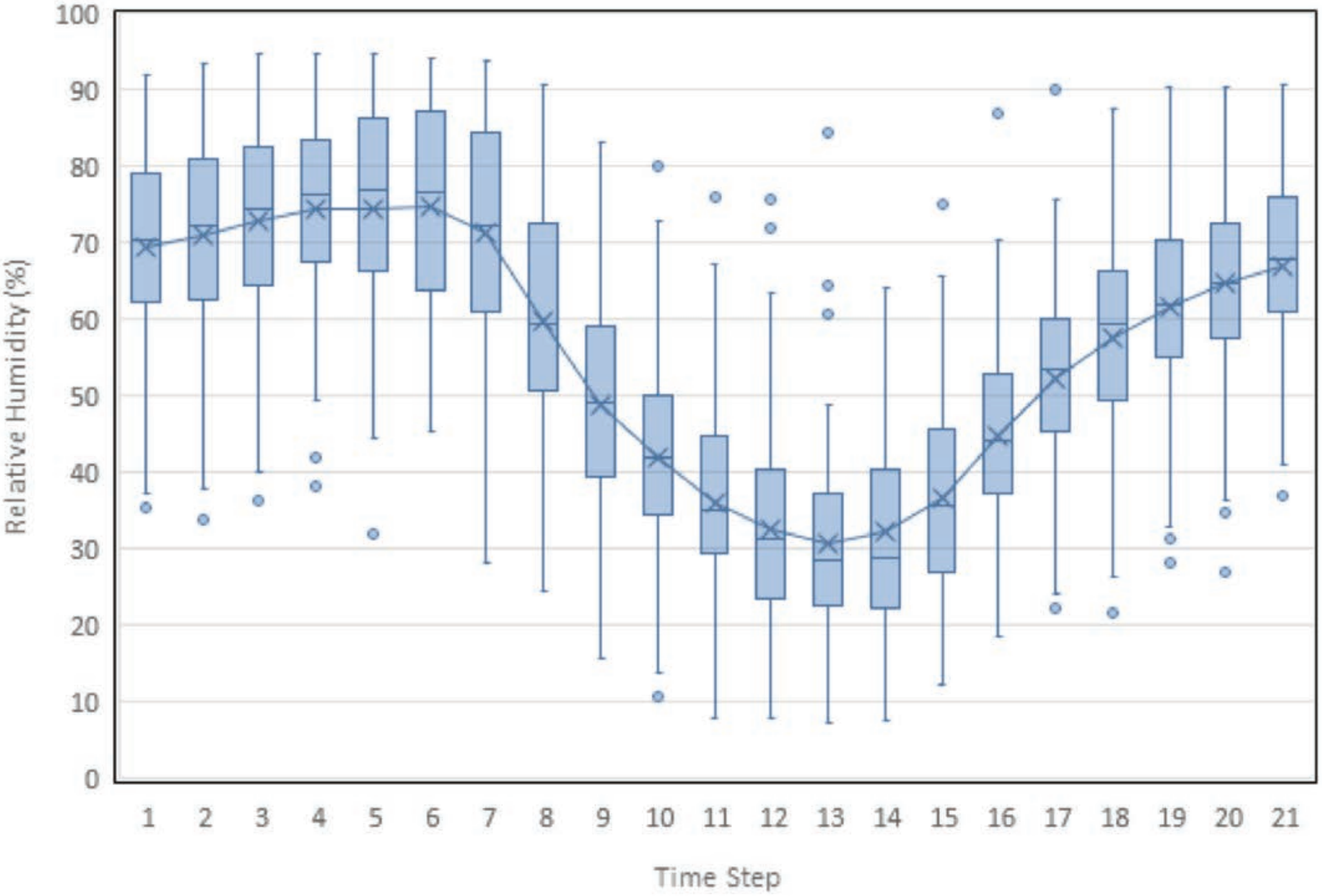


Figure 3.10 - MBR Solar Park Daily Relative Humidity Profile - November (2013, 2014, 2015)

Table 3.3 - Air Temperature and Relative Humidity Boundaries for November MBR Solar Park Weather Data

		2014	2015
Temperature (°C)	maximum	48.23	49.43
	minimum	7.32	8.00
Relative Humidity (%)	maximum	100.00	100.00
	minimum	3.00	0.20
% of time within comfort T		11.14	10.97
% of time above comfort T		60.43	64.58
% of time below comfort T		28.42	24.46
% of time within comfort H		32.49	31.96
% of time above comfort H		37.1707	28.98
% of time below comfort H		30.3346	39.02
% of time within comfort T & H		4.24	3.31

Wind Conditions

Annual Analysis: The software package Rhino combined with the MBR weather file was used to produce wind roses and examine the effects of wind conditions at the MBR Solar Park.The below analysis include wind direction, speed, temperature and relative humidity of the winds to explore the prospect of potential passive building strategies. As shown in Figure 3 11 the prevalent winds are observed from the south and west north west direction. These winds reach temperatures upwards of 40°C and over 90% relative humidity. Only 0.4% of the duration was considered calm equating to approximately 35 hours.

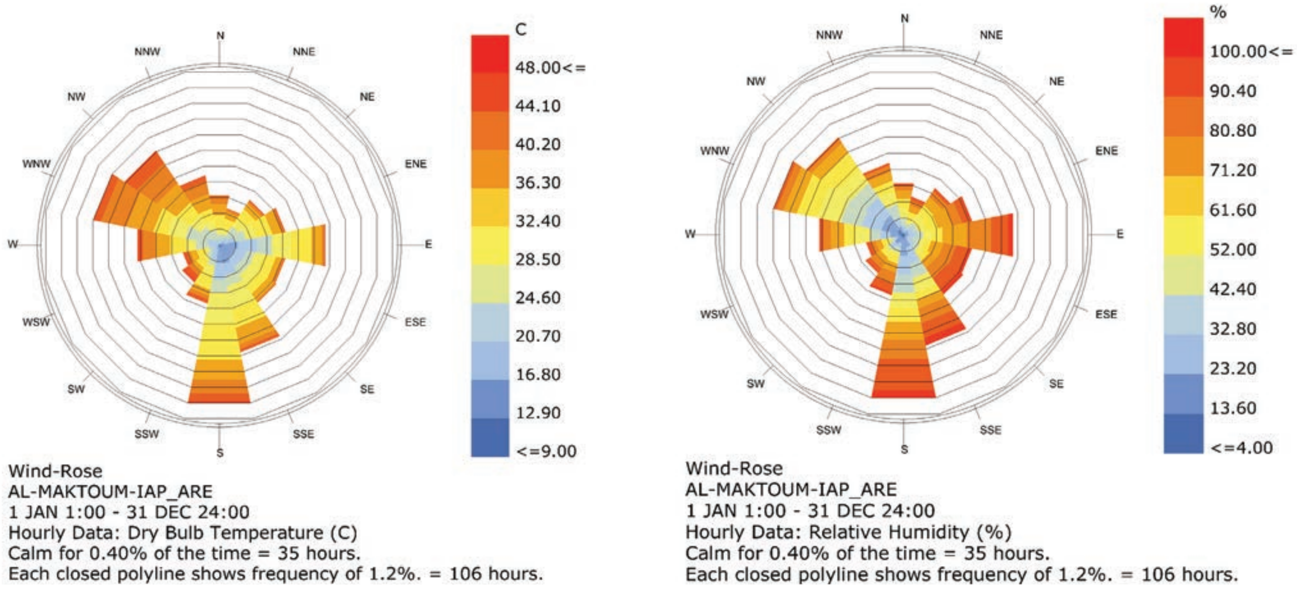


Figure 3 11 – Annual Wind Rose For Mbr Solar Park - Dry Bulb Temperature and Humidity

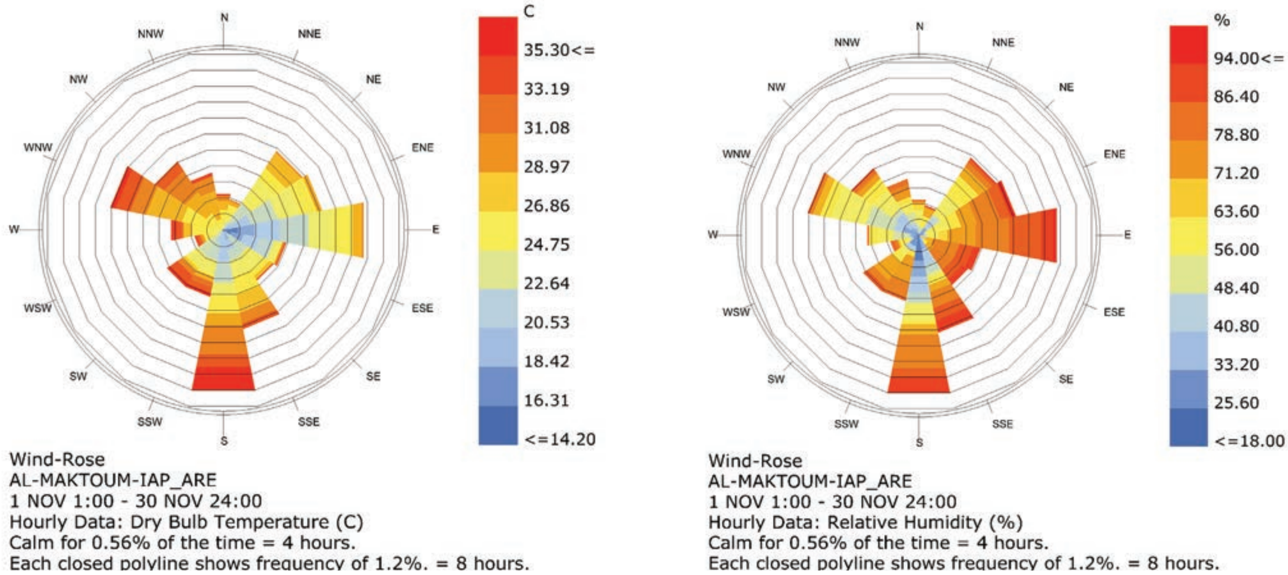


Figure 3 12 - November Wind Rose For Mbr Solar Park – Dry Bulb Temperature and Relative Humidity

A second wind rose for November was produced limiting the dry bulb temperature to be less than or equal to 25°C and the relative humidity to be less than or equal to 65%. The results displayed in Figure 3.13 show that these "cool" winds predominately come from the north east but account for only 8.75% of the November hours. If natural ventilation was to be employed during the competition period it is recommended to encourage winds from this direction, note that this does not account for dust levels in the air and may still not be appropriate from IEQ perspective.

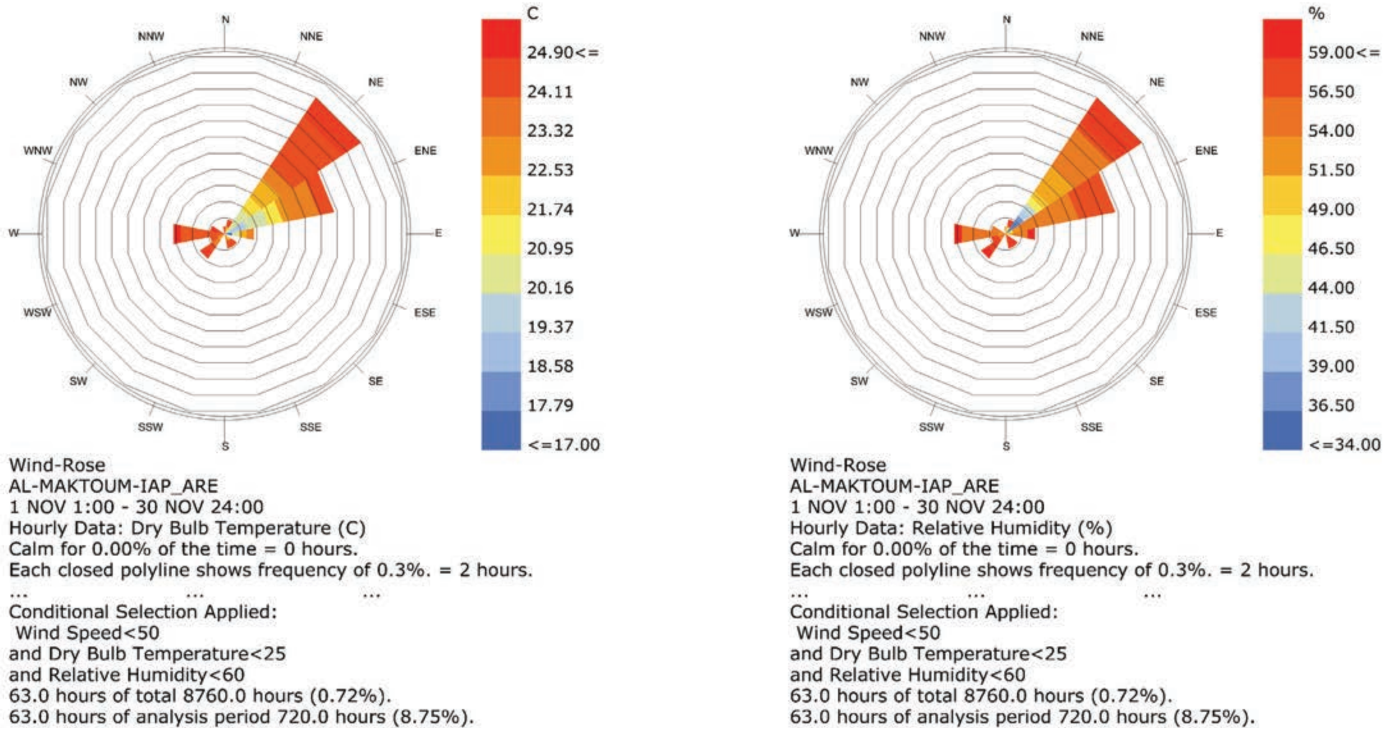


Figure 3.13- November Wind Rose For Mbr Solar Park Below – Dry Bulb Temperature < 25°C and Relative Humidity < 60%

Solar Radiation

The irradiance levels for the MBR Solar Park with the daily global horizontal irradiance displayed for years 2014 and 2015 in Figure 3.13. As shown a large amount of solar radiation is experience especially in the summer months with days experiencing up to 7,000 W/m2. This drops to around 4,000 to 4,500 W/m2 during the competition period of November. Examining further for the November period Figure 3.14 illustrates that 600 W/m2 is experienced for 5 time steps in the middle of the day. This irradiance highlights great potential for solar PV generation but passive methods for reducing the solar heat gains into the building envelope is required.

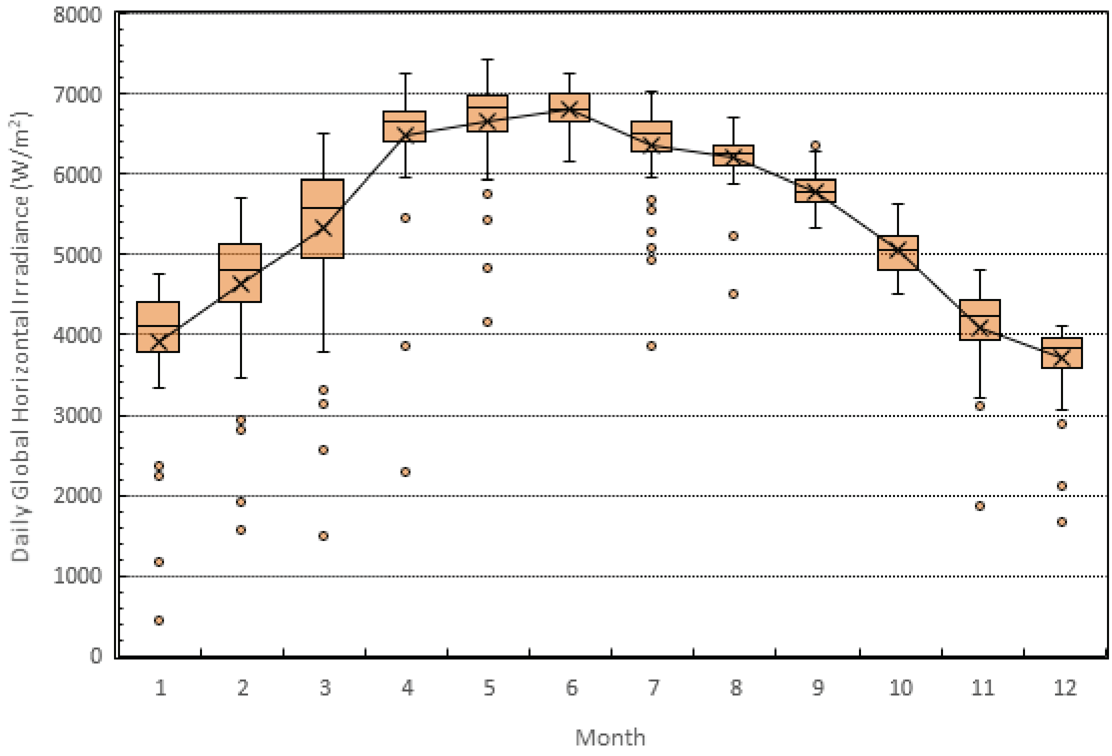


Figure 3.14 - MBR Solar Park Daily Global Irradiance

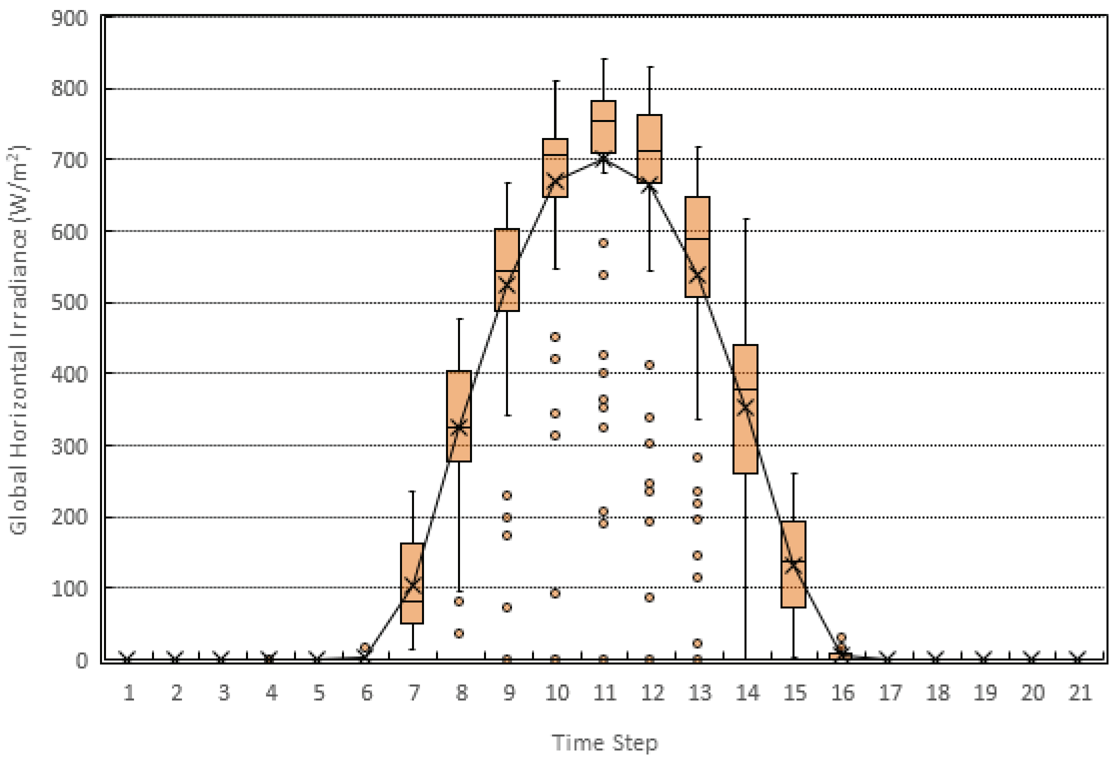


Figure 3.15 - MBR Solar Park Daily Global Irradiance - November

3.2.3.1 Team Energy Efficiency Measure (EEM)

Passive Design Strategies and House Envelope

As illustrated in the above climate and weather analysis Dubai is dominated by an extremely hot and humid climate with the majority of dwelling energy dedicated to cooling. To address this Team UOW have designed our building envelope and adopted several passive design strategies to reduce solar heat gains and increase the overall energy efficiency of the Desert Rose house.

Highly insulated wall, floors and ceiling values are achieved primarily through glasswool insulation in the cavities and extruded polystyrene (XPS) applied externally to the steel frames to increase the R value and reduce thermal bridging. A ventilated cavity has been designed between the external façade and the XPS layer, this is open at the base and top of the walls allowing built up hot air to escape.

The Desert Rose consists of a series of panelised wall, roof and floor modules with numerous joins throughout. To address the possibility of a high infiltration rate, the house is wrapped in an airtight membrane with the joins between panels sealed prior to installing the external façade / roof sheeting. Awning windows are fitted with seals and external doors have been custom designed to ensure a flush transition between inside and outside whilst achieving a airtight seal. These measures lower the overall infiltration rate of the envelope and improve energy efficiency.

The Desert Rose has been designed to meet the privacy needs of the middle east and to be suitable as both a standalone dwelling and for use in a higher density aged care village where the houses would be positioned in a line and share common western and eastern walls. This reduces the number of external walls and further decrease the energy lost to the outside. Following these concepts and to reduce solar heat gains, Team UOW's design minimises window openings on the eastern and western house façades whilst maximising windows on the northern façade for daylighting. Clearstory windows are provided in the living area enabling natural light to penetrate deep within the house whilst reducing direct solar heat gains.

Although Dubai's extreme climate rarely falls within a comfortable band the Desert Rose has been designed for natural ventilation when returned to Australia. The clerestory windows combined with the courtyard window allow for cross ventilation with a minor stack effect in the main living room.

Recycled hardwood timber frames and triple glazed, argon filled low e coated windows and doors are employed throughout the house to reduce heat gains throughout the day and heat loss on cooler nights. The glazed surfaces located next to the Southern courtyard are affected by direct sunlight. To address this Viridian's Microshade mesh has been installed on the internal surface of the external layer of glass. The Microshade consists of microscopic lamellas which shade the direct sun progressively. Microshade has the equivalent effectiveness of exterior shades, whilst maintaining natural lighting. In summer when the sun is high in the sky, the energy from the sunlight can be reduced by up to 90%. Honeycomb blinds are fitted to most windows and provide privacy and additional insulation when in the closed position.

Building Integrated Photovoltaic Thermal (BIPV-T) tiles are fitted to the south facing roof and provide a 5-in-1 combination of roof, insulation, electricity, solar PV cooling and hot water, and is engineered to withstand the extreme weather conditions, offering longevity with low maintenance. The north facing roof is sheeted in Colorbond's Coolmax steel which has a high reflective coating that achieves a Nominal Solar Reflectance1 = 0.77 and Solar Reflectance Index (SRI)1 =0 95, thus reducing solar heat gains. A ventilated cavity has been constructed beneath the BIPV-T tiles and Colorbond sheets to prevent pockets of hot air building up.

The Desert Rose's south, east and western facades are wrapped in an innovative lightweight second skin wall that was designed and built by Team UOW students. This concrete wall acts as a shading element, reducing direct solar heat gains. The second skin wall has a series of holes and is open at the top and bottom to allow air to freely move around the wall, cooling the concrete at night.

Active Systems

Building Automation: The Desert Rose building management system (BMS) acts as the brain of the house, constantly monitoring and controlling the home to ensure the optimal usage of renewable resources and maintaining of comfortable indoor conditions. The Desert Rose BMS is able to control and monitor lights, windows, HVAC systems, plumbing fixtures, EV charger, smart appliances and even the renewable energy systems. The key innovation of the Desert Rose BMS is the linking of all MEP systems into one IoT based BMS that can control the building holistically and have all systems work in conjunction with one another to ensure maximum energy efficiency.

The Desert Rose utilises a student designed model predictive control (MPC) to maximise the amount of renewable energy used within the home. By predicating over the next 24 hours various factors such as the weather, the power output of the solar PV system, amount of charge in the battery and the occupants energy habits, the BMS can optimise the use of the energy and HVAC systems within the home. For example, if the BMS predicts the weather to be very hot during the middle of the day, it will operate the HVAC system in the morning to pre-cool the building. Alternatively, the BMS may choose to run the HVAC system when solar PV output is high as this is free energy from the sun. This is an example of how often decoupled systems, such as HVAC and solar PV systems work together in the Desert Rose house. Another example is that if the BMS predicts the next day will be cloudy, it will choose to keep the battery fully charged until the peak period on the cloudy day to avoid high electricity costs.

Majority of the building controls communicate over KNX, MQTT (IoT protocol) and TCP/IP. The open source nature of KNX allows Team UOW to customise the building controls and have off the shelf devices work with student developed devices such as LED controllers, smart plumbing fixtures and smart power plugs. Using these three protocols allows Team UOW to bring all monitoring data and controls online into an IoT platform called Node Red. Node Red allows flow-based programming that connects all online systems in the house. Using Node Red, the Desert Rose can have solar PV, batteries, HVAC, EV charging and plumbing fixtures communicate and work in conjunction with one another which is particularly innovative for a residential house.

Appliances

The Desert Rose house is designed for those living with age related diseases, such as dementia, Team UOW's goal was to not only incorporate energy efficient appliances in the home, but also appliances that are user friendly.

All appliances in the Desert Rose house have an Australian energy rating of at least 4/6 stars. One of Team UOW's unique appliances is the AEG L99699HWD combined washer/dryer that uses heat pump technology for the drying cycle with a 6 star energy rating. This is one of the first combined washer dyers with a heat pump in the world. Heat pump technology greatly reduces the energy required to dry clothes and unlike a conventional dryer it does not introduce moisture into the air. This further reduces internal heat gains and reduces the risk of mould developing.

The kitchen is fitted with a Miele KM 6363-1 induction cook top. Induction cooktops use electrical induction as opposed to conventional gas or electric heating. This leads to increased energy efficiency as cookware heats faster and heat losses in the system are reduced. The cooktop also contains mechanical knobs to control the heat which is more user friendly for those living with dementia who often do not recognise LED touch screens as a means to control the cooktop.

Finally, the electrical prediction model that is linked to the BMS provides feedback to the occupant such that if an appliance is operated at a certain time it will use: only renewable energy, partial renewable energy/ grid energy, or only grid energy. This allows the occupants to become more knowledgeable and actively contribute to maximising the self-consumption of renewables in the home.

<u>BIPVT:</u> The Desert Rose has an extremely unique building integrated photovoltaic-thermal (BIPV-T) system installed on the southern facing roof. The system is made up of 104 solar tiles with a combined rated output of 10.4 kW from Australian company, Tractile Solar. The system will generate approximately Team UOW have been able to incorporate the solar tiles in the building construction to create a 5-in-1 system. The solar tiles not only produce all of the required electricity, but they also completely replace the roof construction on the southern facing portion of the house. The unique design means there is no need for roof sheeting. Instead, the interlocking tiles make up the entire roof and are able to withstand extreme weather conditions such as cyclonic winds and hail.

Along with producing electricity, the solar tiles also have water channels that run underneath the tiles which serve three purposes. Firstly, the water channels are connected to the hot water unit which pumps water through the tiles during the hottest parts of the day to produce our domestic hot water. Secondly, running water through the solar tiles creates a heat exchange effect, cooling the tiles down which significantly increases the solar PV efficiency. This is key in the hot Dubai climate. Finally, by cooling the tiles down, the roof construction is essentially cooled down which in turn cools down the building envelope, acting like an insulating element. Again, this feature is extremely beneficial for the hot Dubai climate.

<u>Lighting</u>: The Desert Rose incorporates a smart DALI lighting control system in the house. Using DALI it is possible to dim individual downlights in the house to maintain optimal indoor lighting conditions. The DALI lighting is linked with the KNX building management system (BMS) that monitors indoor lighting and occupant levels in each room. If the BMS detects that no one is in the room, it can switch the lights off accordingly. The house also employs an 'All Off' switch at the entrance of the house which turns off all lights and standby power when the occupant leaves the home. This reduces the possibility of forgetting to turn lights off in the house which adds to the overall energy efficiency of the home. When the BMS detects that the

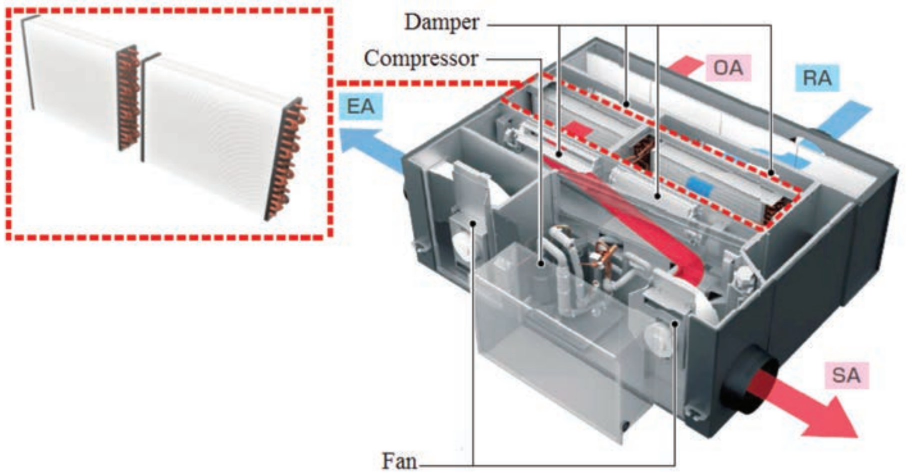


Figure 3.16 - Schematic Of The Heat Pump Desiccant Unit - Desica (SA-Supply Air, OA-Outdoor Air, RA-Return Air, EA-Exhaust Air) (Daikin 2017)

occupant returns all active systems turn back on accordingly.

HVAC

Dehumidification

The dehumidification device used in the HVAC system is a commercial heat pump desiccant unit (HPD), namely Desica, from Daikin, as illustrated in Figure 3.26. The key feature of Desica is two desiccant coated heat exchangers (DCHEs) which serve as condenser and evaporator of the heat pump, respectively, as can be seen in Figure 3 26. Due to the fact that moisture can be more effectively trapped on desiccant material at a lower temperature, the desiccant coated heat exchanger enables the removal of the adsorption heat during the air dehumidification process when it serves as an evaporator, which significantly improves the dehumidification performance. The desiccant can then be switched and regenerated by using the released heat when the DCHE is served as a condenser, which provides a reliable and energy-saving approach for regeneration. The coefficient of performance (COP) of the Desica can be over 5, which significantly improve the energy efficiency for air conditioning.

Enthalpy Recovery

An enthalpy recovery ventilator (ERV) is used in the HVAC system to reduce the heating and cooling loads introduced by fresh air, as shown in Figure 3.17. Different from an ordinary heat recovery ventilator, both sensible heat and latent heat can be recovered through the ERV, as it employs a thin film element to exchange the temperature and humidity. The thin film used decreases the moisture exchange resistance, while releasing more space for extra film layers in the element.

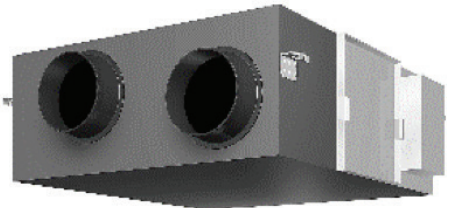
Integration of Desica into the HVAC System

Integration and using Desica in the HVAC system for dehumidification enables the decoupled control of humidity and temperature. The HVAC system no longer relies on the fan coils to cover all the cooling load, as Desica will cover the latent cooling load. The chiller or heat pump of the HVAC system only requires to provide the cooling capacity to cover the sensible cooling load, thus the supply chilled water temperature can be increased. Consequently, the COP of the chiller or heat pump can be enhanced effectively.

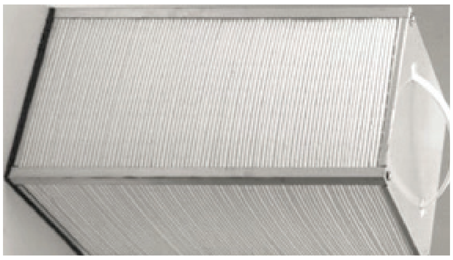
The ERV is also integrated with dampers which are able to bypass the return air without exchanging enthalpy with the ambient air.

Various Operation Modes for Air Distribution in the HVAC System

Due to the coupling of ERV, Desica and fan coils in the air distribution system, there are different operation modes for the HVAC system, corresponding to the indoor air conditioning and health demand, as shown in Figures - 18 through to 21. In the normal condition, only the fan coils are working, while the ERV can be bypassed or switched off when there is no heat recovery demand or no fresh air demand (see Figure 5.18). The ERV can be switched on to heat recovery mode, when there is fresh air and heat recovery demand (see Figure 5.19). When there is dehumidification demand, the Desica can be switched on (see Figure 3.20 and Figure 3.21). The selection of operation modes make use of necessary HVAC components, rather than using all HVAC devices even when some of them are not necessary, which facilitate the power saving of the HVAC system.



a) ERV



b) Thin File Element

Figure 3.17 - Enthalpy Recovery Ventilator from Daikin

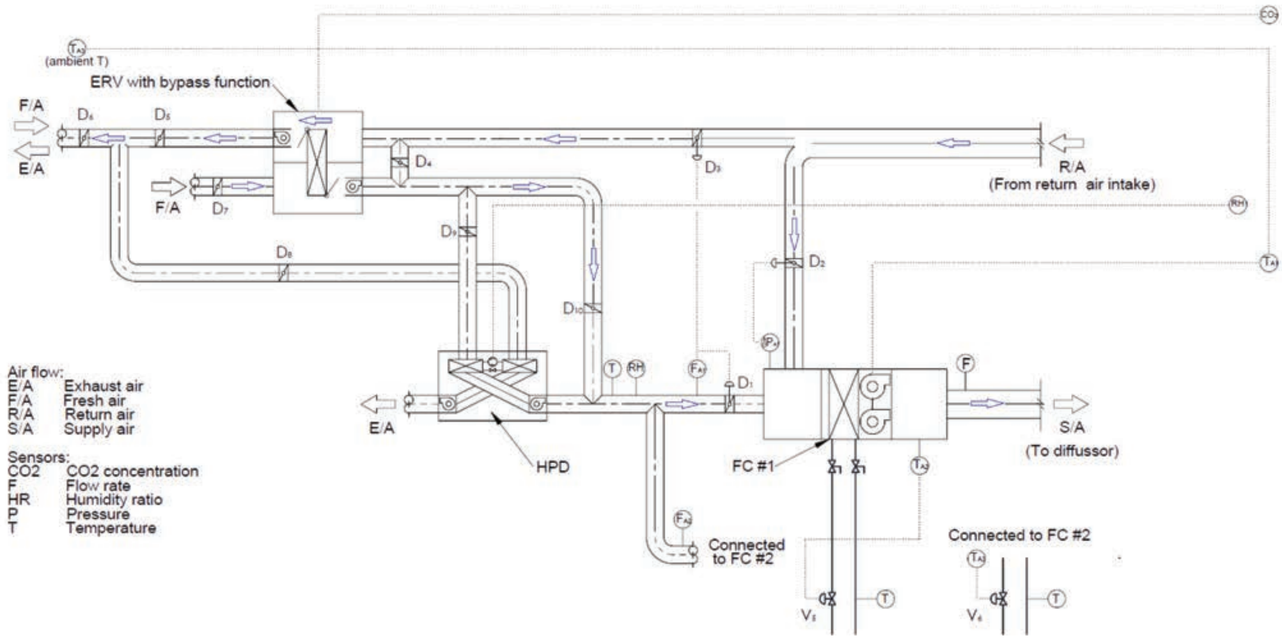


Figure 3.18 - HVAC System - Normal Operation Mode

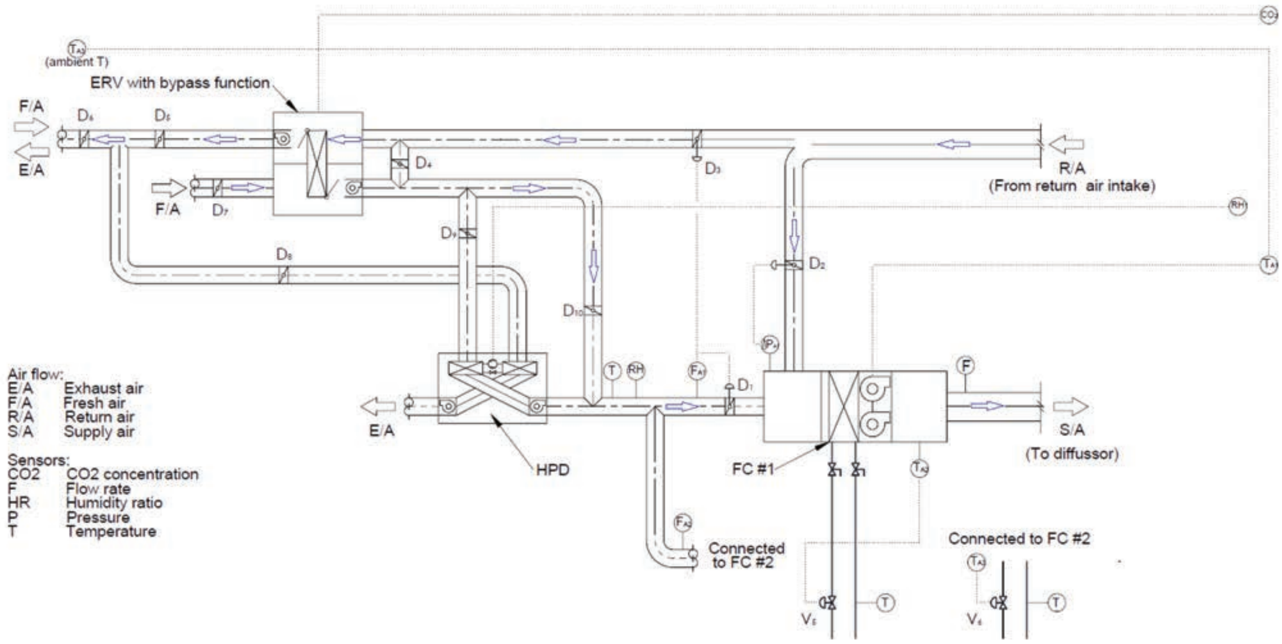


Figure 3.19 - HVAC System - Heat Recovery Mode

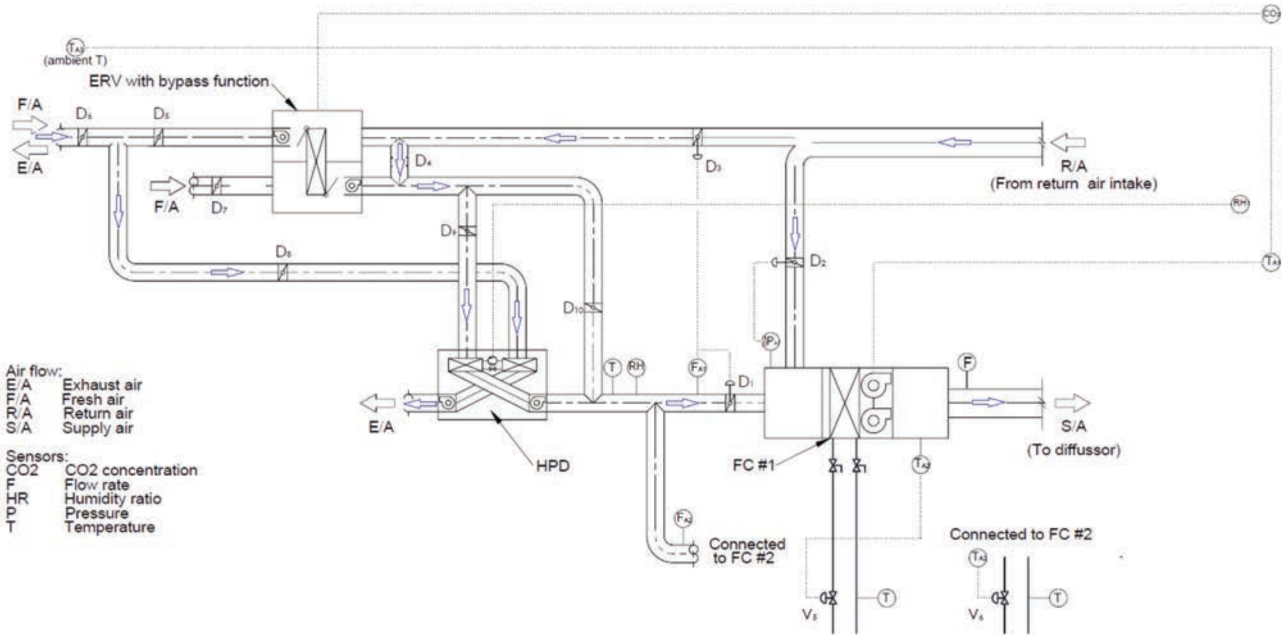


Figure 3.20 - HVAC System - Dehumidification Only Mode

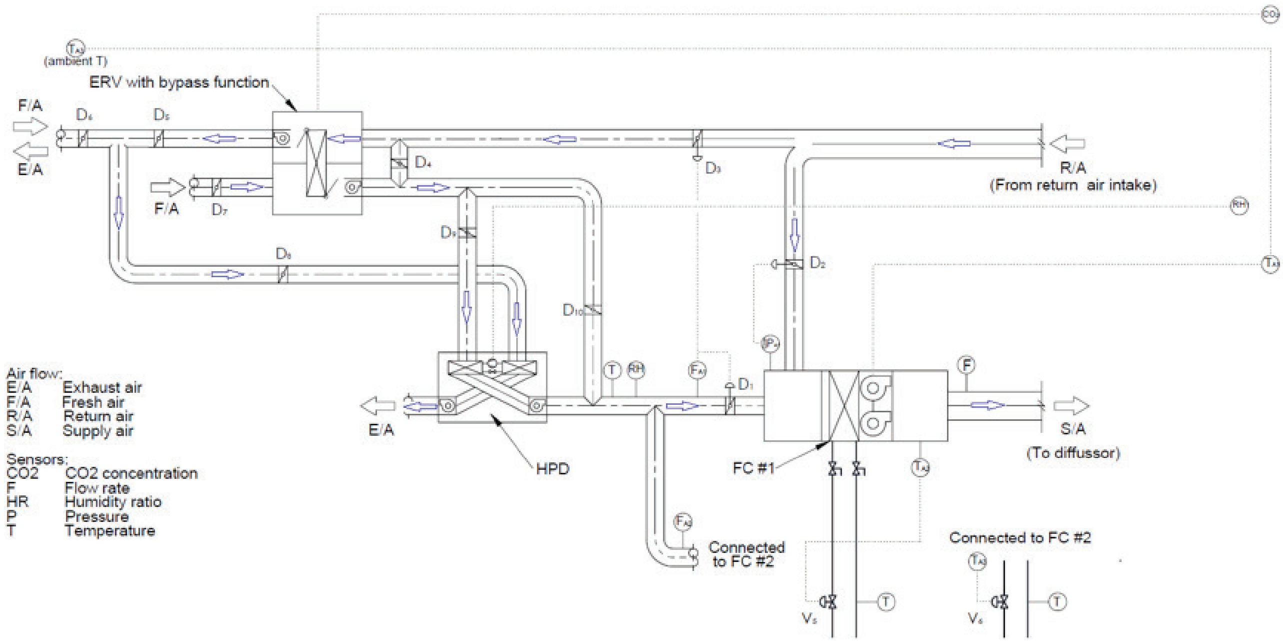


Figure 3.21 - HVAC System - Dehumidification and Heat Recovery Mode

Chilled Water-Based HVAC System

The primary air conditioning device used in the HVAC system for the Desert Rose is an air-to-water heat pump, which is able to generate chilled or hot water. As an advantage, the water-based system enables multiple distribution terminals, including the fan coils and radiant panels. A small number of radiant panels and two fan coils will be used, which add the flexibility to efficiently cater the indoor cooling or heating load. The using of radiant panels will result in a more comfortable indoor operative temperature, and it can be directly used for indoor air conditioning when the indoor cooling or cooling load is small. The two fan coils are coupled within a special building configuration. It reduces the length of the ducts, while enabling greater air distribution efficiency and at different locations of the house. As a result, a good indoor air flow organisation can be ensured while the pressure loss and heat loss of air distribution loss is minimised.

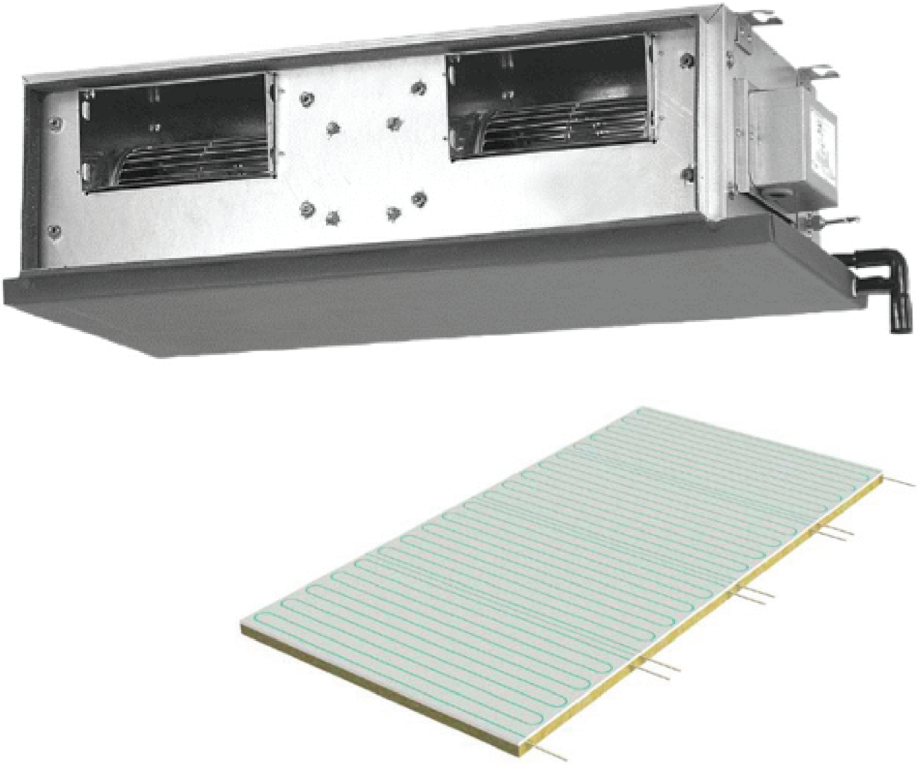


Figure 3.22 - (A) Chilled Water Fan Coil (Daikin 2017) And (B) Radiant Panels (Radiant Heating And Cooling Solutions 2017) Used in the Hvac System

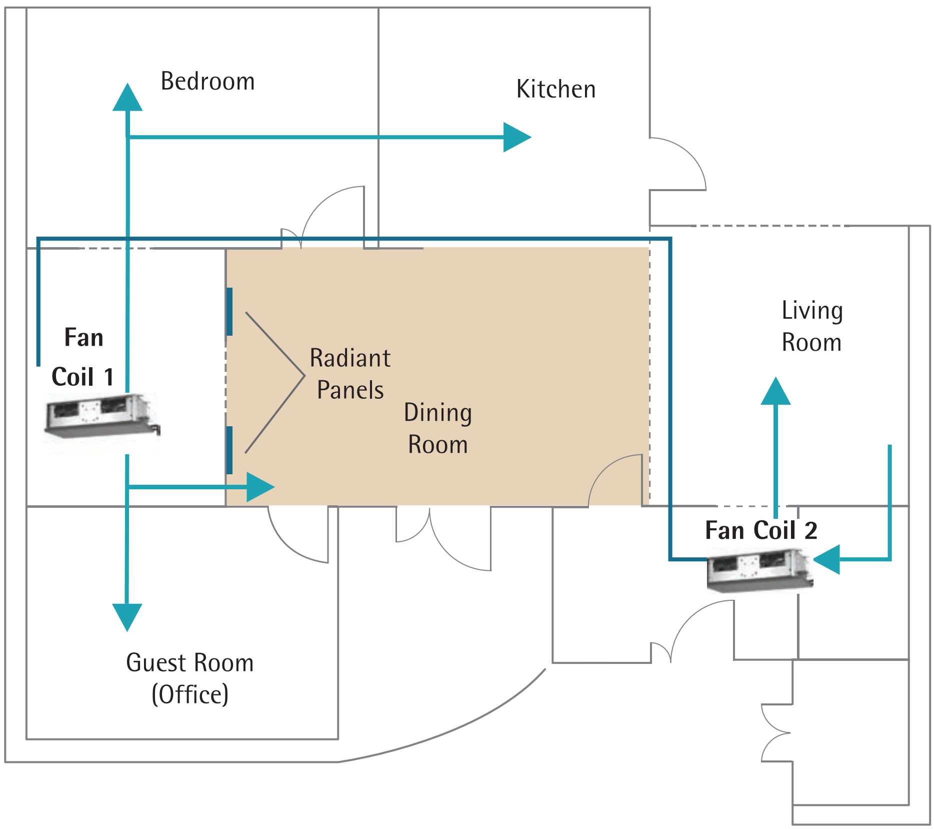


Figure 3.23 - Integration Floor Plan Schematic of Fan Coils and Radiant Panels

PCM Thermal Energy Storage

Water-based thermal energy storage (TES) using phase change materials (PCMs) will be used in the HVAC system. The water-based PCM TES system tends to be more efficient and compact than an air-based one. The main benefit of using PCM TES is for peak-load-shifting, which contributes to the power grid safety, while saving the operation cost of air conditioning for customers. By using the PCM TES units, the coolness generated by the chiller or heat pump can be stored during the night-time when the power price is low. It can then be extracted and used for air conditioning during the peak power demand period, when power price is high. Furthermore, during the charging period during the night-time, the ambient temperature tends to be relatively low, resulting in a higher COP for the chiller or heat pump. The PCM to be used has a phase change temperature of around 10°C and is encapsulated in high density polyene polytene, as can be seen in Figure 3.24. The material used is a type of salt hydrate which is suitable for building use, as it is non-flammable, non-toxic and can be easily obtained. In total there are 338 tubes, each with a storage capacity of 0.102 kWh, equating to almost 35kWh of thermal storage capacity.

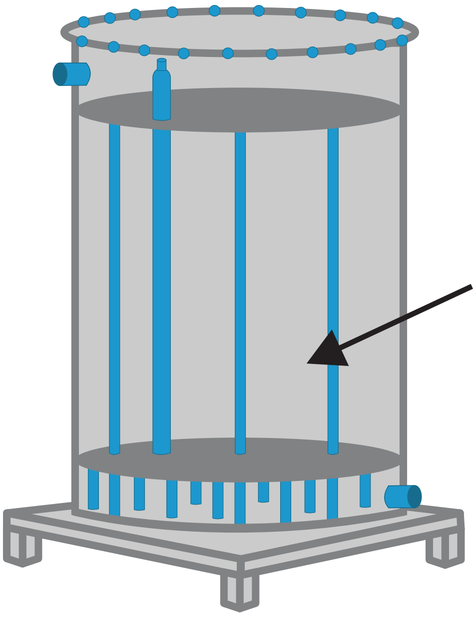


Figure 3.24 - Phase Change Materials and PCM TES Unit Used in the HVAC System (PCM Products 2017)

3.2.2 Brief House and System's Description

3.2.2.1 Description of the House Envelope Including its Thermal and Optical Characteristics

Building Envelope Construction

The following section contains a detailed description of the material properties used in the construction of the Desert Rose.

Floor Construction: The clear subfloor height is 480 millimetres above the ground. The environmental exposed surface facing the ground (in this case sand) is a rigid XPS insulation (8). The continuous rigid insulation layer reduces the potential of condensation and unwanted heat gains. It is attached to a structural board (6) (Plywood) with an airtight permeable membrane (7) on it. The steel-frame (4) is 152 mm high with joists infilled at 100 mm high. The stud cavity is filled with soft insulation (5). On top of the steel frame a second supporting structural board (3) is mounted. This board forms the base for the flooring assembly which contains a thin footfall rubber underlay (2), before the floorboard finish (1) is installed.

Wall construction: The wall construction is shaded by a second skin wall (9) on the south, east and west façades. The environmental exposed cladding (8) is a light weight façade panel attached to timber battens which allow natural ventilation through a vertical air gap (7). The slightly naturally ventilated gap between the cladding and the continuous insulation provides additional sound protection, thermal stability, and moisture exchange. The continuous rigid insulation (6) is attached to the structural board (4) with the self-adhesive airtight permeable membrane (5). The main load bearing structure (2) is light gauge steel-frame, 90 mm wide with soft insulation (3) batts between the studs. The inside finish (1) is gypsum board.

The wall construction was analysed for its hygrothermal properties both for Dubai and for when it returns to Australia. It was found that the wall construction is durable in both climate conditions and falls into a yearly equilibrium when the simulation period is set to 10 years. The simulation is carefully analysed with multiple failure modes added in to test the maximum moisture content of the plywood. It is recommended that the water content of timber products not reach18% or higher as the water content can damage the material. In this simulation the maximum water content reached is 13.7%.

Table 3.4 Typical Floor Construction

Typical Floor Construction				
Thickness: 242mm R-Value = 6.12m²K/W				
	Layer purpose (i-e)	Material	Thickness (mm)	Thermal conductivity (W/mk)
1	Finish, inside	Floor boards, Tasmanian oak	19	0.13
2	Rubber underlay	Rubber underlay	4	0.83
3	Structural board	Plywood	21	0.13
4	Load bearing construction	Steel-frame, Enduroframe 150mm		
5	Soft Insulation	Mineral wool	150	0.035
6	Structural board	Plywood, non-bearing (but supporting)	9	0.13
7	Airtight layer	Permeable airtight membrane	0.5	2.3
8	Continuous external insulation	Rigid insulation board (XPS)	40	0.028

Table 3.5 Typical Wall Construction

Typical Wall Construction				
Thickness: 267.5mm (excluding second skin) R-Value = 6.21m²K/W				
	Layer purpose (i-e)	Material	Thickness (mm)	Thermal conductivity (W/mk)
1	Finish, inside	Gypsum plasterboard	13	0.16
2	Load bearing construction	Steel-frame, Enduroframe 90mm		-
3	Soft insulation	Bradford Black glass fibre	90	0.035
4	Structural board	Plywood	9	0.13
5	Airtight layer	Permeable airtight membrane	1	2.3
6	Continuous external insulation	Rigid insulation, XPS	100	0.028
7	Ventilation gap	Ventilated air gap	45	-
8	Finish, outside	Weathertex cladding	9.5	-
	Outside air	Distance to external shading skin	100-200	
9	Shading	Second skin shading, lightweight concrete, 50mm	50	

Table 3.6 Typical External Wall WUFI Hygro-Thermal Analysis

WUFI Output	Value	Unit
Temperature XPS surface left side max.	46	C
Temperature XPS surface left side min.	10	C
Heat flux inside (right side)	157.21	MJ/m²
Water content plywood max. (in equilibrium)	13.7	M.-%
Water content plywood min. (in equilibrium)	8.05	M.-%
Moisture flux inside (right side)	3.26	kg/m²

The wall construction was analysed for its hygrothermal properties both for Dubai and for when it returns to Australia. It was found that the wall construction is durable in both climate conditions and falls into a yearly equilibrium when the simulation period is set to 10 years. The simulation is carefully analysed with multiple failure modes added in to test the maximum moisture content of the plywood. It is recommended that the water content of timber products not reach18% or higher as the water content can damage the material. In this simulation the maximum water content reached is 13.7%.

Roof Construction: The roof is divided in three primary sections. The first is a Tractile BIPV-T roof facing south with some sections constructed with a traditional trussed roof and another section as a raked ceiling. The third section is a Colourbond steel roof that faces north and utilises traditional trussed roof sections.

Roof Construction – Trussed Roof Construction: The roof facing the north of the house has a 3° slope and is constructed from 75 mm light gauge steel frame trusses. Attached to the bottom chord of the truss is ceiling top hats and the interior gyprock finish (1). 75mm of Bradford Black glass fibre is placed on the base of the steel frame construction (2). Insulation is attached to the top of the ceiling cavity (4). The structural board (5) on top of the top chord holds self-adhesive airtight membrane (6). The joint points must be taped on site to ensure an airtight seal. Timber joists running in line with steel-frame overlap the construction to form eaves. The gap in between the joists holds the continuous rigid insulation (7) . A waterproof membrane (8) is applied on top of the ridged insulation followed by a continuous air cavity (9). Top hat battens are installed (10) followed by Colorbond's Coolmax metal sheeting. This sheeting is coated with a highly reflectance coating that achieves a Nominal Solar Reflectance1 = 0.77 and Solar Reflectance Index (SRI)1 =0 95, thus reducing solar heat gains.

Table 3.7 Typical Trussed Roof Construction

Typical Trussed Roof Construction				
Thickness: 397mm (minimum) R-Value = 5.08m²K/W				
	Layer purpose (i-e)	Material	Thickness (mm)	Thermal conductivity (W/mk)
1	Finish, inside	Gypsum plasterboard	13	0.16
2	Truss cavity with ceiling insulation	Installation cavity, still air (average 480mm) filled with 75mm Bradford Black glass fibre insulation.	varying	0.035
3	Load bearing construction	Steel-frame, Enduroframe, 75mm		-
4	Roof insulation	Bradford Black glass fibre	75	0.035
5	Structural board	Plywood	12	0.13
6	Airtight layer	Permeable airtight membrane	1	2.3
7	Continuous insulation	Rigid insulation, XPS	80	0.028
8	Waterproof membrane	Sarking waterproof membrane	1	2.3
9	Ventilation gap		30	-
10	Roof construction	Top-hats, railing construction to attach the roof sheeting	21	-
11	Roof sheeting	Metal sheeting, light colour	0.8	

The construction also found to durable in both climate conditions and reach a yearly equilibrium after simulating for a 10 year period.

Roof Construction Tractile Raked Ceiling: Two separate roof constructions make up the Tractile roof. The first is a raked ceiling component located above the dining room. The raked ceiling consists of a plasterboard finish (1) followed by a 152 mm high steel-frame construction (2) that is insulated with Bradford Black glass fibre insulation (3) between the rafters. A structural board (4) on top holds self-adhesive airtight membrane (5). Timber joists are installed on top of the steel structure and follow the whole length to form the eaves and lead to the drain gutter. A waterproof membrane (8) is placed on top of a continuous layer of XPS insulation (6). This is followed by a ventilation gap (7) and top-hats that form the battens for the tractile roof to attach to. The tractile roof construction (9) replaces the need of a separate roofing system.

Table 3.8 Typical Trussed Roof WUFI Hygro-Thermal Analysis

WUFI Output	Value	Unit
Temperature XPS surface left side max.	48	C
Temperature XPS surface left side min.	8	C
Heat flux inside (right side)	163.29	MJ/m²
Water content plywood max. (in equilibrium)	11.6	M.-%
Water content plywood min. (in equilibrium)	9.3	M.-%
Moisture flux inside (right side)	2.08	kg/m²

Table 3.9 Typical Raked Roof Construction

Typical Raked Roof Construction				
Thickness: 372mm R-Value = 4.99m²K/W				
	Layer purpose (i-e)	Material	Thickness (mm)	Thermal conductivity (W/mk)
1	Finish, inside	Gypsum plasterboard	13	0.16
2	Load bearing construction	Steel-frame, Enduroframe, 152mm height (flush with connection truss roof to the outside)		-
3	Rafter main insulation	Bradford Black glass fibre	152	0.035
4	Structural board	Plywood	12	0.13
5	Airtight layer	Permeable airtight membrane	0.5	2.3
	Construction	Timber joists 90mm		
6	Continuous insulation	Rigid insulation, XPS (continuous chosen thickness for connecting roof with trusses)	80	0.028
7	Waterproof membrane	Sarking waterproof membrane	1	2.3
8	Ventilation gap	Air gap	20	-
9	Roofing system	Tractile roofing system (21mm top-hats, pocket and panel)	108	-

Table 3.10 Typical Raked Roof WUFI Hygro-Thermal Analysis

WUFI Output	Value	Unit
Temperature XPS surface left side max.	60	°C
Temperature XPS surface left side min.	13	°C
Heat flux inside (right side)	185.65	MJ/m²
Water content plywood max. (in equilibrium)	10.1	M.-%
Water content plywood min. (in equilibrium)	8.0	M.-%
Moisture flux inside (right side)	1.14	kg/m²

Table 3.11 Typical Trussed Solar Roof Construction

Typical Trussed Solar Roof Construction				
Thickness: 397mm R-Value = 5.08m²K/W				
	Layer purpose (i-e)	**Material**	**Thickness (mm)**	**Thermal conductivity (W/mk)**
1	Finish, inside	Gypsum plasterboard	13	0.16
2	Truss cavity with ceiling insulation	Installation cavity, still air (average 480mm) filled with 75mm Bradford Black glass fibre insulation	varying	0.035
3	Load bearing construction	Steel-frame, Enduroframe, 75mm		-
4	Roof insulation	Bradford Black glass fibre	75	0.035
5	Structural board	Plywood	12	0.13
6	Airtight layer	Permeable airtight membrane	1	2.3
7	Continuous insulation	Rigid insulation, XPS	80	0.028
8	Waterproof membrane	Sarking waterproof membrane	1	2.3
9	Ventilation gap		30	-
10	Roof construction	Top-hats, railing construction to attach the roof sheeting	21	-
11	Roofing system	Tractile roofing system	87	-

Table 3.12 Typical Trussed Solar Roof WUFI Hygro-Thermal Analysis

WUFI Output	Value	Unit
Temperature XPS surface left side max.	60	°C
Temperature XPS surface left side min.	14	°C
Heat flux inside (right side)	185.18	MJ/m²
Water content plywood max. (in equilibrium)	10.3	M.-%
Water content plywood min. (in equilibrium)	8.7	M.-%
Moisture flux inside (right side)	0.9	kg/m²

Roof Construction Tractile Solar PV Trussed: The remaining Tractile roof is a standard cavity roof construction as per the - Trussed Roof Construction with the exception of the Tractile solar tiles replacing the Colorbond metal sheeting. This roof construction is found above the guest bedroom, entrance, water closet and plant room.

Windows and Doors

Recycled hardwood timber frames and triple glazed, argon filled low e coated windows and doors are employed throughout the house to reduce heat gains throughout the day and heat loss on cooler nights. The glazed surfaces located next to the Southern courtyard are affected by direct sunlight. To address this Viridian's Microshade mesh has been installed on the internal surface of the external layer of glass. The Microshade consists of microscopic lamellas which shade the direct sun progressively. Microshade has the equivalent effectiveness of exterior shades, whilst maintaining natural lighting. In summer when the sun is high in the sky, the energy from the sunlight can be reduced by up to 90%. Honeycomb blinds are fitted to most windows and provide privacy and additional insulation when in the closed position.

The locally sourced windows of the Desert Rose are made from recycled hardwood timber that would otherwise be sent to landfill. The window case is 40 mm thick and overlaps the wall construction to the exterior and the interior with 25 mm which is a width of 325 mm. For the hardwood frames a thermal conductivity of 0.13 W/mK was assumed.

The glazing itself is provided by Viridian. It is triple glazed argon filled and manufactured. The glass make up is as followed and runs from outside to inside:

Standard Glazing: 4 mm clear toughened, 10 mm argon, 4 mm PerformaTech (PH12(30) Clear Toughed, 8mm argon, 4 mm EnergyTech Clear (Toughened)

Microshade Glazing: 4 mm clear toughened + MicroShade, 10 mm argon, 4 mm PerformaTech (PH12(30) Clear Toughed, 8mm argon, 4mm EnergyTech Clear (Toughened).The window U-Values calculated via Design Builder equalled 1.4 W/m2K for all windows.

Figure 3.25 - Desert Rose Floor Plan

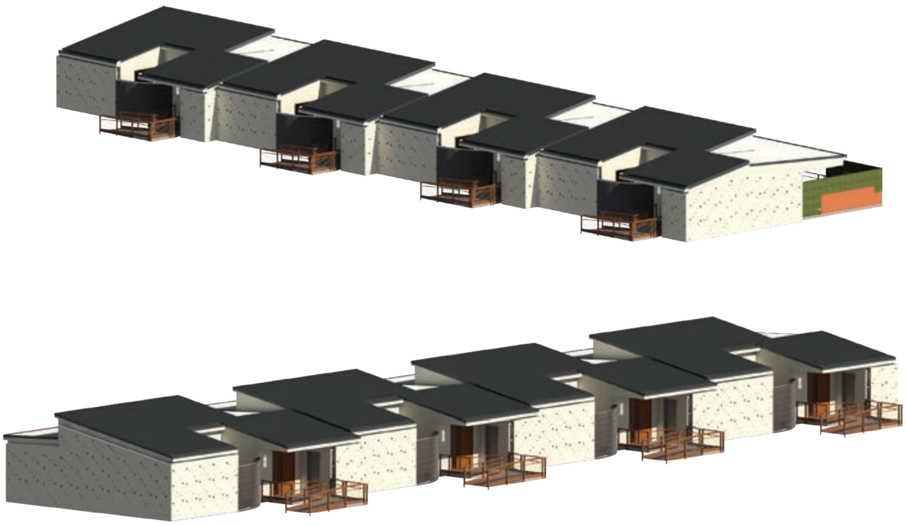


Figure 3.26 - Desert Rose as in a Higher Density Aged Care Village

3.2.2.2 Passive Design Strategies Including Project Geometric, Shading Devices, Orientation of the Spaces, Buffer Zones, and Other Strategies

The geometry of Desert Rose is detailed in Figure 3.25, for more details please refer to the Project Drawings. The design philosophy that Team UOW has adopted for the Desert Rose is "architecture that celebrates human life rather than itself" with a motto of creating "A House for Life". Team UOW's vision for the Desert Rose is that someone approaching retirement age will move into a house able to adapt to their needs as they continue to age. Should the occupants develop a disability such as arthritis, mobility issues, or dementia then the Desert Rose is designed to be easily adapted to meet those needs so that the residents can enjoy the highest quality of life possible. As such a large governing factor to the geometry of the house was accessibility and enabling occupants to be able to perform tasks. However, several decisions around geometry were governed by energy efficiency including the exclusion of windows on the east and west façades. This decision was made for three reasons; a) to provide privacy by not having any windows face the street, b) to reduce solar heat gains from low lying sun, and c) to enable the Desert Rose to be stacked alongside one another as part of an aged care village with higher densities. This last decision also has great energy benefits as two external walls become common with neighbours, reducing losses and thus cooling demands.

A raked ceiling was installed in the Dining Room allowing clerestory windows to be installed. These windows allow light to penetrate deep into the living room and allow for cross flow ventilation and a minor stack effect although as described in the climate analysis natural ventilation will most likely not be employed in Dubai.

The majority of the living spaces are located on the northern side of the Desert Rose with buffer zones on the south that can be closed off from these living spaces, assisting the occupants with the management of cooling loads. Additionally, the plant room is located out the front of the house and is thermally isolated from the remainder of the house, this ensures that the heat generated from the batteries and other electrical equipment is not funnelled into the house.

The external wall area was minimised through modifying the location and shape of the rooms within the house, however as mentioned above accessibility and meeting the needs for an occupant living with dementia was of our primary concern which resulted in compromises in energy efficiency being made.

Table 3.13 Desert Rose Floor Areas

Zones	Floor Area m^2
Bedroom	15
Kitchen	11
Dining room	21
Living room	13
Guest bedroom	12
Bathroom	9
Entrance	7
WC	3
Plant room	3
Air conditioned area	72
Total measurable area	90

Shading Devices, Orientation and Other Strategies

Several passive design strategies have been employed in the Desert Rose and are illustrated in Figure 5.27. These are described in more detail below.

Southern Façade: The southern facing entrance area is shaded by a large cantilever roof and contains the only window that faces the street. The windows and doors facing the court yard introduce daylight into the dining and sleeping area, these windows are partially shaded by the walls of the house but have been fitted with Microshade. The Microshade consists of microscopic lamellas which shade the direct sun progressively. Microshade has the equivalent effectiveness of exterior shades, whilst maintaining natural lighting. In summer when the sun is high in the sky, the energy from the sunlight can be reduced by up to 90%. Honeycomb blinds are also fitted to the windows and provide privacy and additional insulation when in the closed position. A high window is placed above the courtyard door and can be controlled via the BMS to allow for crossflow ventilation.

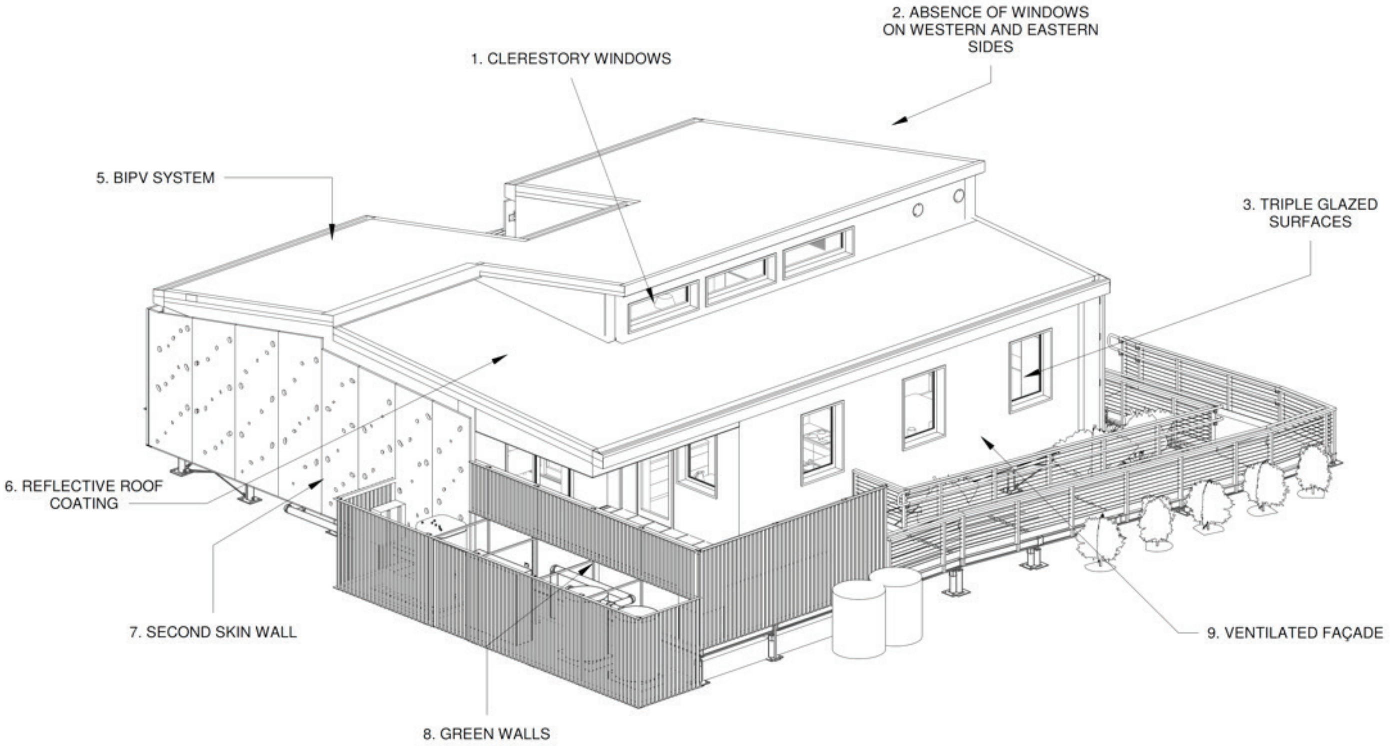


Figure 3.27 - Design Strategies

Northern façade: Natural lighting will be introduced by north facing windows. These windows are recessed in the façade and additionally shaded by an overhanging eve. This aims to maximise the natural daylight, while minimising solar heat gains. A private and shaded outside living area is attached to the living room as well as to the kitchen. The continuous roof construction as well as the green wall offer shading as well as privacy. The green wall aims to maintain a micro climate to support natural cooling around the outside area.

East and West Façade: The east and west facing surfaces have no windows. This helps do reduce solar heat gains as well as makes the house more adaptable to dense building areas. As mentioned above the house can be duplicated to both sides and organised in a row. In our case the wall is shaded by a second skin wall, an additional innovative shading system developed by students of Team UOW. The light weight concrete material contains recycled glass as a cement replacement.

Roof design: The roof is divided in two sections. A south facing roof with a slope of 10 degrees with an innovative building integrated photovoltaic system called Tractile. This system replaces a traditional roof construction. It consists of modules which generate electric energy as well as hot water for the domestic hot water supply. The roof structure has an air gap that allows air to ventilate between the sheeting and the external insulation, reducing heat build-ups. The north facing roof has a slope of 3 degrees and is also naturally ventilated. The high reflective metal sheeting reduces solar heat gains and is beneficial for the natural daylight offered by the clerestory windows.

3.2.3 House and HVAC Simulations Inputs

3.2.3.1 Brief Simulation Descriptions and Tools Used (Capabilities and Limitations)

EnergyPlus

EnergyPlus, which was developed by the U.S Department of Energy, is a free whole building energy simulation software designed for engineers, architects and researchers. EnergyPlus is now widely used in the building design phase and research area and it has more than 2100 locations' of weather data available, including many Australian locations and verification of simulation accuracy by standard verification software BESTEST. Version 7.0 of the software, released in November 2011 has been used for this research.

DesignBuilder

DesignBuilder is a user-friendly EnergyPlus interface. DesignBuilder has its own database that contains construction materials, properties and control schedules. Most work can be easily input by dragging and selecting in DesignBuilder. Additionally, DesignBuilder provides an easy to use modelling tool that makes defining building geometry similar to most CAD software. Once input, DesignBuilder automatically exports an input file to EnergyPlus and runs the simulation. The output from EnergyPlus is then handled within the DesignBuilder software for post evaluation.

Open Studio

OpenStudio is a plugin to Sketch Up that utilises EnergyPlus to undertake energy simulations. It is also capable of using Radiance to perform daylight analysis.

Open studio was used in tutorial classes and assignments for early design modelling. Illuminance was used in the early design stage to analyse natural daylight and rate the radiance in the building. Window sizes and positions have been optimised based on the simulation results and luminance requirements. Aim was to provide the most amount of natural daylight in the rooms to ensure 300 – 500 lux throughout the living spaces. Windows are the main source for heat loss in cold climate and heat gains in hot climate conditions and therefore need to be planned and positioned wisely.

WUFI Pro

WUFI is a program used for evaluating building envelopes and changing moisture conditions. It is able to provide one-dimensional hygrothermal calculations on wall sections. WUFI was used to analyse the performance of the building assembly in both climatic conditions to ensure durability and prevent moisture issues. Due to the changing climatic conditions and resulting environmental influences on the construction, a hygro-thermal analysis was a major part whole developing the construction assemblies. The evaluation concentrated on heat and moisture flux throughout the construction variations. The constructions were analysed on the total water content and water content of the different layer over a period of 10 years. The water content itself has to be in an equilibrium to ensure durability of the construction. If the water content constantly rises over the time the building construction is most probably fails and could show moisture related problems like mold grow, rot and loss of thermal performance in the construction.

TRNSYS

TRNSYS is a comprehensive simulation tool for understanding the behaviour of transient systems and contains a large library of components . For the Desert Rose TRNSYS has been used in the design and optimisation of the HVAC system and its many components.

3.2.3.2 Housing Unit Modelling Assumptions Including Internal Gains, Occupancy Behaviour, Patterns, Ventilation and Comfortable Temperature

Thermal model simulation programs generate internal gains by using occupancy and usage schedules. These schedules are addressed to defined load values. Internal gains are generated by people and their activity, lighting and appliances. Time schedules can also be used to define the operation of HVAC system settings (heating cooling ventilation). Different standards describe different time schedules for varies scenarios.

Standards: NatHERS, ASHRAE160.

Scenarios: Residential to office buildings, libraries, pools etc.

The schedules for internal gains were based on the Australian Nationwide House Energy Rating Scheme (NatHERS) with minor modifications to suit the Solar Decathlon competition calendar.

Conditioned Area: Master bedroom, kitchen, dining room, living room, guest bedroom.

Un-Conditioned Area: Bathroom, entrance, water closet, plant room.

Infiltration Rate: 0.075 ACH

The competition occurs over ten days of measured contests. During these days' tasks are performed to simulate normal conditions within a home and include cooking, running of appliances, lighting etc. In addition to this the Desert Rose will be open for tours, the number of people touring the house at any one time has been estimated at 20 people. A table listing the dates to the day competition is provided in Table 3.15. The appliance schedule and loads can be found in Table 3.16 and Table 3.17 respectively.

Table 3.14 Competition Dates

Date	18/11	19/11	20/11	21/18	22/18	23/18	24/18	25/18	26/8	27/18
Day of competition	1	2	3	4	5	6	7	8	9	10

Table 3.15 Competition Appliance Schedule

Date	18/11	19/11	20/11	21/18	22/18	23/18	24/18	25/18	26/8	27/18
Appliances	1	2	3	4	5	6	7	8	9	10
Clothes Washing	x	x	x	x				x	x	x
Clothes Dryer	x	x	x	x				x	x	x
Dishwasher		x	x	x				x	x	x
Oven Task	x		x	x				x	x	x
Stove Top Task	x	x	x	x				x	x	x
TV	x	x	x	x	x	x	x	x	x	x
Computer Monitor	x	x	x	x	x	x	x	x	x	x
Dinner Party (Oven)		x			x		x			

Table 3.16 Appliance Load Schedules

Appliance Load Schedule						
Appliance	**Model No.**	**Electrical Load (W)**	**Time Running (h)**	**Time of Operation**	**Energy (Wh)**	**Energy Load (W/m²)**
Kitchen				**Area**	**12**	**m²**
Dishwasher	DWA6315X1	1800	0.37	1200-2000	666	150.00
Oven	WVES613S-L	2300	1	1200-2000	2300	191.67
Cooking	KM 6363-1	2300	1.33	1200-2000	51.111	191.67
Fridge/Freezer	NRK6193UX-AU	120	24	constant	685	10.00
Dinner Party - Additional Loads						
Oven	WVES613S-L	2300	1.5	1200-1300, 1800-1830	3450	191.67
Cooking	KM 6363-1	2300	1.5	1200-1300, 1800-1830	3450	191.67
Note: Assumed food preparation begins at 12:00						
Bathroom				**Area**	**9**	**m²**
Clothes Washer	L99699HWD	2200	0.48090909	1200-2000	1058	244.44
Clothes Dryer	L99699HWD	2200	0.94	1200-2000	2077	244.44
Hot Water Draws			0.6	800-900, 1200-2000		0.00
Note: Hot water system is not in model as it is located outside of building envelope						
Living Room				**Area**	**13**	**m²**
TV	Hisense 39P4	45	6	0900-1200, 1500-1800	270	3.46
Guest Bedroom				**Area**	**21**	**m²**
Computer Moniter	Dell E2219HN	120	10	0900-1200, 1500-1800	1200	5.71

Table 3.17 Competition Occupancy Schedule

	Day of Competition									
	1	2	3	4	5	6	7	8	9	10
Time	Number of Occupants									
0000-0800	2	2	2	2	2	2	2	2	2	2
0800-0900	20	20	20	20	20	20	20	20	20	20
0900-1000	20	20	20	20	20	20	20	20	20	20
1000-1100	20	20	20	20	20	20	20	20	20	20
1100-1200	2	2	2	2	20	20	20	2	2	2
1200-1300	2	2	2	2	20	20	20	2	2	2
1300-1400	2	2	2	2	20	20	20	2	2	2
1400-1500	2	2	2	2	20	20	20	2	2	2
1500-1600	2	2	2	2	20	20	20	2	2	2
1600-1700	2	2	2	2	20	20	20	2	2	2
1700-1800	2	2	2	2	20	20	20	2	2	2
1800-1900	2	8	2	2	2	2	2	2	2	2
1900-2000	2	8	2	2	8	2	8	2	2	2
2000-2100					8		8			
2100-2400										

During the competition it is assumed that 20 people will be in the house during touring times, 8 during the dinner parties and 2 people at all other times that the house is open. It is assumed that each person has a load of 100 watts. The occupancy schedule and occupancy loads are displayed in Table 3.18 and Table 3.19 respectively.

The Bathroom lights will be on during tour times and the Kitchen and Living Room lights will be on during competition measurement times to ensure 300 lux is reached. During the dinner parties it is assumed that the Kitchen, Dining Room lights will be on and all other lights in the house are on for 15% of the time. The lighting schedule and loads can be found in Table 3.20 and Table 3.21 respectively.

Table 3.18 Competition Occupancy Loads

	Day of Competition									
	1	2	3	4	5	6	7	8	9	10
Time	Energy Load (W/m^2)									
0000-0800										
0800-0900	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
0900-1000	22.22	22.22	22.22	22.22	22.22	22.22	22.22	22.22	22.22	22.22
1000-1100	22.22	22.22	22.22	22.22	22.22	22.22	22.22	22.22	22.22	22.22
1100-1200	22.22	22.22	22.22	22.22	22.22	22.22	22.22	22.22	22.22	22.22
1200-1300	2.22	2.22	2.22	2.22	22.22	22.22	22.22	2.22	2.22	2.22
1300-1400	2.22	2.22	2.22	2.22	22.22	22.22	22.22	2.22	2.22	2.22
1400-1500	2.22	2.22	2.22	2.22	22.22	22.22	22.22	2.22	2.22	2.22
1500-1600	2.22	2.22	2.22	2.22	22.22	22.22	22.22	2.22	2.22	2.22
1600-1700	2.22	2.22	2.22	2.22	22.22	22.22	22.22	2.22	2.22	2.22
1700-1800	2.22	2.22	2.22	2.22	22.22	22.22	22.22	2.22	2.22	2.22
1800-1900	2.22	8.89	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
1900-2000	2.22	8.89	2.22	2.22	8.89	2.22	8.89	2.22	2.22	2.22
2000-2100					8.89		8.89			
2100-2400										

Table 3.19 Competition Lighting Schedule

	Day of Competition									
	1	2	3	4	5	6	7	8	9	10
Time	**Rooms with Lighting**									
0000-0800										
0800-0900										
0900-1000	BR	BR	BR	BR	BR	BR	BR	BR	BR	BR
1000-1100	BR	BR	BR	BR	BR	BR	BR	BR	BR	BR
1100-1200	BR	BR	BR	BR	BR	BR	BR	BR	BR	BR
1200-1300	K,L	K,L	K,L	K,L	BR	BR	BR	K,L	K,L	K,L
1300-1400	K,L	K,L	K,L	K,L	BR	BR	BR	K,L	K,L	K,L
1400-1500	K,L	K,L	K,L	K,L	BR	BR	BR	K,L	K,L	K,L
1500-1600	K,L	K,L	K,L	K,L	BR	BR	BR	K,L	K,L	K,L
1600-1700	K,L	K,L	K,L	K,L	BR	BR	BR	K,L	K,L	K,L
1700-1800	K,L	K,L	K,L	K,L	BR	BR	BR	K,L	K,L	K,L
1800-1900	K,L	K,DR, (All 15%)	K,L	K,L	K,DR, (All 15%)	K,DR, (All 15%)	K,DR, (All 15%)	K,L	K,L	K,L
1900-2000	K,L	K,DR, (All 15%)	K,L	K,L	K,DR, (All 15%)	K,DR, (All 15%)	K,DR, (All 15%)	K,L	K,L	K,L
2000-2100										
2100-2400										

Note: Kitchen = K, Dining Room = DR, Living Room = LR, Master Bedroom = MB, Guest Bedroom = GB, Entrance = E, Bathroom = BR, WC

Table 3.20 Competition Lighting Loads

	Quantity	Electrical Load (W)	Total watt	Energy Load (W/m²)
Kitchen			Area	12
Downlight	2	9	18	1.50
Pendant	1	25	25	2.08
			Total	**3.58**
Dining Room			Area	21
Downlight	6	9	54	2.57
Pendant	1	12	12	0.57
			Total	**3.14**
Living Room			Area	13
Downlight	4	9	36	**2.77**
Master Bedroom			Area	16
Downlight	2	9		1.13
Bed lamp (not in calc)	2	9		0.00
			Total	**1.13**
Guest Bedroom			Area	13
Downlight	2	9	18	**1.38**
Entrance			Area	7
Downlight	1	9	9	**1.29**
Bathroom			Area	9
Downlight	2	9	18	2.00
Pixalux Panel	1	17	17	1.89
			Total	**3.89**
WC			Area	3
Downlight	1	9	9	3.00
Pixalux Panel	1	17	17	5.67
			Total	**8.67**

To meet the competition comfort conditions the boundaries outlined in Table 3.23 were applied.

Table 3.21 Competition Mechanical Ventilation Schedule

	Day of Competition									
	1	2	3	4	5	6	7	8	9	10
Time	**Mechanical Ventilation**									
0000-0800										
0800-0900	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
0900-1000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1000-1100	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1100-1200	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1200-1300	10%	10%	10%	10%	100%	100%	100%	10%	10%	10%
1300-1400					100%	100%	100%			
1400-1500					100%	100%	100%			
1500-1600					100%	100%	100%			
1600-1700					100%	100%	100%			
1700-1800		10%			100%	100%	100%			
1800-1900		50%			10%		10%			
1900-2000		50%			50%		50%			
2000-2100		10%			50%		50%			
2100-2400					10%		10%			

Construction Settings and Assumptions

Infiltration: The house is targeted to research an "Aspirational Passivhaus" (YourHome 2017) which is a Passive house standard requirement. Accordingly, the air tightness is ACH50 of 0.6 air change rate per hour, which is 0.03 air change rate per hour under natural ventilation condition. Thus, the infiltration rate for all the air condition zones (i.e. Kitchen and dining room, living room, bedroom and office) was set as 0.03. For the roof space, the infiltration rate was set as 0.6, considering a ventilated roof space design.

The constructions are set as developed above. The R-values of the constructions vary slightly from the above described values due to use of a different software (above Wufi). The constructions are addressed to the zones in the house. The trussed roof space is set as a separate unconditioned room. The room facing material is set as plasterboard

Table 3.22 Competition Comfort Boundaries

	Min	Max
Temperature	23°C	25°C
Relative Humidity	35%	60%
CO_2	-	8:00pm

Table 3.23 Transys Constructive Building Assumptions

Constructive Building Assumptions		
1	**Infiltration rate**	
	Natural infiltration, introducing of heat gains/ losses by air leakage throughout the construction components, Evidence: Blower door test , n50 value	0.03 1/h
2	**Thermal bridges**	
	Heat gain/loss through façade components, Evidence: Psi value calculation by using simulation programs like: therm, fluid	non

The Desert Rose HVAC system is illustrated below in Figure 5.28. The HVAC system consists of an air-to-source heat pump, a heat pump dehumidifier (i.e. Desica), an ERV, two fan coils, four radiant panels, a main pump (i.e. pump 2), a PCM thermal energy storage unit, and corresponding dampers and valves. It can be divided into two sub-systems: air sub-system and water sub-system. The air sub-system is directly coupled with the indoor environment, which is used to maintain the required indoor air quality and thermal comfort; while the water sub-system is mainly used to supply chilled or hot water for the air sub-system. The two sub-system are coupled through fan coils. The primary HVAC equipment is listed in Table 5.25, for more information please refer to the Project Drawings.

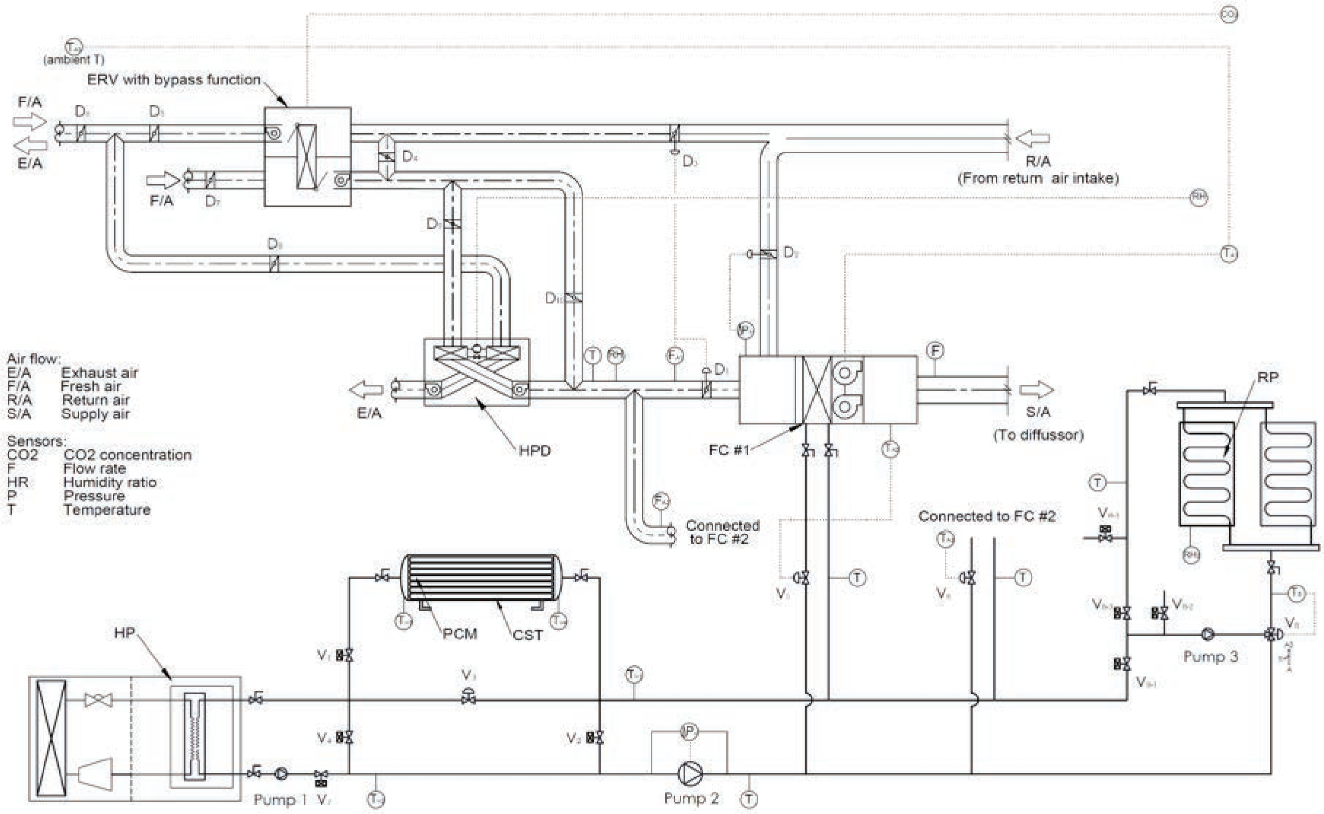


Figure 3.28 - Schematic of the HVAC System Used in the House.

Table 3.24 HVAC Equipment

Symbol	Item	Description	Specification	Quantity
CST	Cold storage unit	TubeICE PCM tank	D825mmx1200mm	2
ERV	Enthalpy recovery ventilator	Daikin VAM-350GJVE	350m3/h	1
CFC	Chilled water fan coil	Daikin FWC03C Daikin FWC11C	2.9kW (cooling) 11.14kW (cooling)	1 1
HPD	Heat pump dehumidifier	Daikin Desica HDMP25D	250m3/h	1
HP	Air to water heat pump	Daikin ERLQ-008CV3 Daikin EhBX08C3V	7.4kW	1 1
PCM	Phase change material	PCM E8 TubeICE	D50mmx1000mm	338
RP	Radiant Panel	B!klimax radiant panel	1220mmx600mm	4
EVC	UVC emitter	Steril-Aire UVC emitter	24" and 42"	2

To investigate the passive performance of the house without HVAC system, the Dessert Rose was free running, this is only natural ventilation was available (when the outdoor temperature was between 20°C to 26°C). The indoor air temperature and relative humidity variation of the main building zones, i.e. bedrooms, kitchen-and living, were compared to the indoor thermal comfort requirement of SDME2018. The temperature variation for each zone is shown in Figure 5.30 through to Figure 5.31. As a summary, the annual temperature distribution and the relative humidity distribution for each zone is shown in Figure 5.36 and Figure 5.37 respectively.

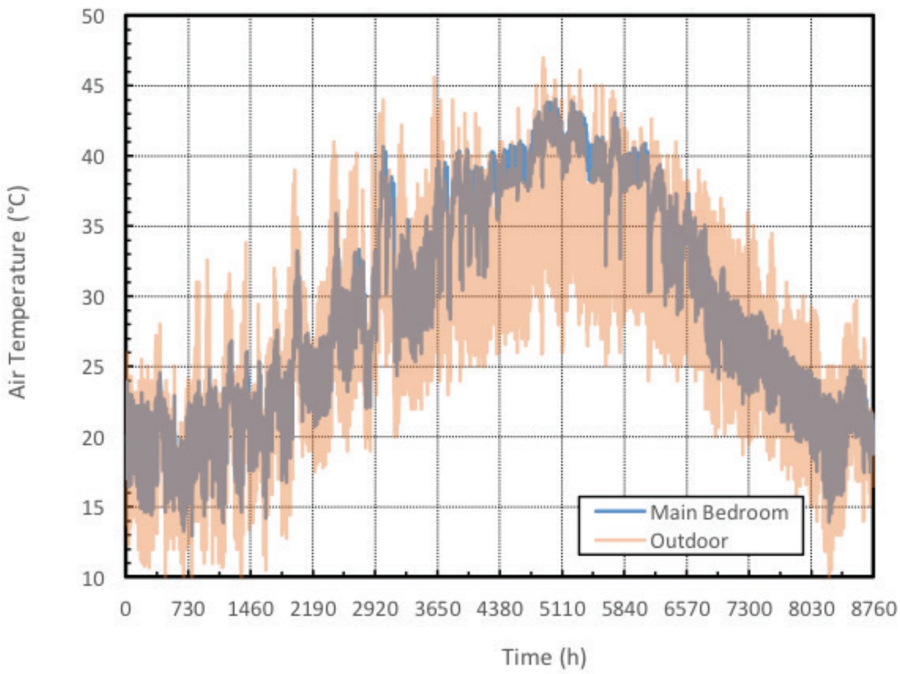


Figure 3.29 – Passive Annual Outdoor and Indoor Air Temperature for Main Bedroom

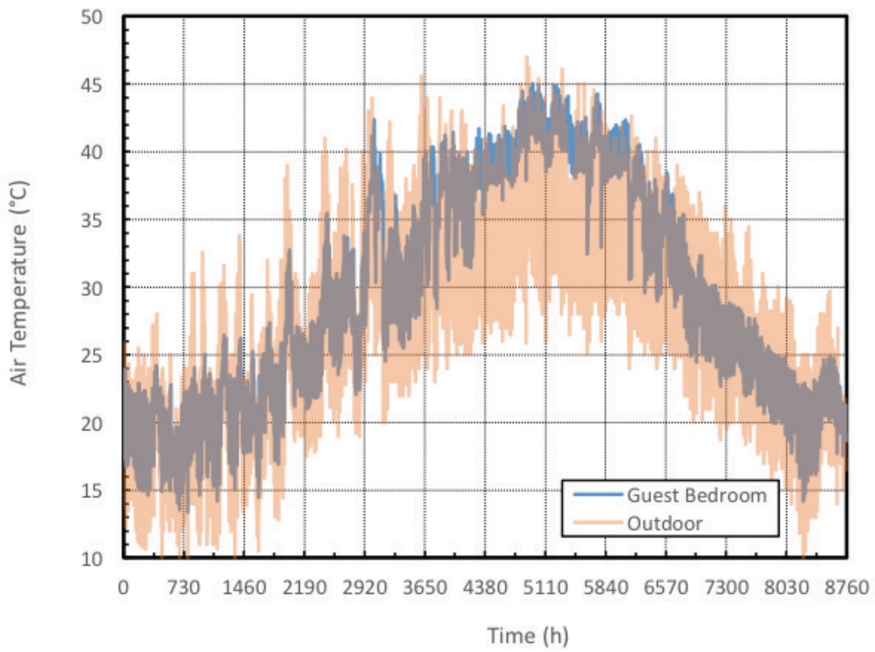


Figure 3.30 - Passive Annual Outdoor and Indoor Air Temperature for Guest Bedroom

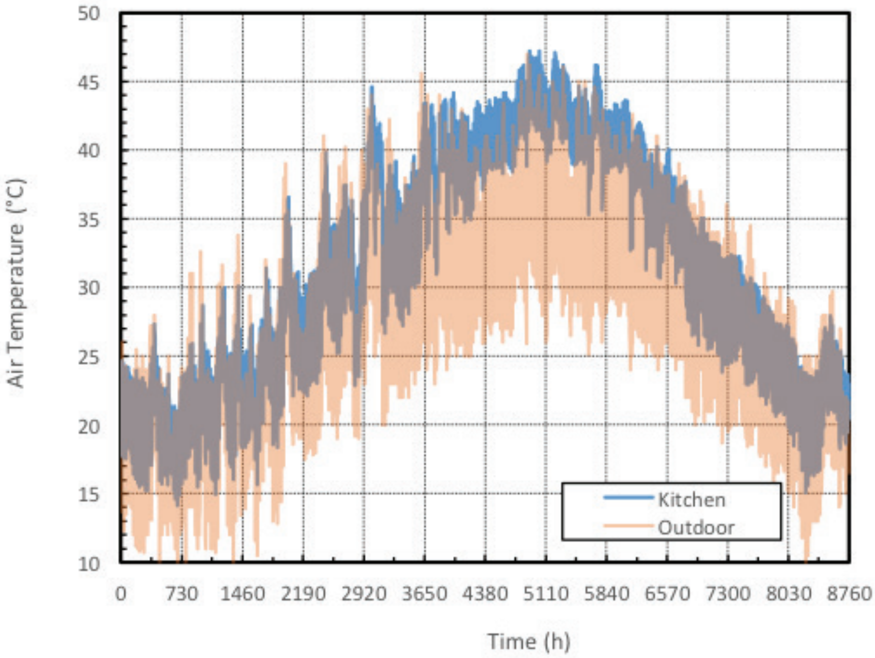


Figure 3.31- Passive Annual Outdoor and Indoor Air Temperature for Kitchen

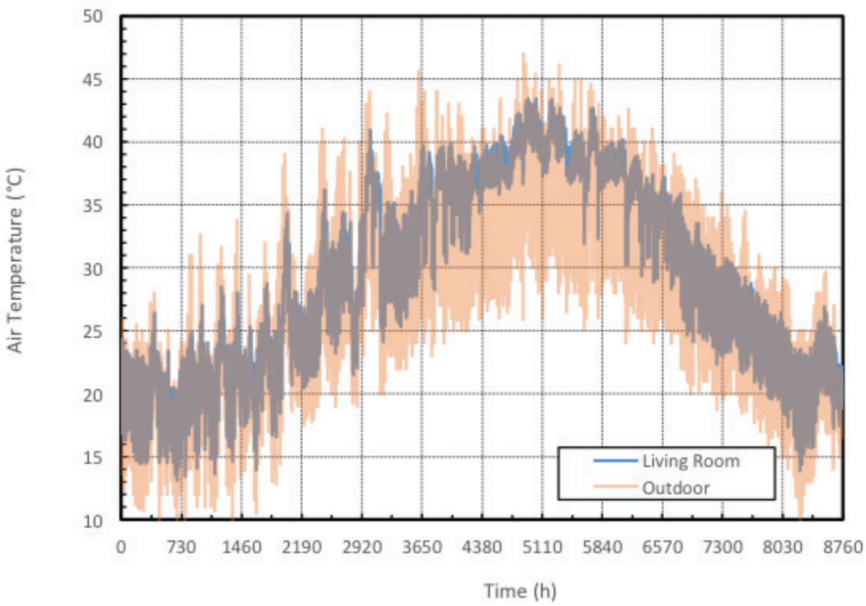


Figure 3.32- Passive Annual Outdoor and Indoor Air Temperature for Living Room

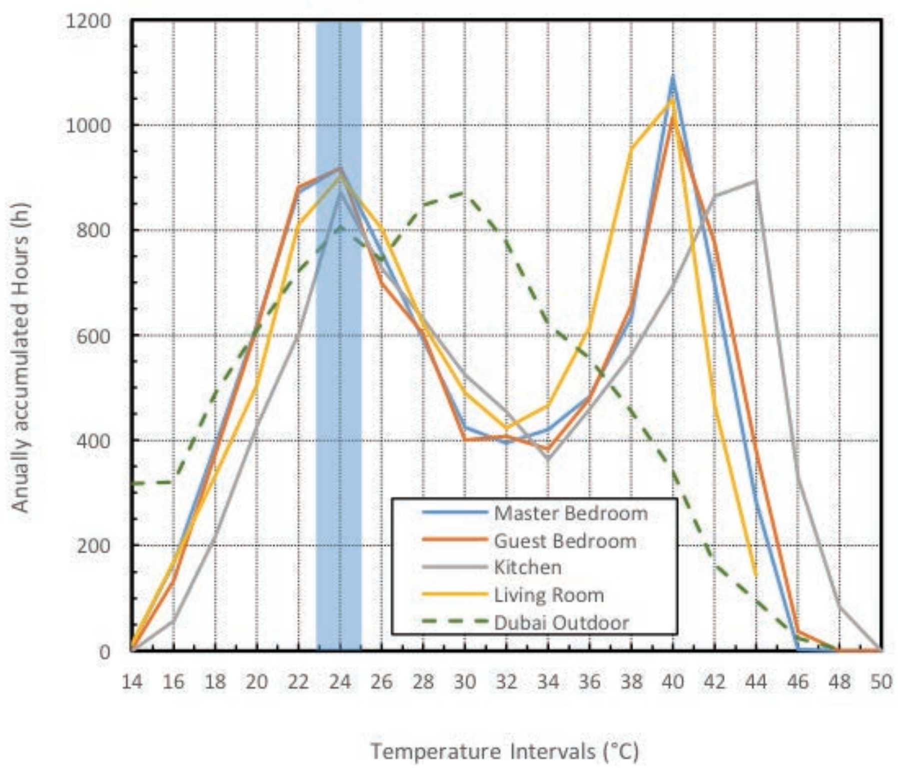


Figure 3.33 - Passive Annual Temperature Distribution of Four Major Zones and the Outdoor

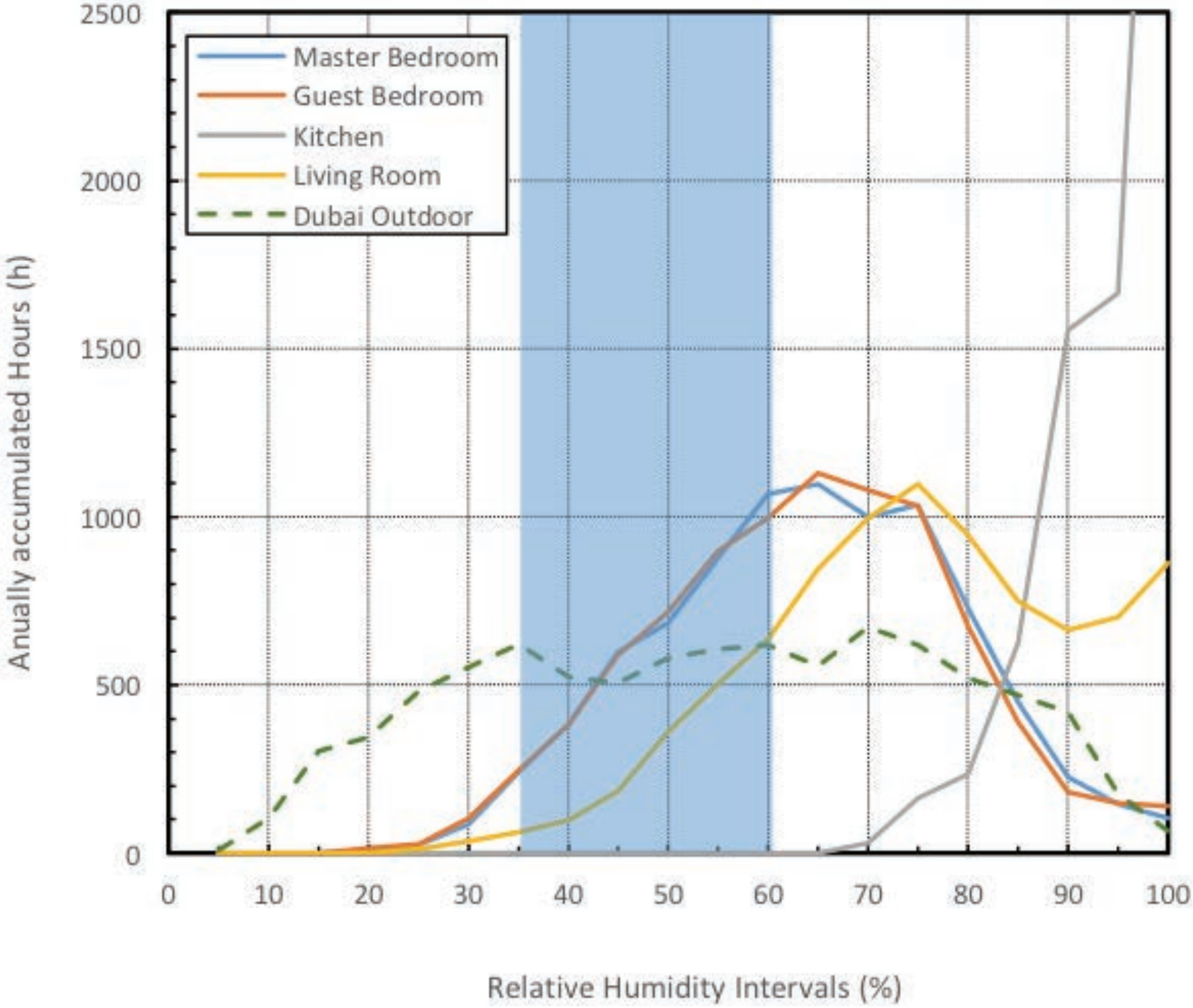


Figure 3.34 – Passive Annual Humidity Distribution for Four Major Zones and the Outdoor

It is clear that the indoor air temperatures of all zones are typically higher than the indoor thermal comfort temperature range (i.e. 23°C to 25°C) for most of the year. The exception is December to March, where some days the indoor air temperature stays within the thermal comfort limits. This is demonstrated in the annual temperature distribution Figure 3.33 where all zones showed two main peak corresponding to winter and summer time. These air temperatures distributions indicated a much higher cooling demand over heating demand to keep the temperature set-points within the comfort temperature range. As expected, the indoor temperatures have much less swing than the outdoor temperatures, the highest temperatures are shown in the Kitchen due to the house internal loads. The relative humidity distribution in all zones tends to be higher than the outdoor relative humidity in all zones. The Kitchen presents relative humidities above the requirement of SDME2018 threshold all year around predominantly due to the latent heat of the space.

The maximum and minimum indoor air temperatures as well as relative humidity for individual rooms are summarized in Table 3.26. All rooms experienced extreme high indoor air temperature during the summer time, with maximum temperatures as high as o 41.05°C to 47.22°C. The indoor minimum air temperature was found to be from 12.96°C to 14.15°C. In terms of relative humidity, the maximum value reached 100% in all zones while the minimum relative humidity oscillates between 18.93% to 66.01%. There is one zone (kitchen) where no time (0%) in the whole year where the relative humidity is within the relative humidity comfort

Table 3.25 - Air Temperature and Relative Humidity Boundaries for the Annual Passive Analysis

Item		Outdoor	Guest Bedroom	Master Bedroom	Kitchen and Dining Room	Living Room
Temperature (°C)	Maximum	47	44.99	44.03	47.22	43.43
	Minimum	5	13.41	12.96	14.15	13.11
Relative humidity (%)	Maximum	100	100	100	100	100
	Minimum	4	19.03	18.98	66.01	19.87
% of time within temperature and humidity boundaries			2	2.2	0	2.9

bands (35% to 60%). Overall, only the living room and the guest bedroom had some time (2% and 2.9%, respectively) within the temperature and relative humidity competition requirements.

This higher relative humidity all year around in all spaces is due to the extremely low infiltration rate of the Desert Rose, highlighting the need for mechanical ventilation.

3.2.4.2 Active Analysis and Housing Unit Energy Loads

The active analysis consisted in undertaking annual simulations of the Desert Rose in Dubai varying five key parameters to understand their influence on the annual thermal energy consumption. The following parameters were investigated:

- Infiltration
- House envelope insulation level (floor, ceiling, walls and roof)
- Heat conduction and Solar heat gain coefficient (SHGC) and for glazing
- Second skin wall
- Shading devices (internal blinds and microshade for two windows)

It should be noted that only one parameter at the time was changed while keeping the rest of the parameters at their base case values.

Infiltration

The air tightness and infiltration rate are important properties of the building envelope due to their high impact on the thermal performance of a building. An analysis of different infiltration levels was investigated by modifying the infiltration rate at natural pressure of a passive house standard to an Australian typical infiltration rate for new dwellings (Ambrose and Syme, 2015). Hence, air change rates between 0.03 to 0.75 ACH at natural pressure were simulated to determine the influence of air tightness on the annual energy demand of the Desert Rose house. It is seen that the effect on the energy performance of the Desert Rose from a typical Australian construction infiltration rate to a passive house standards is extremely significant. The Desert Rose with the best practice infiltration rate specified at 1.5ACH (YourHome 2013) saved as much as 27% of the energy compared to the house with the typical Australian dwelling infiltration rate. Therefore, the Desert Rose team decided to achieve 0.075 ACH.

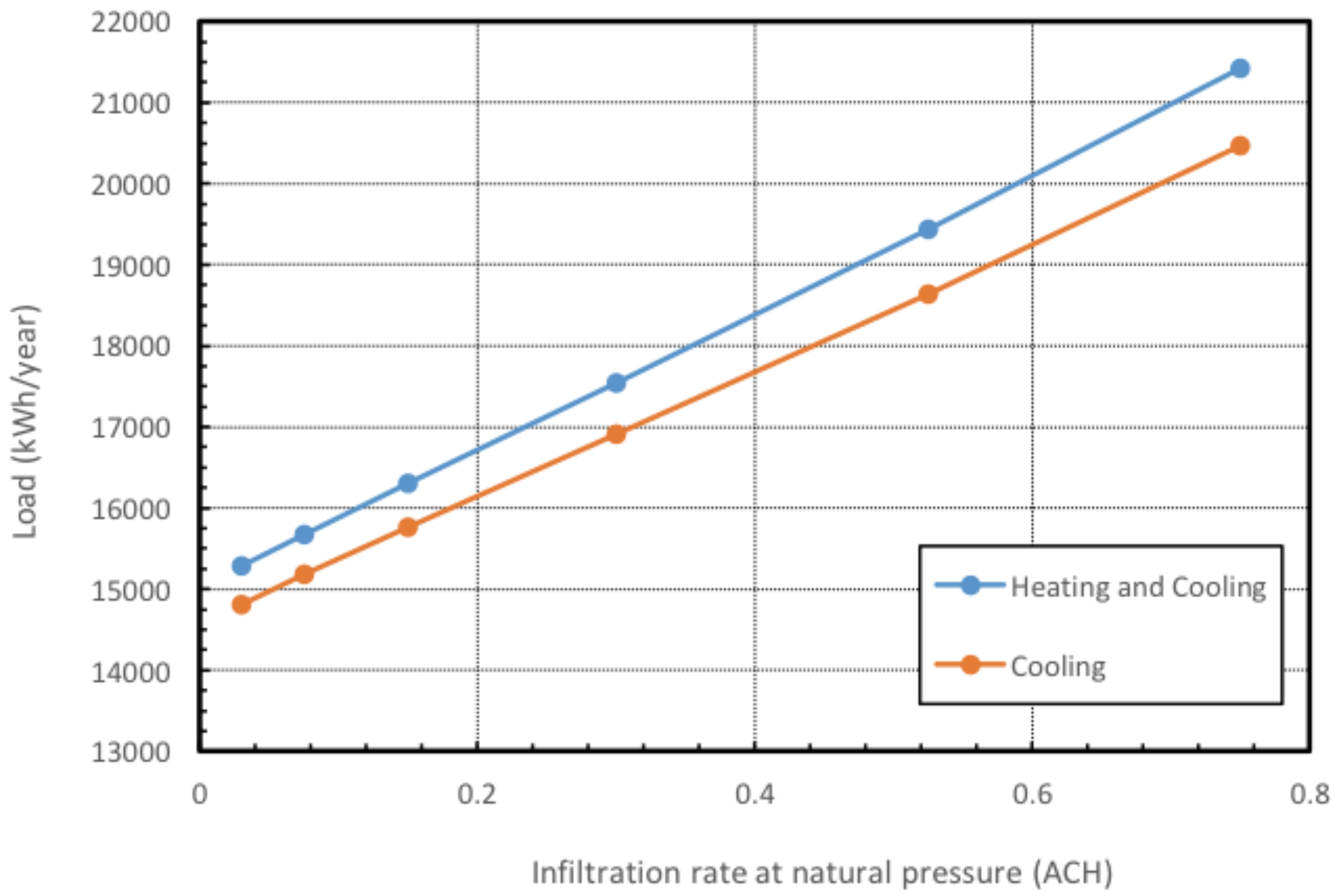


Figure 3.35 - Annual H&C Energy Consumption Vs. Infiltration Rate

To determine the impact of the insulation levels of the house envelope on the energy performance, the ceiling, floor, external wall and roof R-value was modified (Figure 5.36).

It is observed that the effect of varying the external walls, floor and roof insulation levels is very similar as the R-value increases. This implies that there is a pronounced increase in the energy performance (i.e. steep decrease in the cooling and heating demand) for an increase of the insulation levels when the R-value is small (i.e. when there is no to very little insulation). As the R-value increases, the effect of varying the insulation levels on the overall energy performance of the house is diminished. It is seen that the effect of the envelope insulation levels beyond R-6 on the Desert Rose energy performance is limited. This is why, the different components of the envelope (external walls, floor and roof) will aim at an R-value from 5 m2k/W to 6 m2k/W. The implementation of ceiling insulation showed a decrease in the annual energy consumption of around 5.5% (945kWh per year) for roof R-values of 5.6. Therefore, it was decided to include ceiling insulation in the Desert Rose.

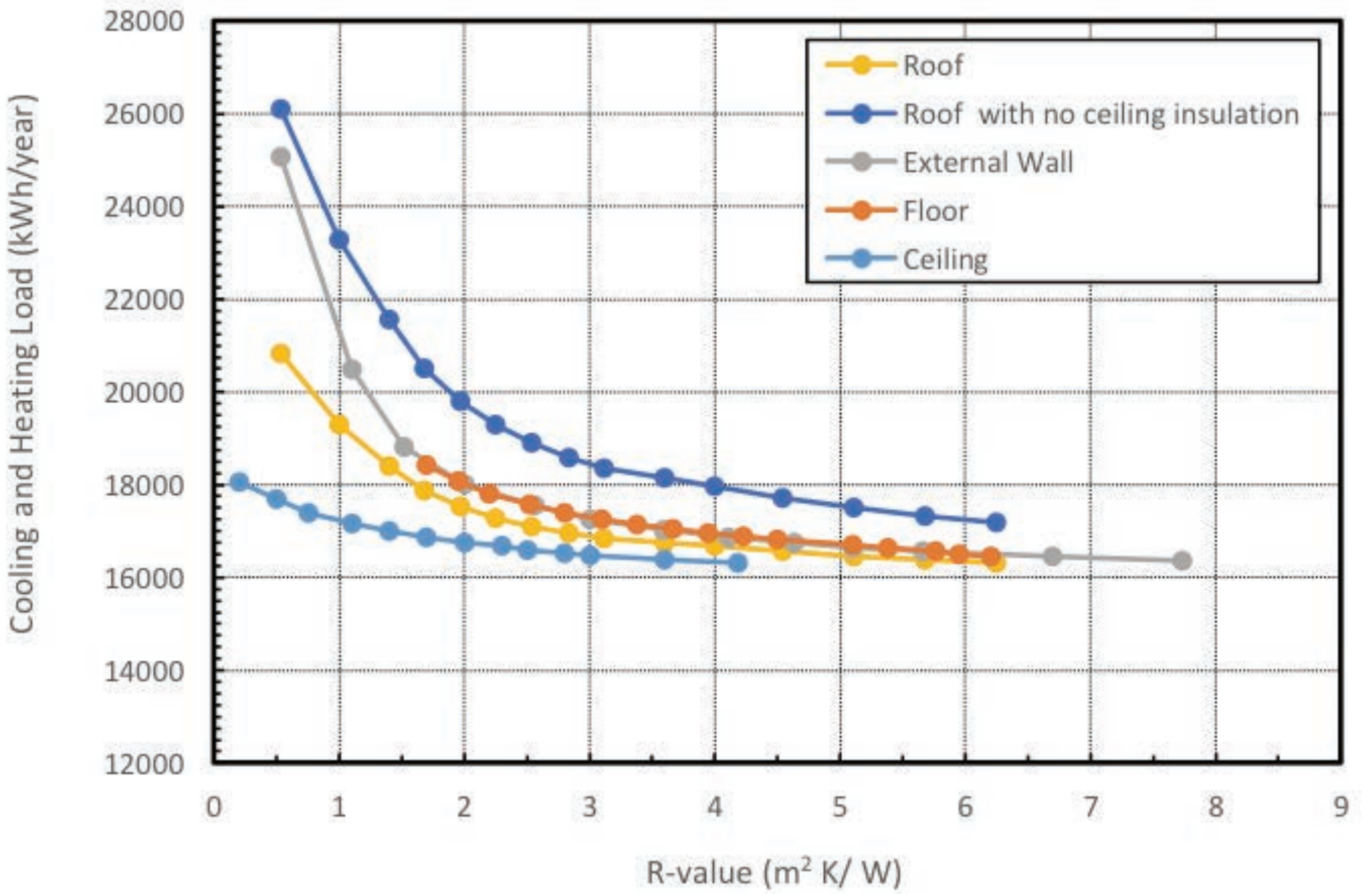


Figure 3.36 - Annual Heating and Cooling Energy Demand Vs R-Value for Different Envelope Parameters

Heat transfer through external glazing is a major portion of the heat gain to the house in summer (and a major cause of heat loss in winter). Figure 3.37 illustrates the relationship between different window types (i.e. clear single glazing, U-5.77, low-e single glazing, U-3.77, clear double glazing, U-2.77, clear triple glazing, U-1.4 and low-e triple glazing, U-0.77) and the house's annual cooling and heating thermal energy. In this analysis, it has not been possible to decouple the effect of the Solar Heat Gain Coefficient (SHGC) from the U-value. This is because commercially available windows with different U-values and SHGC were tested. It should be noted that the all windows except the higher level windows had an internal shading device (blinds) with an equivalent R-value of 0.4 m2K/W when the glass incident solar radiation was higher than 120 W/m2.

It is seen that there is a pronounced improvement in the energy performance of the Desert Rose employing a low-e single glazing compared to clear single glazing, translated into 5.8% energy savings. Typically, the low-e glass had a large effect (higher slope) than switching from single to double glazed or from double to triple glazed. Nevertheless, due to strategic requirements it was decided to employ a clear triple glazing, which reduced the energy load by 13.5% compared to clear single glazing windows.

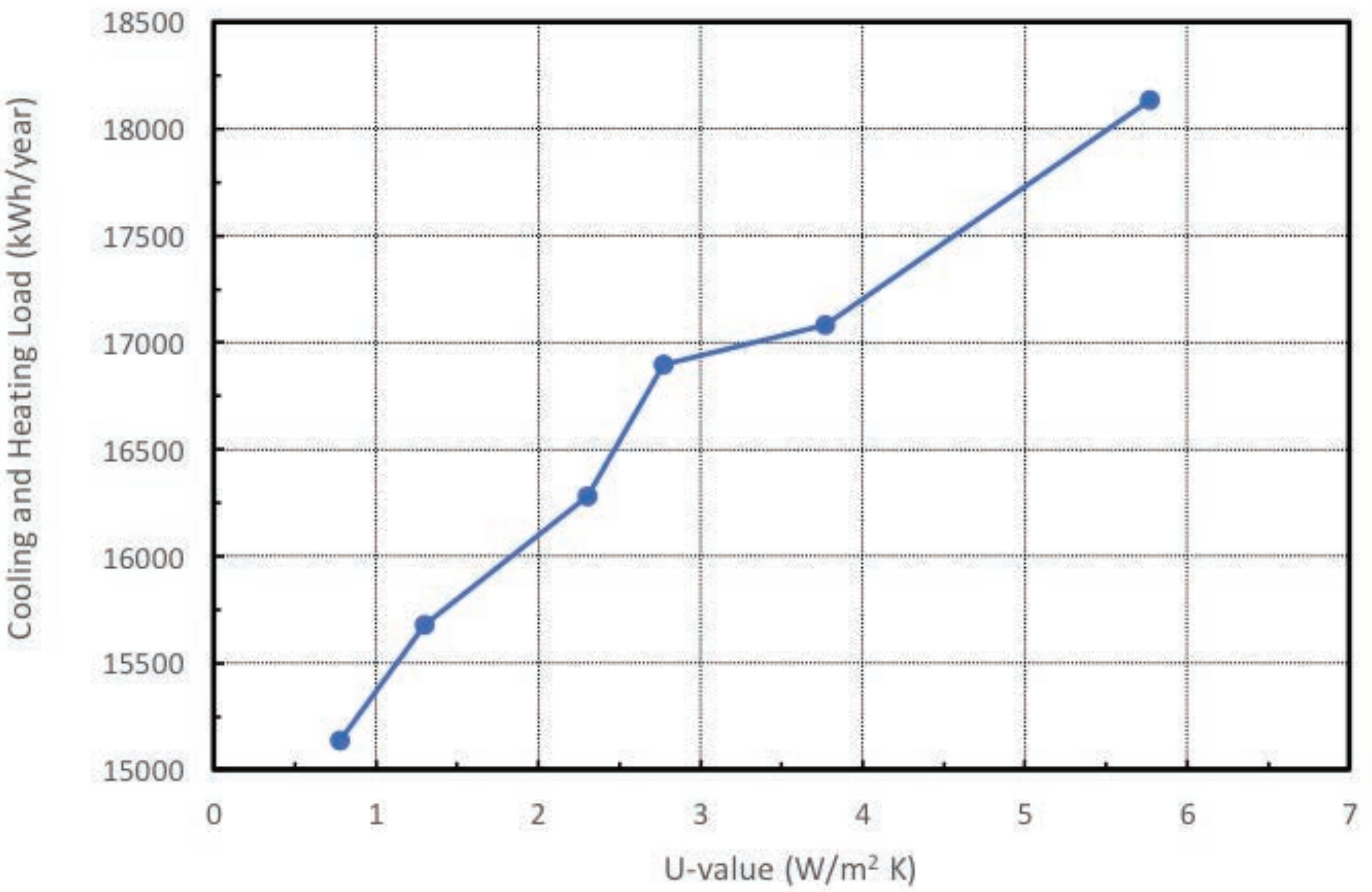


Figure 3.37 - Annual Heating and Cooling Energy Load Versus Windows U-Value

The effect of solar gains through the walls can increase the cooling load, and thereby the impact on the annual cooling load of an external wall shading device via a second skin wall compared to not having a second skin wall has been investigated.

Due to the effect of the second skin wall being expected to vary depending on the R-value of the external wall, the cooling loads of the Desert Rose with a second skin wall at different external wall R-value compared to the house without the second skin wall for these R-values of the external wall is presented (Figure 3.38). It is seen that the increase of the external wall R-value leads to minimising the effect of the second skin wall. In other words, at lower external walls R-value the cooling loads savings due to the second skin wall could be as high as 12.4% while at high R-values both cooling loads with and without the second skin load tended to converge. Looking at it from the opposite perspective if we employ the second skin wall with an external wall value of 2.5, to reach the same cooling load without the second skin wall the R value of the external wall would have to be approximately 4.

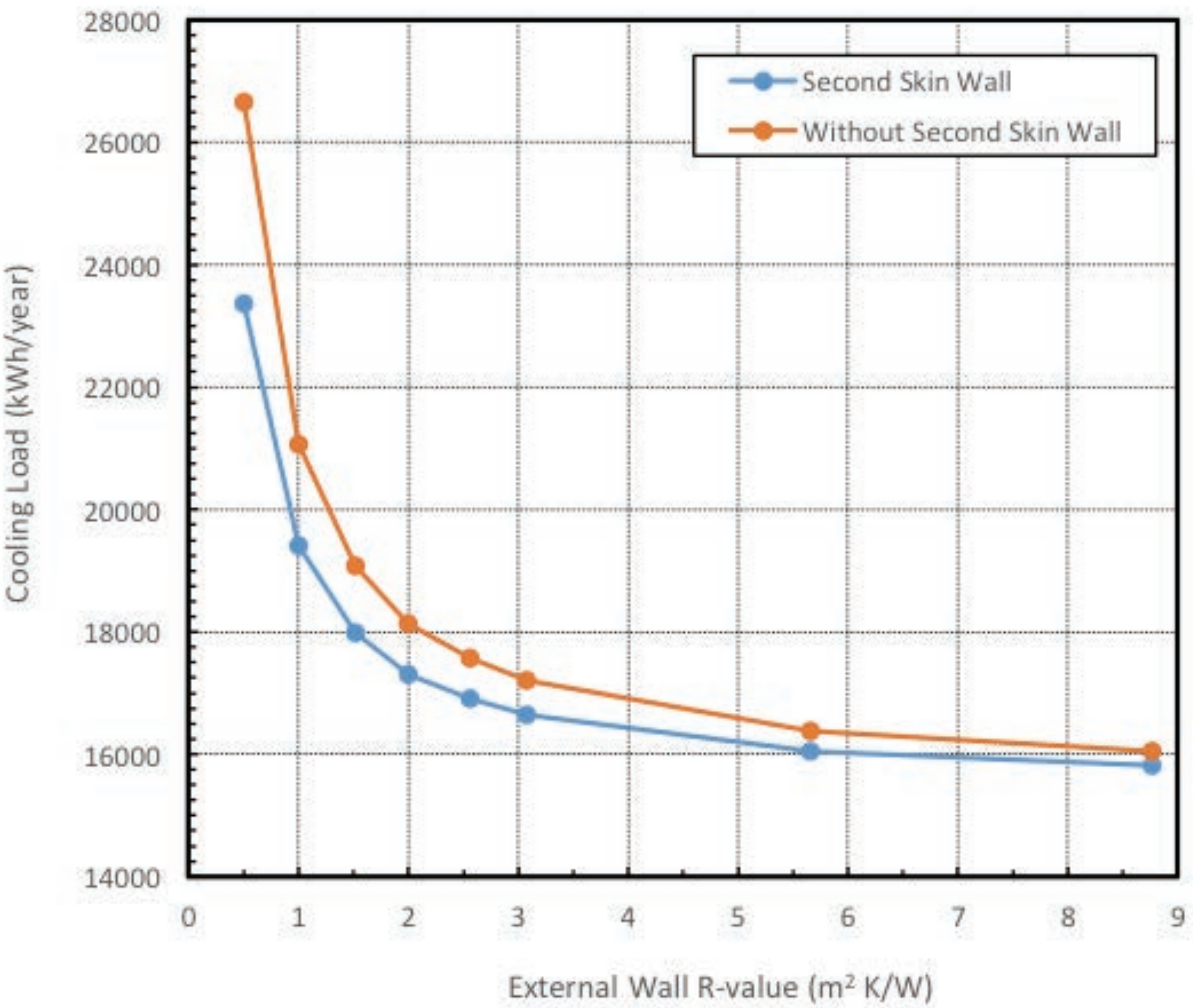


Figure 3.38 - Annual Cooling Energy Load Versus External Wall R-Value

The solar gains through the external window can contribute to a high cooling load. Hence, internal blinds for all windows except for the high-level windows were tested. Two windows with microshade were included in the southern court-yard glazing (i.e guest bedroom window and dinning glazing door). The microshade was modelled as an external blind with a fixed angle for the slat angle fixed at 16 degrees.

The simulation results compared the monthly cooling load as well as the solar heat gains via the windows for three scenarios: a) Desert Rose with no blinds nor microshade, b) blinds included but no microshade and c) blinds and microshade both implemented.

Results showed annual cooling energy savings of 1346kWh (8.7% cooling reduction) with the shading (both blinds and microshade) compared to the windows without any shading. These cooling savings were. 90% due to the microshade while the blinds accounted for 10%. The solar heat gain through the windows is dramatically decreased with both blinds and microshade. The decrease of the solar heat gain through the windows with a shading device compared to not using any shading corresponded to 11% for the blinds only and 48.3% for both blinds and microshade. This is why the Desert Rose was fitted with internal blinds as well as microshade for the dining and guest bedroom. A monthly breakdown is plotted in Figure 3.39.

The results from the parametric studies are shown below in Table 3.26 and define the base model envelope configurations that will be used for further studies (i.e. competition period energy analysis).

Analysis of the House Performance with HVAC Equipment

An active house performance analysis was performed to determine the indoor heating, ventilation and air conditioning demands, so as to consider and size the necessary HVAC equipment to achieve acceptable indoor thermal comfort and indoor air quality. Thus, based on the active house performance analysis with HVAC equipment, the consideration and sizing of the above-mentioned HVAC system components are detailed as follows:

<u>Air-to-water heat pump</u>

Function: used to generate chilled or hot water for fan coils and radiant panels

Consideration:

• System coupling: easier coupling with a water-based PCM TES unit which tends to be more efficient than an air-based one; improve the system operation flexibility by coupling with multiple terminals (i.e. Fan coils and radiant panels)

• Energy efficiency: reduce the heat loss and pressure loss in air distribution system

• Indoor thermal comfort: capacity safety factors (based on total cooling load) over 1.15 to cover the unexpected high cooling or heating load in case when only the air-to-water heat pump was running;

Sizing: based on maximal annual heating and cooling loads;

Figure 3.28 illustrates the annual heating and cooling loads of the building, in which both the sensible and latent loads are shown. The maximal annual cooling and heating loads of the house were 4.0 kW and 2.44 kW, respectively. Accordingly, the air-to-water heat pump ERLQ008CV3 (outdoor unit) - EHBX083V (indoor HydroBox) with a maximal cooling capacity of 4.67 kW under ambient temperature of 41.8oC and leaving chilled water temperature of 13oC was selected. Considering the using of fan coils to cover the sensible cooling load while relying on Desica to cover the latent cooling load, the safety factor under design condition (ambient temperature of 41.8oC and leaving chilled water temperature of 13oC) can reach 1.91 (based on sensible cooling load). It is therefore able to cool down or heat up the house quickly even when only the air-to-water heat pump is used. Note: the heat pump used in the Desert Rose was upgraded to a single outdoor unit as a conservative measure as specified above in the HVAC equipment.

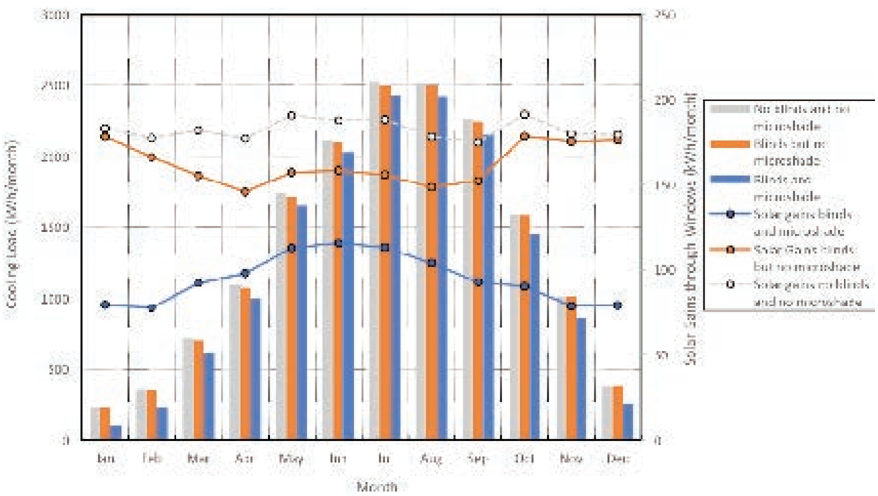


Figure 3.39 - Monthly Cooling Load for Windows Fitted with Blinds and Microshade, Windows only with Microshade and Windows Without Any Shading (No Blinds Neither Microshade).

Table 3.26- Base Model Envelope Properties

Parameter	Value
Infiltration Rate	0.075 ACH
Roof R-value	5.1 m²K/W
Ceiling R-value	2.5 m²K/W
Floor R-value	5.67 m²K/W
External wall R-value	5.78 m²K/W
Window U-value	1.4 W/m²

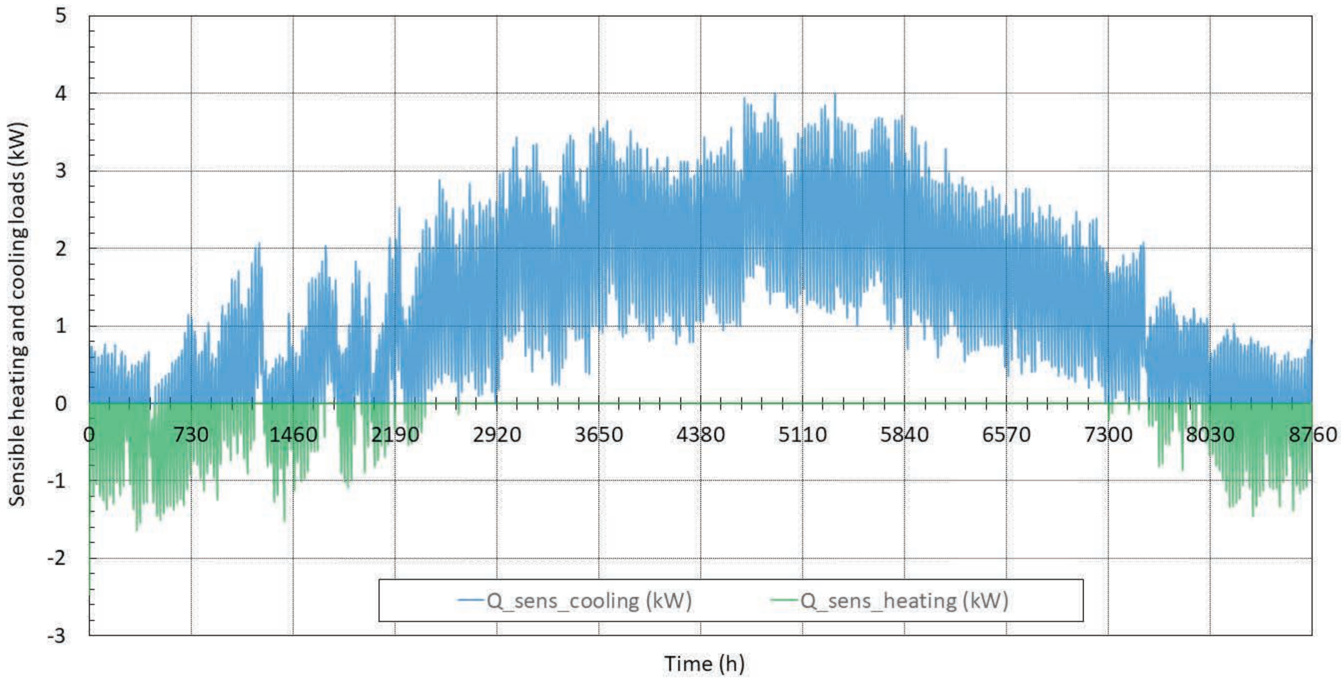


Figure 3.40 - Annual Building Sensible Heating and Cooling Loads

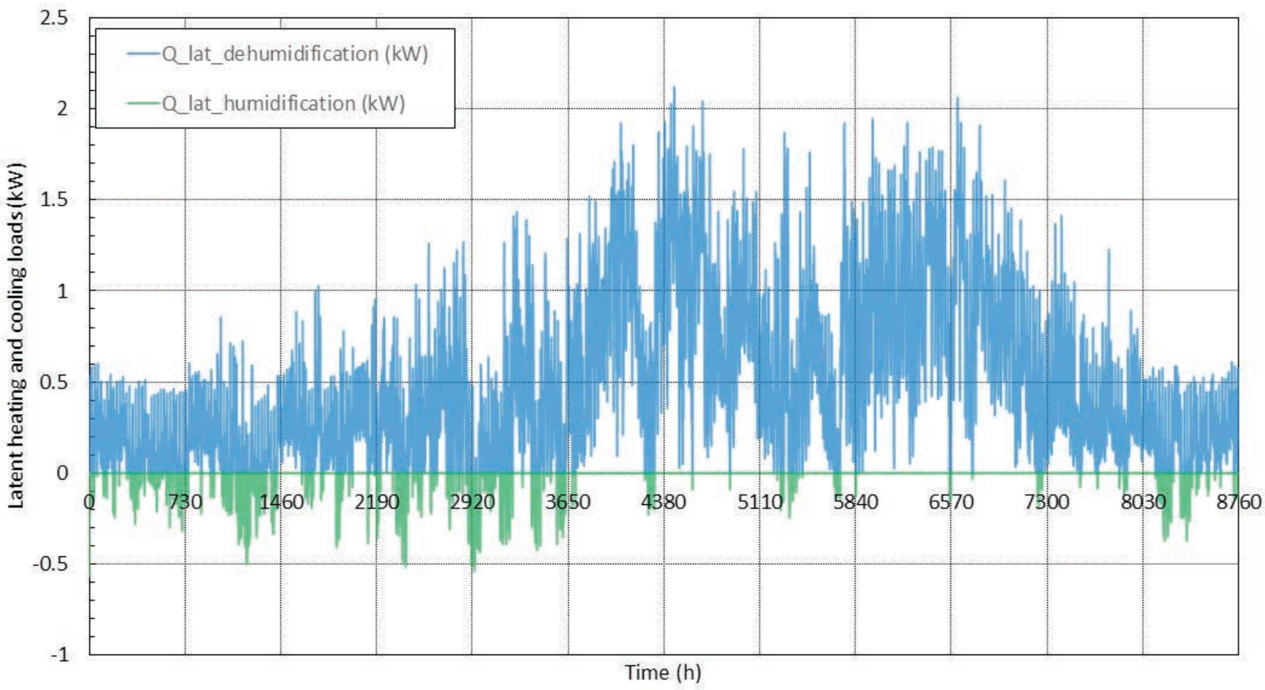


Figure 3.41 - Annual Building Sensible Heating and Cooling Loads

Desica

Function: used to dehumidify the indoor air, covering the latent cooling load; Consideration:

• Energy efficiency: enables a higher chilled water temperature as no dehumidification is needed within the fan coils;

• Energy efficiency: the Desica has a higher COP (up to just below 5) for cooling and dehumidification than an ordinary heat pump;

• Indoor thermal comfort: enhance the indoor thermal comfort by enabling the separated indoor humidity control which is decoupled with fan coils;

Sizing: based on maximal annual latent cooling load;

The maximal annual latent cooling load was 2.12 kW (see Figure 3.41). Accordingly, Desica HDMP25D with nominal dehumidification capacity of 2.2 kW was selected, which is able to provide a maximal dehumidification capacity of 3.1 kW.

ERV (indoor CO2 concentration)

Function: used to reduce the heating and cooling load introduced by fresh air intake; Consideration:

• Indoor air quality: CO2 concentration indoor is required to be below 800 ppm, mechanical ventilation is the only effective approach to maintain an acceptable indoor CO2 concentration, under the case of low infiltration design for the house;

• Energy efficiency: recover both sensible and latent heat from exhaust air during fresh air intake through enthalpy exchange;

• Energy efficiency: thin film enthalpy exchange element to further improve the enthalpy recover efficiency;

• Energy efficiency: enable the intake of fresh air without enthalpy exchange when the ambient air temperature is lower than the indoor air temperature under cooling conditions, or when the ambient air temperature is higher than the indoor air temperature under heating condition;

Sizing:

• Fresh air demand for each person: 15L/s, which is approximate minimal fresh air flow rate to keep the indoor air CO2 concentration lower than 800 ppm, as shown in;

• Analysis based on 2 people in the house, but consider the capacity demand at the condition of dinner party with a maximum of8 people;

• Ambient air CO2 concentration of 400 ppm;

• CO2 generation rate is 0.02m3/h/person;

• Infiltration rate of 0.03 at natural ventilation condition;

• Dynamic simulation with initial condition that the initial CO2 concentration in the house equals to the ambient CO2 concentration.

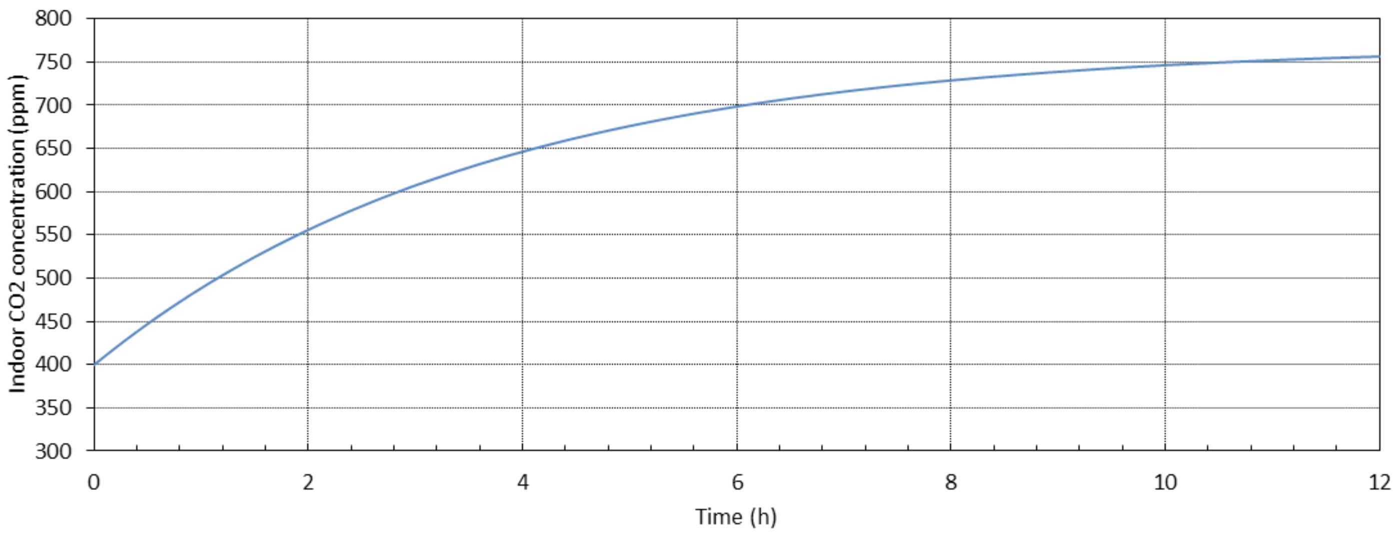


Figure 3.42 - Dynamic Indoor Co2 Concentration for 2 People In The House With 15L/S/Person Fresh Air Flow Rate

As a result, for 8 people maximum in the house, the total fresh air flow rate required is 432 m3/h (i.e. 15L/s/person×8 people). Accordingly, the ERV selected is VAM350GJVE from Daikin, which can provide a maximum fresh air flow rate to 600 m3/h

Fan Coils and Radiant Panels

Function: distribute the heat or coolness generated by the air-to-water heat pump;

Consideration:

• System coupling: the deliverable capacity of the fan coils need to match the maximal heating or cooling capacity of the air-to-water heat pump;

• System coupling: the fan coil need to be oversized, as their deliverable cooling capacity is less than the nominal cooling capacity due to the increasing of the chilled water temperature when cooling;

• Energy efficiency: two fan coils for better air distribution, so that the pressure drop and heat loss can be reduced;

• Indoor thermal comfort: for using radiant panels, leads to more stable indoor operative temperature due the radiant heat exchange; for two fan coils, better indoor air flow organisation due to the using of multiple terminals;

Sizing: corresponding to the maximal capacity of the air-to-water heat pump of 7.44 kW.

Accordingly, the fan coils selected are FWC03C and FWC11C, whose nominal cooling capacities are 2.9 kW and 11.14 kW. To match an actual total capacity of 7.44 kW under an inlet water flow rate of 13oC, the outlet water temperature will reach 17.3oC, with a reason temperature difference of 4.3oC. It indicates that the selection of fan coils is reasonable. The fan coil FWC03C is for living room only, while the fan coil FWC11C is for bedroom, office, kitchen and dining room.

PCM Thermal Energy Storage Unit

Function: store coolness during the night-time for peak load shifting during the peak power period during the daytime;

Consideration:

• Economic efficiency: reduce the operation cost of the HVAC system by shifting the power consumption from peak period to the off-peak period whose power price is one fourth of that of the peak period;

• Energy efficiency: make use of the relative low night-time ambient temperature to enhance the COP of the air-to-water heat pump;

• System installation: pre-encapsulated PCM tubes for the easier installation of PCM TES unit;

• Economic investment: the PCM used are salt hydrate which is much cheaper than that of organic PCMs;

Sizing: based on the maximal daily cooling demand Figure 4 44 illustrates the daily cooling demand over three time spans: from 7:00am to 10:00pm, from 9:30am to 7:30pm, and from 12:00am to 5:00pm, which corresponding to the whole peak period, semi-peak period and pure peak period, respectively. The maximal daily cooling demand for time span of 9:30am to 7:30 am was 36.7 kWh. The power price during the time period is over 2.5 times of the off-peak period. Accordingly, PCMs E10 which is inorganic PCM encapsulated in plastic tubes with a nominal phase change temperature of 10oC was used. The total amount of the PCM tubes is 338, and the total coolness storage capacity it can provide is 33.5 kWh, which can technically cover over 90% of the daily cooling demand.

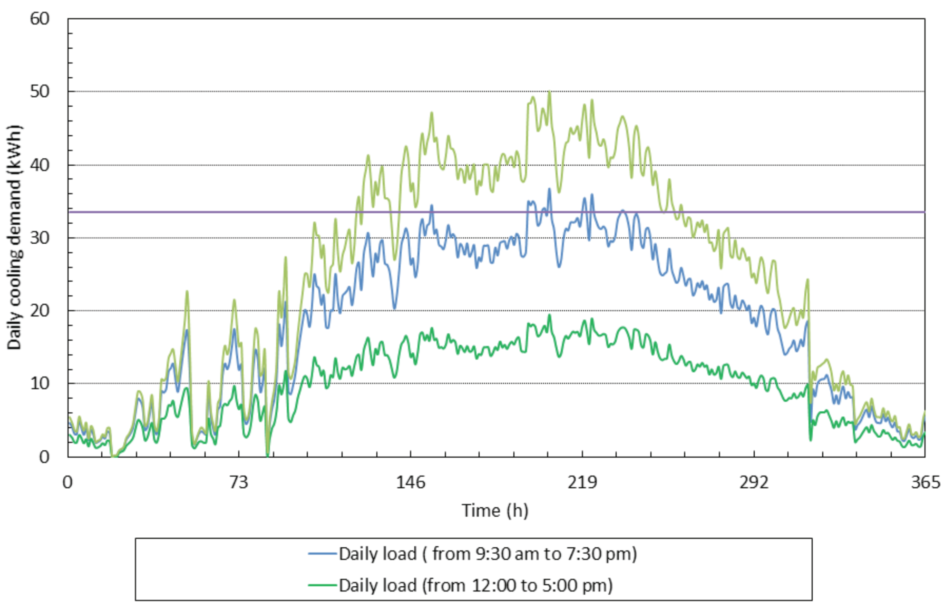


Figure 3.43 - Daily Cooling Loads for PCM TES Sizing

Table 3.27 - HVAC Settings

Design Conditions	Time	Simulation Settings
HVAC	Constant	Indoor setpoint for heating and cooling is set to 24 degrees, there will be no set-back temperature, relative humidity is set to 47.5%
Natural/mechanical ventilation	Yes	Natural ventilation is only used when: Tamb<Tint, when cooling; or Tamb>TINT, when heating
Occupancy	Constant	2 people, see internal schedule
Chilled water temperature	Corresponding to HVAC	13°C for cooling condition; 40°C for heating condition
Supply air temperature	Corresponding to HVAC	16°C for cooling, 32°C for heating, when total supply air flow rate demand is lower than fresh air flow rate demand
Fresh air flow rate	Corresponding to occupancy	15L/s/person which is appropriate minimal fresh air flow rate to keep the indoor air CO_2 concentration lower than 800 ppm
Total chilled water flow rate	Corresponding to HVAC	0.7L/s for supply chilled water loop before common pipe

The other objective of active house performance analysis is to determine the power consumption of the HVAC system when a suitable indoor thermal comfort is maintained. The setting used for the HVAC system in active house simulation is summarized in Table 3.28.

The detailed explanation of the HVAC settings are as follows:

- A perfect control condition was assumed by setting the indoor air temperature and relative humidity of 24oC and 47.5%, which are the medium valves of the required indoor thermal comfort ranges;
- 2 people in the house all the time, therefore the total fresh air flow rate was 30L/s;
- Natural or mechanical ventilation without enthalpy exchange is available when the direct introducing of ambient fresh air tends to be beneficial to reduce the indoor heating or cooling loads;
- Chilled water temperature for cooling was improved from 7oC to 13oC due to the use of Desica for dehumidification rather than using fan coils; while the hot water temperature for heating was reduced from 50oC (i.e. nominal value) to 40oC due to the using of fan coils using bigger deliverable capacity;
- Supply air temperature difference (with indoor thermostat) of 8oC for both heating and cooling conditions to enable a stable indoor air temperature field;
- A decoupled chilled water piping system was used in the HVAC system, in which the supply side will keep having a nominal water flow rate of 0.7L/s, while the water flow rate of the user side will be determined by the heating or cooling demand of indoor environment;

Due to the fact that the demanded fresh air flow rate is lower than the nominal air flow rate of Desica, the Desica can be operated intermittently in practice, which will result in an acceptable but fluctuating indoor air relative humidity. In the simulation, a stable indoor relative humidity was assumed, so the mixing of fresh air from ERV and return air will be supplied to Desica to ensure its static performance. The overall numerical performance result will be technically close to that of the practical one.

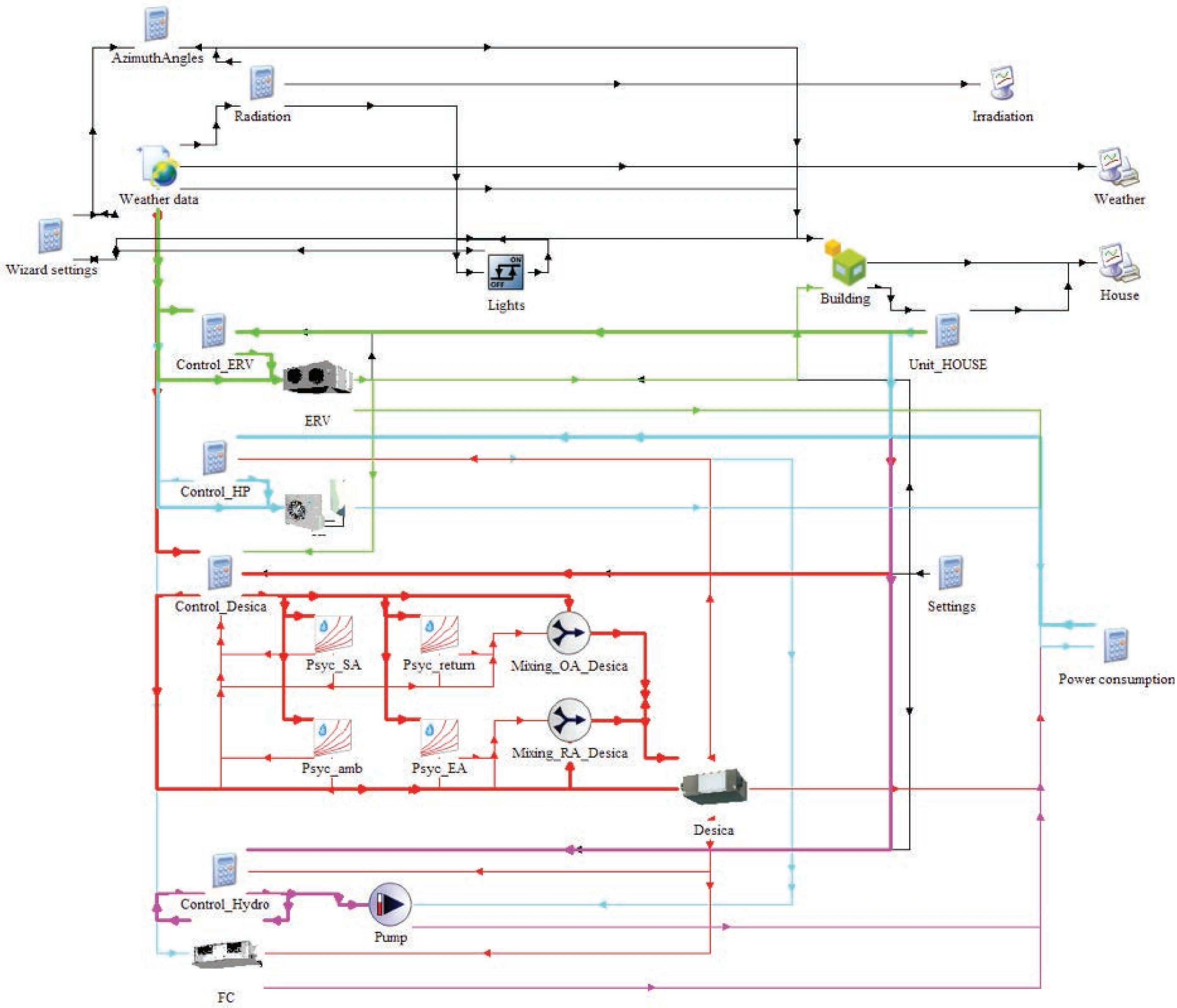


Figure 3.44 - TRNSYS Model for Analysis

The simulation of the air-to-water heat pump and the Desica were based on the performance maps provided by the suppliers. For the air-to-water heat pump, the house heating and cooling loads, as well as the load introduced by the power consumption of supply pump, the ambient air temperature and leaving chilled (or hot) water temperature, as well as the partial load factor (PLR) were used to identify the power consumption of the heat pump:

$P_{HP} = f(Q_{load} + Q_{pump}, T_{amb}, T_w)$

Similarly, for the Desica, the latent cooling load, the return air temperature, the outdoor air temperature, and the PLR for latent cooling load were used to identify the power consumption of Desica:

$P_{Desica} = f(Q_{lat\ load}, T_{ra}, T_{oa})$

The heat transfer within the two fan coils is modelled as the heat transfer with in an equivalent fan coil with the same capacity and power consumption. The heat transfer modelling results will determine the air flow rate and the water flow rate, based on which, the power of fans and pump can be determined.

It is worthwhile to mention that the PCM TES unit was not considered in the active house simulation, as its main benefit is for peak load shifting, and there is no direct power consumer in the PCM TES system. The UV emitter was not considered as well, due to the fact that there will be no condensation for fan coils ideally, as the Desica will cover the latent load. Thus, the UV emitter will be just used occasionally for deactivation of moulds and bacteria.

Accordingly, the total power consumption is calculated as:

$P_{total} = P_{hp} + P_{desica} + P_{ERV} + P_{pump} + P_{fan}$

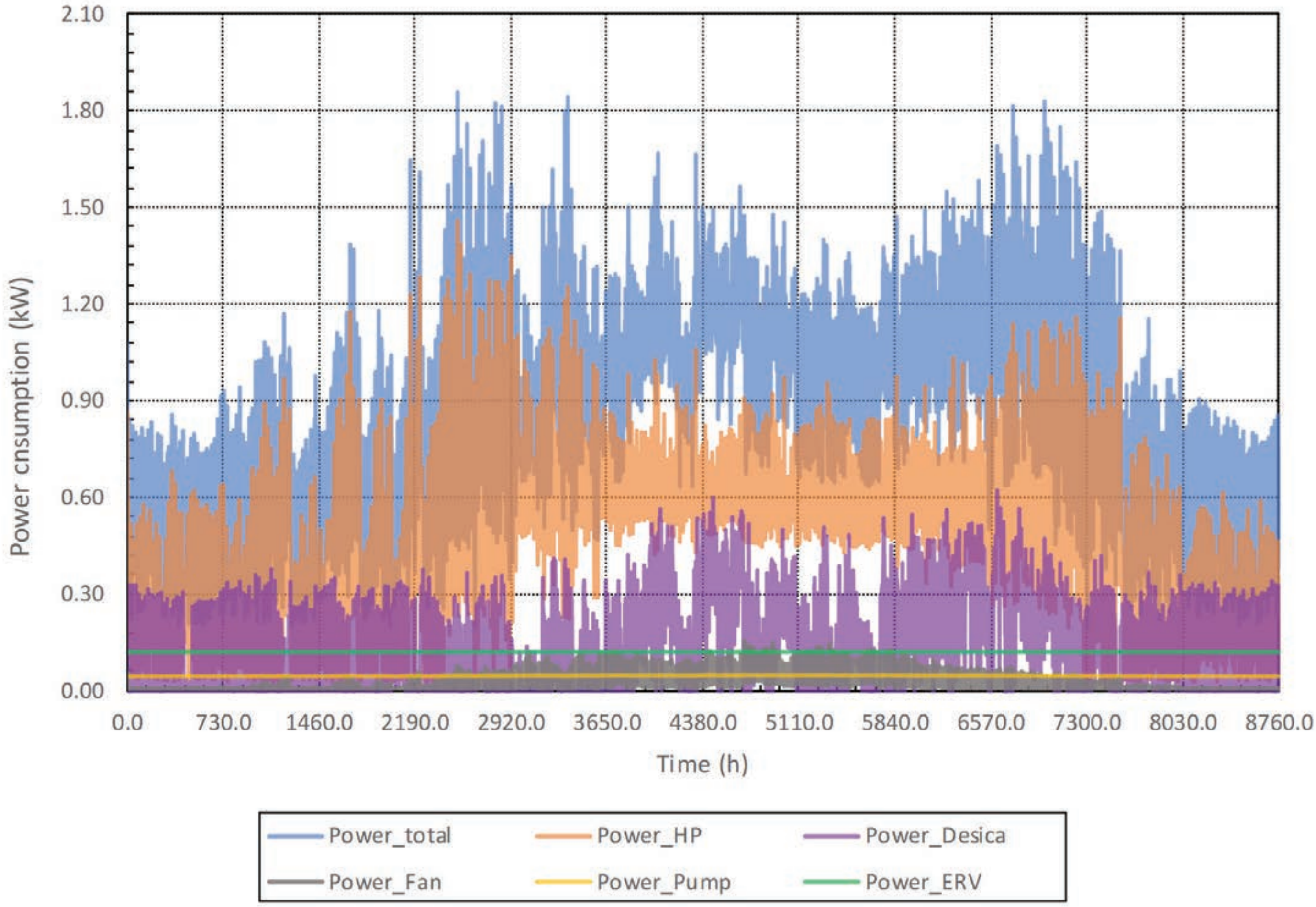


Figure 3.45 - Annual Power Consumption of the HVAC system

The annual total power consumption was further summarised in Table 3.29. It can be seen that the air-to-water heat pump is the major power consumer in the HVAC system, whose peak power consumption is 1.44 kW and annual power consumption is 4,265.71 kWh, as it is used to cover the sensible cooling and heating loads of the house. The second biggest power consumer is Desica, which consumed 1,180.69 kWh of the power annually, while peak power consumption reached 0.62 kWh. The following power consumers are ERV, pump and fan coils, but interestingly, the peak power consumption of fan coils was higher than that of the ERV and pump. This situation occurred in the hot summer period when a large amount of air flow rate was needed to cool the indoor environment, while the power consumption of ERV was constant, and the power consumption for the pump is relative stable with minor fluctuation all the year round.

It is noteworthy that the power consumption of the HVAC system in practice may be lower than the simulation. This is because in practice, a comfort temperature and relative humidity range is acceptable rather than set as fixed value in the simulation. Also, the deviation between the simulation and the practical system operation is also due to the error introduced in the simulation. Some components, e.g. Desica, are still undergoing testing in our facilities for its performance characteristics, as limited information is provided through the user manual.

Table 3.28 - Annual Total Power Consumption of the HVAC System

HVAC device	Total power consumption (kWh)	Peak power consumption (kW)
Air-to-water heat pump	4146.29	1.38
Desica	2220.08	1.05
Enthalpy recovery ventilator	1051.20	0.12
Fan coils	269.68	0.16
Pump	406.92	0.05
Total	8094.17	2.04

3.2.5 House Performance During Contest Period

3.2.5.1 Passive Analysis

The performance of the Desert Rose during the contest period was evaluated for the house in free running mode and with the HVAC on. The internal loads and schedules were implemented in the model following the SDME2018 requirements (CITE APPENDIX/section with schedules). The simulation results for the passive analysis for the 10 day competition period are shown in Figures 4-46 to Figure 4-49.

It can be seen that leaving the house free running results in air temperatures outside the competition comfort bands for some time every day. The kitchen reaches particularly high temperatures due to the appliances contests and dinner parties cooking preparation. The summary of the temperatures distribution is illustrated in Figure 4-50. A very similar temperature distribution is presented in all rooms except the kitchen, where a maximum temperature as high as 52.4°C is reached due to the internal loads. The humidity distribution is presented in Figure 4-51. It can be seen that for the majority of time all spaces presented a relative humidity beyond the competition maximum relative humidity. Equally to the temperature profiles, all the spaces have a similar relative humidity distribution profile except for the kitchen. The significantly lower relative humidity shown in the kitchen compared to the rest of the zones is due to the window opening for a longer time than the rest of the house spaces. The kitchen has natural ventilation because of the high temperatures reached during the contest periods while the rest of the spaces have the windows closed. This resulted in the relative humidity distribution profile in the kitchen following slightly the outdoor relative humidity.

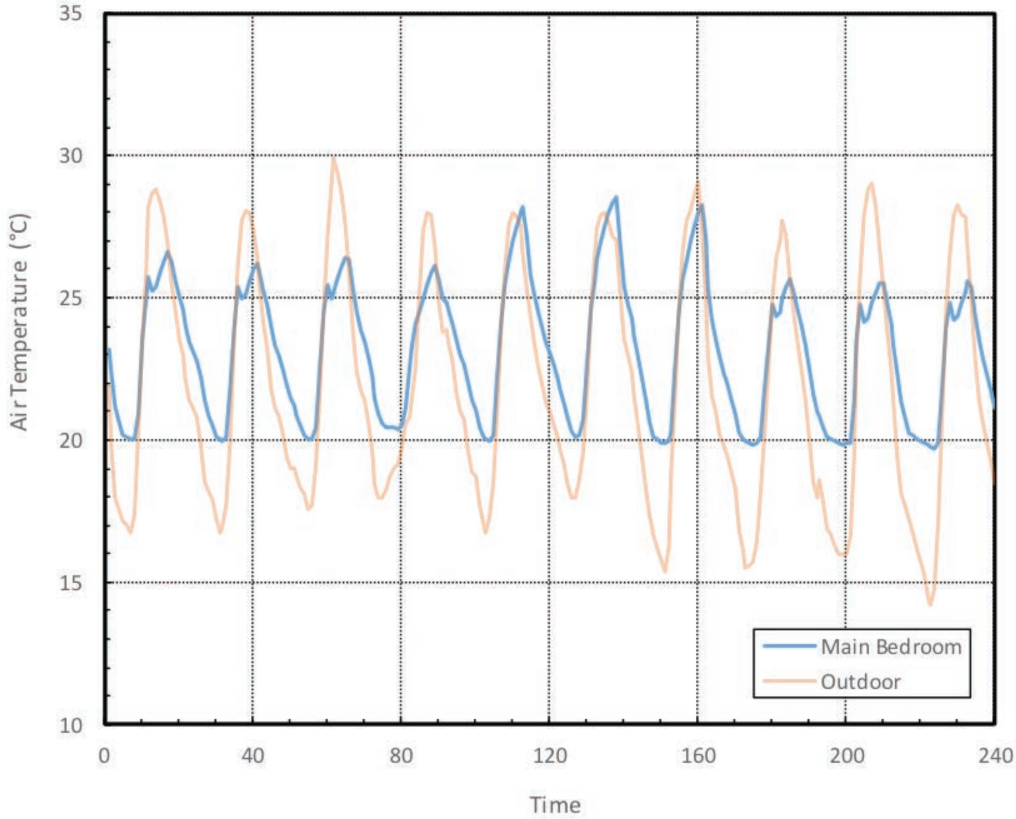


Figure 3.46 - Passive Competition Outdoor and Indoor Air Temperature for Main Bedroom

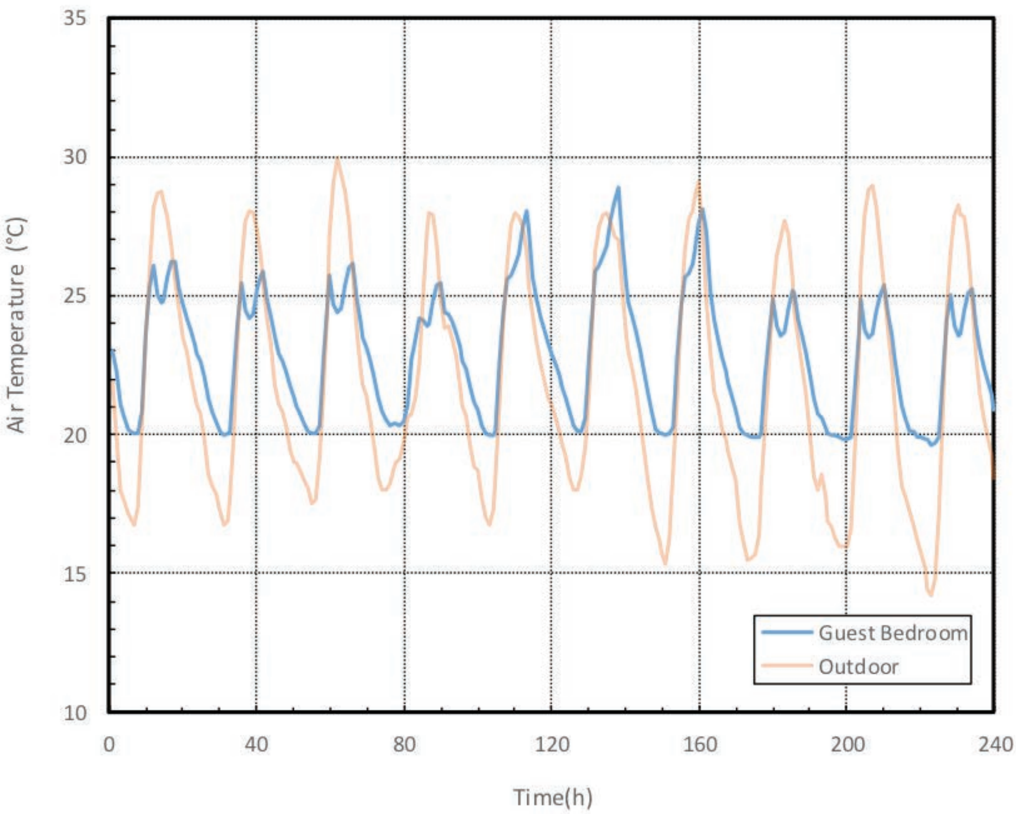


Figure 3.47 - Passive Competition Outdoor and Indoor Air Temperature for Guest Bedroom

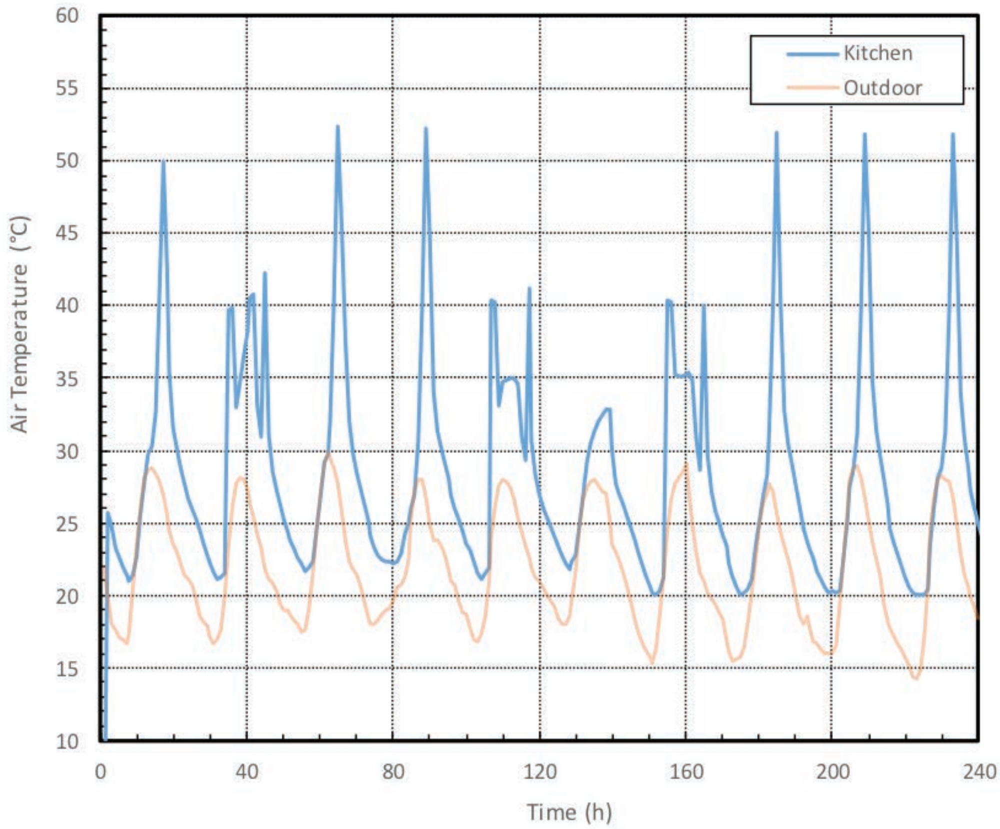


Figure 3.48 - Passive Competition Outdoor and Indoor Air Temperature for Kitchen

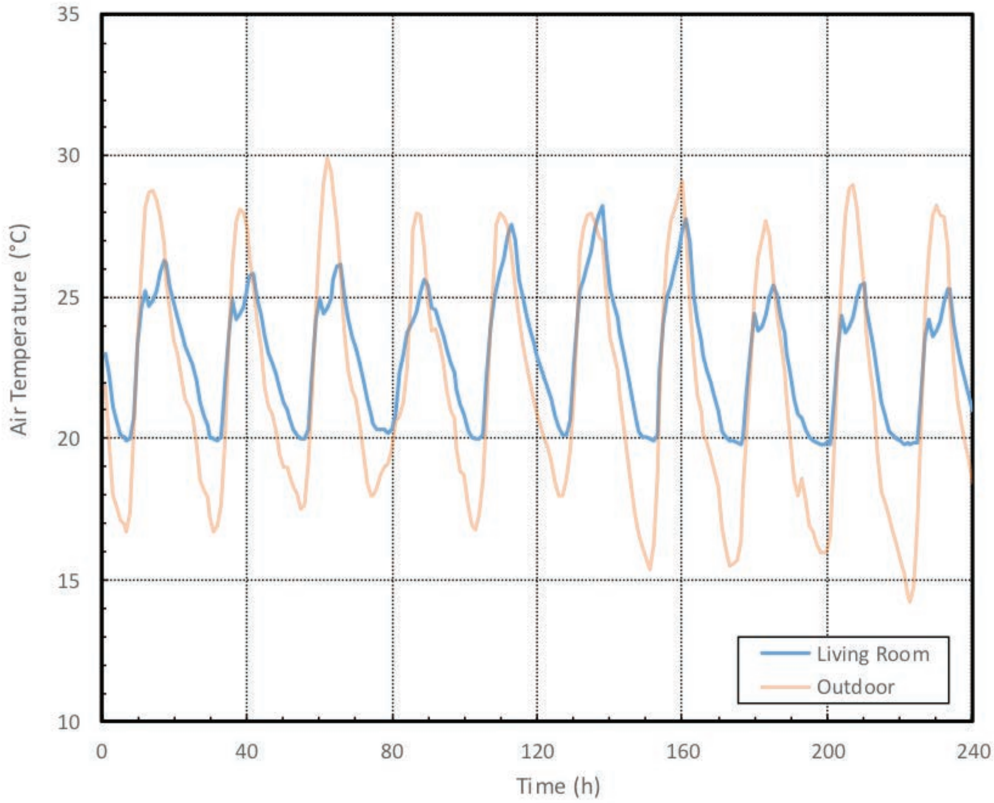


Figure 3.49 - Passive Competition Outdoor and Indoor Air Temperature for Living Room

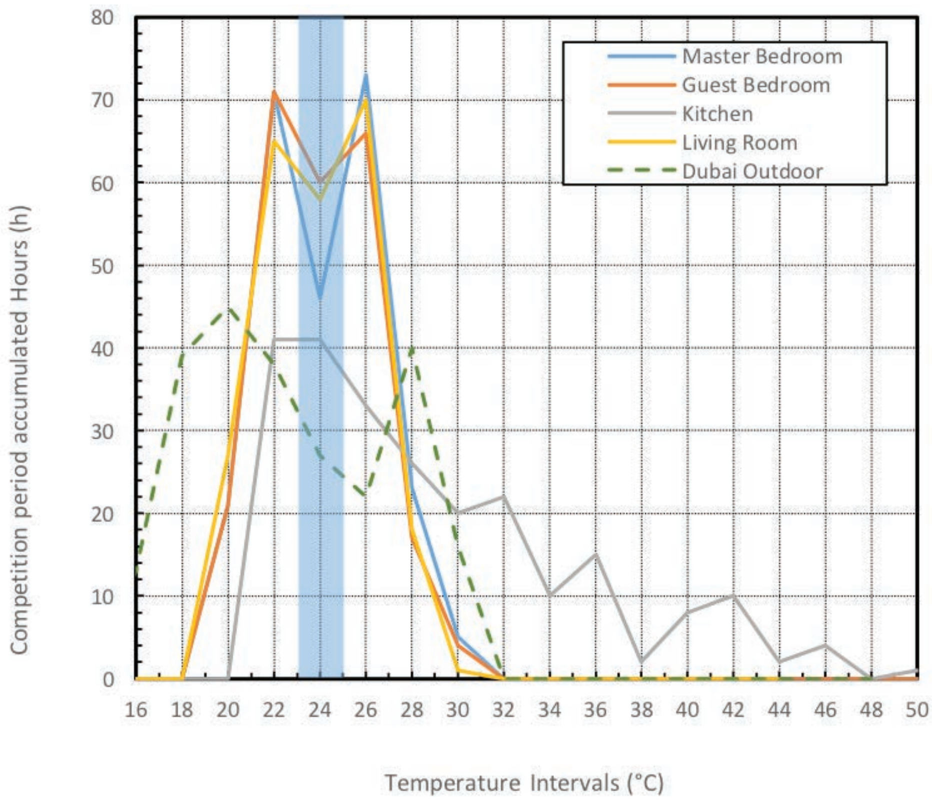


Figure 3.50 - Passive November Temperature for Four Major Zones and the Outdoor

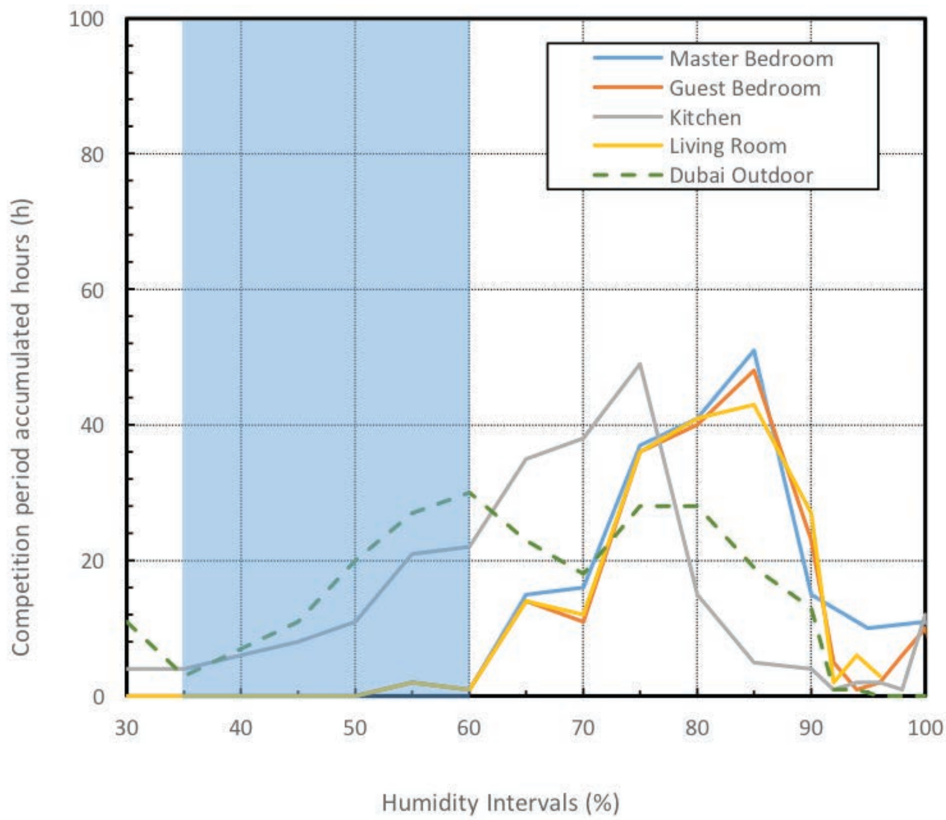


Figure 3.51 - Passive November Relative Humidity Distributions for Four Major Zones and the Outdoor

The maximum and minimum indoor air temperatures as well as relative humidity for individual rooms during the contest period are summarised in Table 3.30. All rooms experienced the lower and upper extreme indoor air temperature outside the stringent competition comfort bands. In terms of relative humidity, the maximum value reached 100% in all zones while the minimum relative humidity oscillates between 24.89% to 50.42%.

It is observed that the comfort competition requirements for both temperature and relative humidity are met for less than 5% of the time during the competition varying from 2.1% in the kitchen and dining to 4.6% of time within the comfort range for the master bedroom.

Table 3.29 - Air Temperature and Relative Humidity Boundaries for the Competition Period Passive Analysis

Item		Outdoor	Guest Bedroom	Master Bedroom	Kitchen and Dining Room	Living Room
Temperature (°C)	maximum	29.92	28.91	28.54	52.53	28.23
	minimum	14.23	19.62	19.69	20.05	19.76
Relative Humidity (%)	maximum	94	100	100	100	100
	minimum	25	49.02	49.53	24.89	50.42
% of time within comfort T			29.3	25.5	13.6	30.5
% of time within comfort H			6.7	7.9	25.9	6.7
% of time within comfort T and H			3.8	4.6	4.2	2.1

3.2.5.2 - Active Analysis

The results of the Desert Rose during the competition period are shown in Figure 5.52 and Figure 5.53.

The house was conditioned 24 hours, including the visitors tours so as not to have too high temperatures at the start of the metered contest and therefore avoiding the high peak on the cooling load. It can be seen that the temperature was maintained within the thermal comfort competition requirements in all main spaces (Figure 5.52). The relative humidity shown in Figure 5.53 demonstrated relatives humidity's above 40% and below 60.1%.

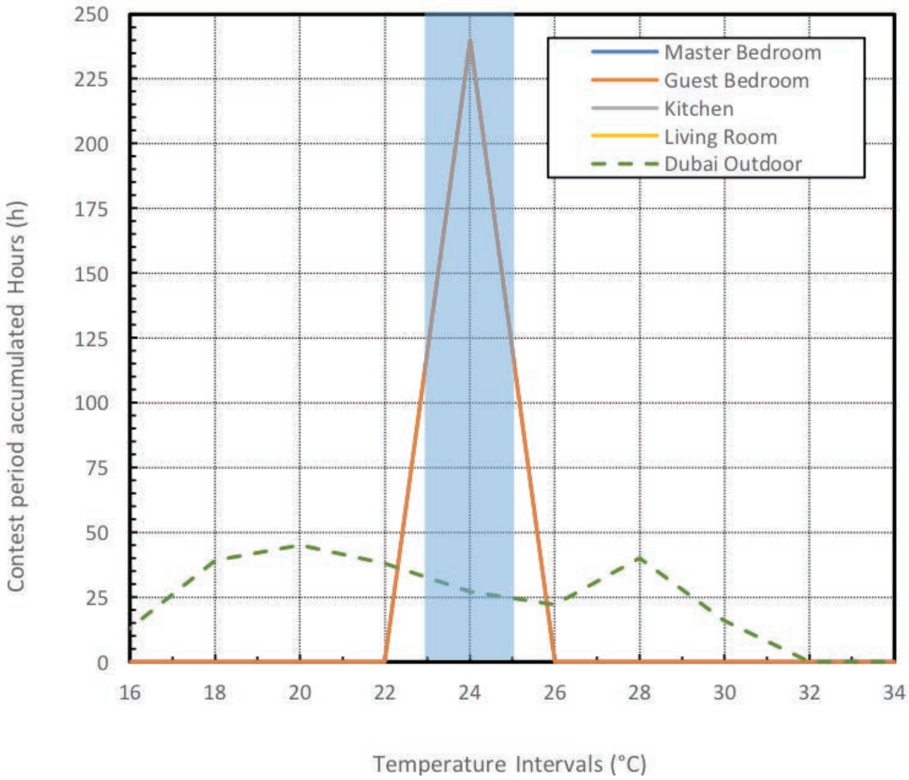


Figure 3.52 - Passive November Relative Humidity Distributions for Four Major Zones and the Outdoor

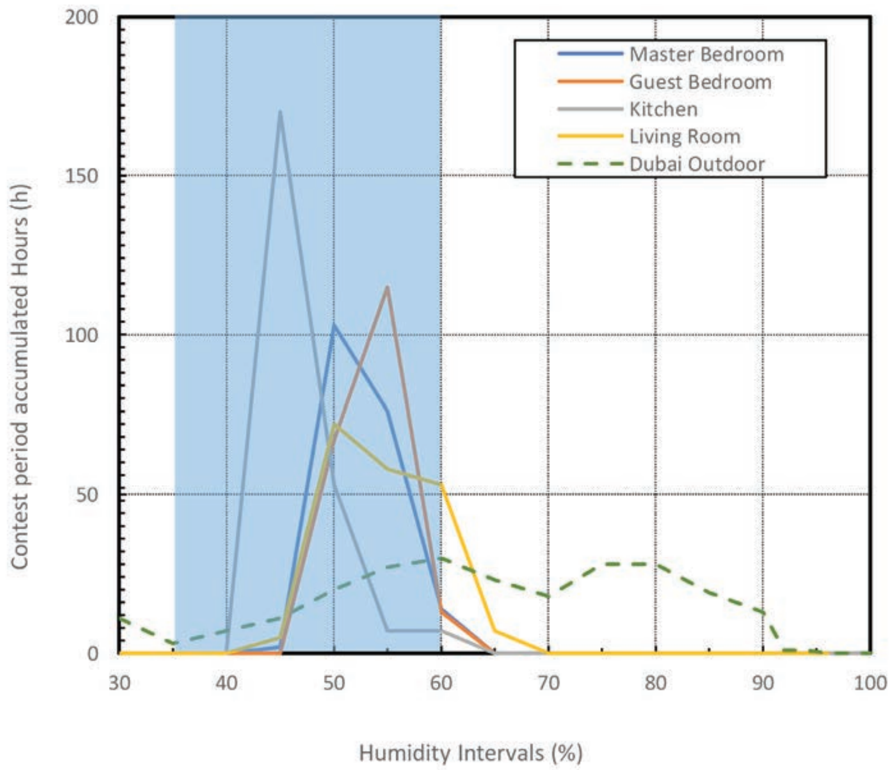


Figure 3.53 - Active Competition Period Relative Humidity Distributions for Four Major Zones and the Outdoor

The total cooling load was calculated to be approximately 230.4 kWh for the competition period resulting in 23.04kWh of cooling per day. Heating required is minimal under competition conditions (<1kWh). The hourly cooling load for the building is shown in Figure 3.54. The spikes in the cooling corresponded to the different metered contests where the internal loads increased particularly in the kitchen with the oven, cooktop and dishwasher. TRNSYS was also used to analyse the HVAC power consumption during the competition period and is illustrated in Figure 3.55 and a summary table provided in Table 3.31. As expected the heat pump was found to consume the greatest amount of power totalling 81.66kWh, with the ERV and Desica systems consuming 28.8 and 23.22 kWh respectively.

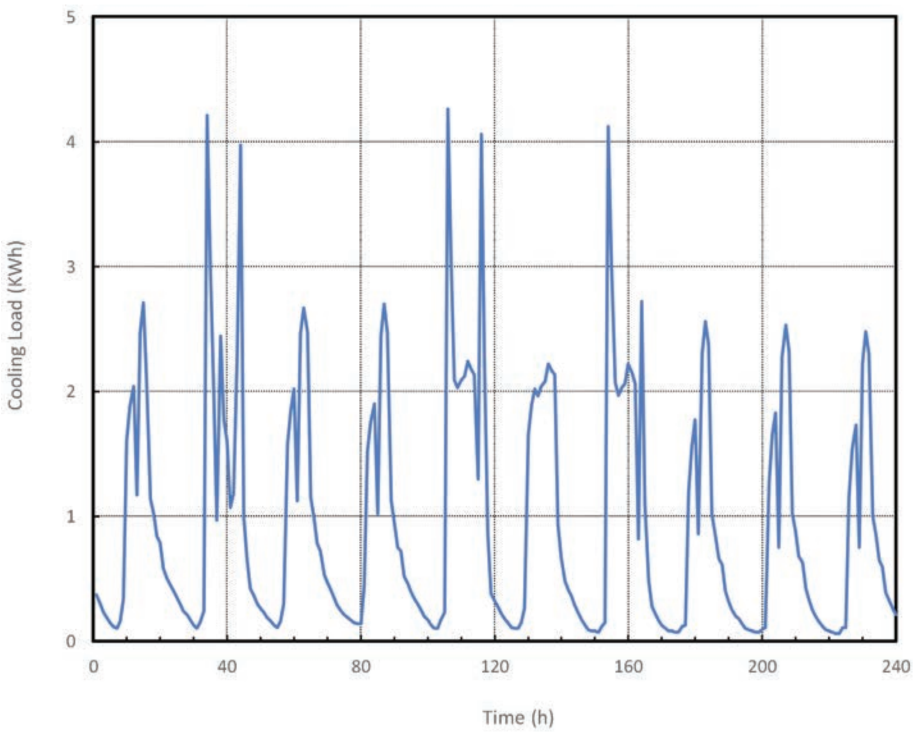


Figure 3.54 - Active Competition Cooling Load

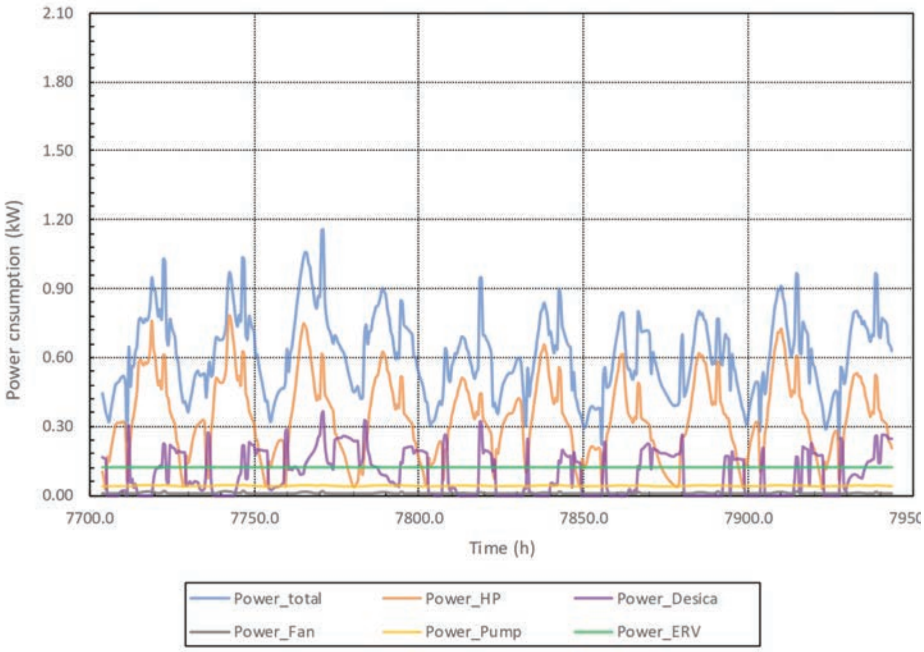


Figure 3.55 - Competition Power Consumption of the HVAC System

3.2.5.3 Conclusions

This section explored the climate of the competition site, Mohammed bin Rashid Al Maktoum Solar Park which revealed an extremely hot and humid climate. Energy efficiency measures and passive strategies employed in the Desert Rose including our second skin wall was discussed and then analysed using Design Builder to measure the effects that they had on annual energy loads. TRNSYS was used to simulate the HVAC system design to understand the required sizing of all the components and the power profiles throughout the year. The results from Design Builder and TRNSYS guided Team UOW in the final design of the Desert Rose with a final analysis showing the passive and active temperature, humidity and load profiles of the Desert Rose during the 10-day competition period. The passive and active strategies have drastically reduced the cooling loads of the Desert Rose with the final model predicting a total of 146.47kWh to be consumed by the HVAC system to maintain the house within the strict comfort bands. The following section will continue into how our Solar System is designed to cover this load along with the other electrical loads of the Desert Rose.

As it isn't possible cannot quantify the value for BIPV-T system in the SDME 'Shams' currency, the following economic analysis will be completed considering Australian dollars. According to Energy Australia [2], the fixed price electricity in Wollongong is AUD $0.2978/kWh. Additionally, they provide a feed in tariff for solar energy of AUD $0.125/kWh in New South Wales [3].

The daily price paid for energy (ignoring connection fees) is therefore:

Daily cost = (E_{import} × $0.2789/kWh)-($E_{export}$×$0.125)

Daily cost=(14.74 kWh × $0.2789/kWh)-(30.53 kWh × $0.125)

Daily cost=AUD $0.2947

Therefore Annual cost=AUD $108.55

Considering no solar, the cost would be:

Daily cost no solar=(E_{import}×$0.2789/kWh)

Daily cost no solar=AUD $12.81

Therefore Annual cost no solar=AUD $4675.65

This gives an annual saving of AUD $4567.10

As the Desert Rose will contain a BIPV-T system that replaces the need for a normal roof construction or solar thermal system, the price of these two components must be subtracted from the total capital investment (CAPEX). The equation for the initial CAPEX of the entire system is therefore:

CAPEX = $C_{Tractile}$ + $C_{Battery}$ + $C_{inverters}$ - C_{Roof} - $C_{(Solar\ Thermal)}$

Where:

- Ctractile is the cost for the Tractile solar roofing system, including flashings, plumbing connections and electrical connections (AUD $30,000 quote).
- Cbattery is the cost of the energy storage system (AUD $10,000 quote)
- Cinverters is the cost of the two ABB-PVI6000 inverters (AUD $4600 quote)
- Croof is the cost for a colourbond roof (70 m^2) in Australia (AUD $14000 [4])
- Csolar thermal is the cost for evacuated tube solar thermal system (AUD $3600)

Therefore, the total capital investment for combined BIPV-T/ energy storage system is $27000.

Using the simple payback formula (6), the payback period can be determined.

Simple Payback = (Initial CAPEX) / (Annual Savings)

Simple Payback= (AUD $27000) / (AUD $4567.10)

Simple Payback= 5.91 years

Even considering a feed-in tariff of $0 (similar to the SDME competition), the payback period is still 8.5 years, much less than the expected life cycle of the BIPV-T and energy storage system.

3.2.6 Conclusions

From the energy report, it is evident the 11.4 kW of BIPV-T will meet all of the energy requirements of the Desert Rose house. Based on current estimates, the system will produce 20,458 kWh of energy annually, while only consuming 16,766.28 kWh of energy, making the Desert Rose net-positive energy. The payback period considering Australian Residential electricity prices and feed-in tariffs is 5.91 years, much less than the expected 15 year life of the assets.

3.3 Electrical Energy Balance Report

3.3.1 Introduction

Several different methodologies were used to determine the electrical production of the Desert Rose house. The primary method was a MATLAB script developed by a student in Team UOW which was then verified using the PVWatts online software suite. Team UOW chose to use a custom script as it provided much more flexibility when testing various solar materials, configurations, tilt angles and weather conditions. This ensured that the optimal amount of solar could be selected to cover the Desert Rose electrical load, even if there are adverse weather conditions.

The weather data used for the analysis is the 3-year historical data provided to teams by the SDME organisers for the Mohammed bin Rashid Al Maktoum Solar Park. This data was averaged over the three years to give average hourly solar irradiance and temperature data for each day of the year. This data was used in conjunction with the MATLAB script to calculate both the clear sky power output curve (ideal theoretical conditions) of the solar PV as well as the average power output curve based on the historical weather data. Integrating under each curve for each day gave the total energy in kWh produced in a day. Summing this energy over the entire year gave the total expected energy production of the system over the course of a year in Dubai. For more details on the algorithms implemented, see Section 4 of this report.

The daily load consumption for the house was then calculated. The HVAC load was determined using a combination of both EnergyPlus and TRNSYS (See House Performance Report). The remaining daily electrical loads were based on recorded data Team UOW collected during the commissioning of the Desert Rose house. This data was used to create typical daily load profiles to then determine the annual electrical consumption of the house.

3.3.2 List of Electrical Loads

The following tables contain a list of the electrical loads in the Desert Rose house along with their expected contest consumption. Note that the contest consumption is taken from November 18th – November 27th as these are the dates when energy is being measured

Table 3.30 - Contest Electrical Loads

Appliance	Make	Model	Rated Power (kW)	Energy During Contest Week (kWh)
Washer	AEG	L99699HWD	2.2	7
Dryer	AEG	L99699HWD	2.2	15.4
Dishwasher	Smeg	DWA6315X1	1.8	5.45
Oven	Westinghouse	WVES613S-L	2.3	20.7
Cooktop	Miele	KM 6363-1	1012.88	2.78
Microwave	Westinghouse	WMF4102SA	1.1	0.1
Fridge/Freezer	Gorenje	NRK6193UX-AU	0.12	6.6
Rangehood	AEG	DGE5860HM	0.27	1.25

HVAC/ Hot Water	Make	Model	Rated Power (kW)	Energy During Contest Week (kWh)
Heat Pump	Daikin	EBHQ-BB6V3	3.87 (cooling)	76.1
Auxiliary Pump			0.3	10.85
Fan Coil Unit 1			0.345	1.24
Fan Coil Unit 2			0.15	0.53
ERV			0.23	28.8
Dehumidifying Heat Pump	Daikin	Desica	1.6	25.44
Hot Water	Rotex	ROSC20-544	2	12

EV/ Inverters /BMS	Make	Model	Rated Power (kW)	Energy During Contest Week (kWh)
Ev Charger	Hager	XEV201C	7	27.6
Inverter Standby Power	E3DC	S10 MINI	0.03	7.2
BMS Standby Power	Various	Various	0.055	13.2

Home Electronics	Make	Model	Rated Power (kW)	Energy During Contest Week (kWh)
TV	Hisense	39P4	0.045	3.71
Monitor	Dell	E2219HN	0.12	3.19

3.3.3 Photovoltaic System Description

The photovoltaic system on the Desert Rose house is a completely building integrated, photovoltaic-thermal (BIPV-T) system. The system is made up of Tractile Eclipse Solar Roof tiles which are replacing the entire roof construction on the pitched portion of the Desert Rose roof. Tractile is known as "the smarter roof" as it is a 5-in-1 module, providing a roof, insulation, electricity, solar panel cooling and hot water all in one system. The Desert Rose house will consist of 104 southern facing solar roof tiles, adding up to a total of 10.4 kWp of generation. The system will also be used to produce domestic hot water. The act of running water under the solar roof tiles will also decrease the solar cell temperature, thus increasing efficiency of the panels.

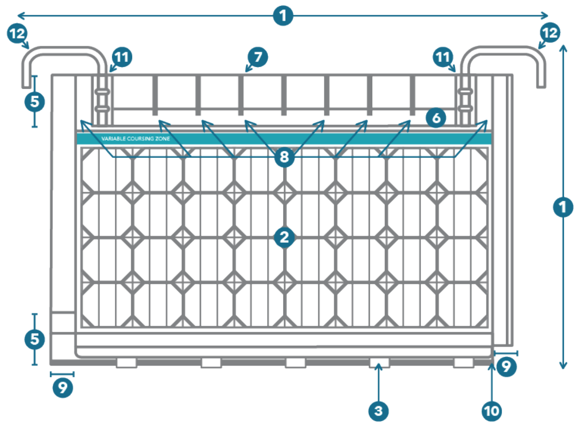
3.3.3.1 Modules

The Tractile Eclipse Solar Roof Tiles are 1100mm x 650mm and attach mechanically end to end. The solar cables are connected via MC4 connectors while the water system is connected tile-tile with copper 'U' pipes and SharkBite push-fit connectors as shown to the right.

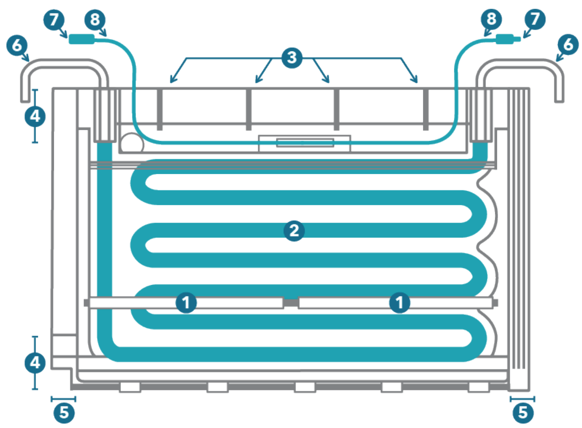
The technical specifications of the modules themselves are found to the right:

3.3.3.2 Wiring

The Desert Rose solar PV wiring was designed to be a plug-and-play system. The plug-and-play nature of the install means Team UOW are able to quickly and safely install the PV system during the short construction window for the SDME competition. All DC cables are twin 4.0mm² tinned copper XLPO insulated solar cables. The solar PV system has a total of 4 arrays, each with two strings. Strings are connected in parallel via genuine MC4 branch connectors. Each array is then wired to a PGK SE042E 1000V MC4 DC isolator. Finally, the DC isolators are then connected to inverters located in the plantroom via MC4 connectors that plug in to the bottom of each inverter.



1. Double height and large side
2. Photovoltaic Module
3. Low profile tile edge
4. Hook and batten fixing system
5. Head and tail lap zones
6. Ramp
7. Back Wall
8. Offset markers and baffles
9. Side lapping
10. Silicone bead channel
11. SharkBite push -it connector
12. Tractile 'U' copper pipe



1. Lower hooks
2. Pipe channel
3. Support fins
4. Head and tail lap zones
5. Side lapping
6. Tractile 'U' copper pipe
7. MC4 connector
8. Cable 600mm

Figure 3.5.6 - Tractile Technical Illustration

Table 3.31- Tractile Technical Specifications

Electrical Parameters			at Standard Test Conditions (STC)	at Nominal Operating Temperature (NOCT)
Power Output	P_{max}	W	100.00	73.3
Power Output Tolerances	ΔP_{max}	%	-0% / +10%	-0% / +10%
Voltage at P_{max}	V_{mpp}	V	27.50	24.97
Current at P_{max}	I_{mpp}	A	3.64	2.94
Open-Circuit Voltage	V_{oc}	V	34.22	24.02
Short Circuit Current	I_{sc}	A	3.89	3.14
Max System	V_{sys}	V	1000	1000
Overcurrent Production Limit		A	9	N/A

3.3.3.3 Inverters

The Desert Rose house contains two solar inverters located in the electrical plant room. The inverters are an all-in-one unit containing both a solar inverter and energy storage unit. The inverters are each rated at 7 kW and have two maximum power point tracking (MPPT) channels. Each inverter will be limited to 4 kW (combined total of 8 kW) for the SDME competition. The technical data for the inverters are as follows:

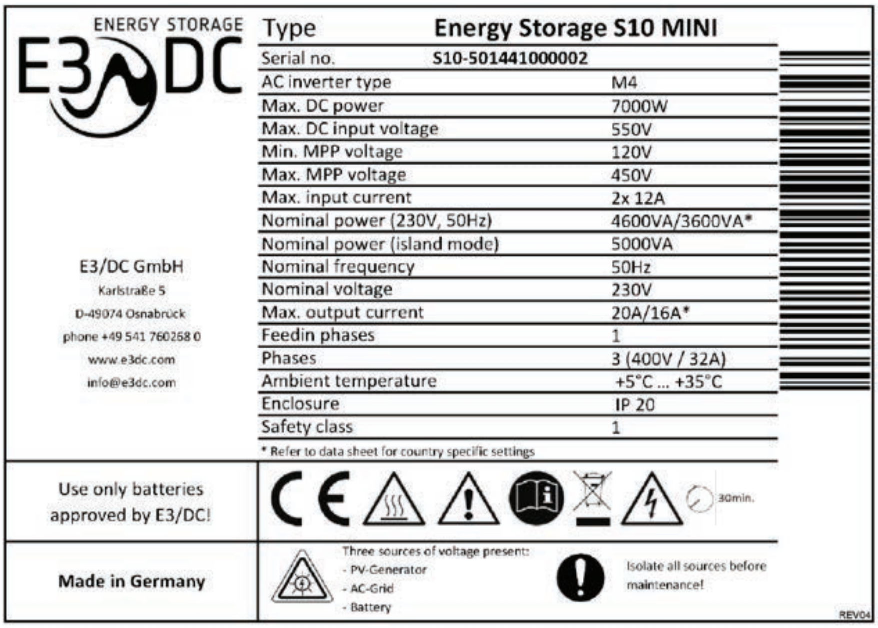


Figure 3.57 - E3DC Inverter Specification

3.3.3.4 Batteries

The Desert Rose house contains two E3DC S10 mini 6.9 kWh energy storage units (ESUs) located in the plantroom. The ESUs contain both a DC/DC converter and hybrid solar inverter to convert the DC power from the battery to AC power that can be used throughout the home. Each ESU contains three 2.3 kWh battery modules that easily slide in and out of the units, making maintenance and replacement fast and safe. The charging and discharging of the batteries is controlled via a student developed model predictive control optimisation algorithm that optimises exchanges between the solar PV, the batteries, the household load and also the greater community.

The technical details for the energy storage are shown below.

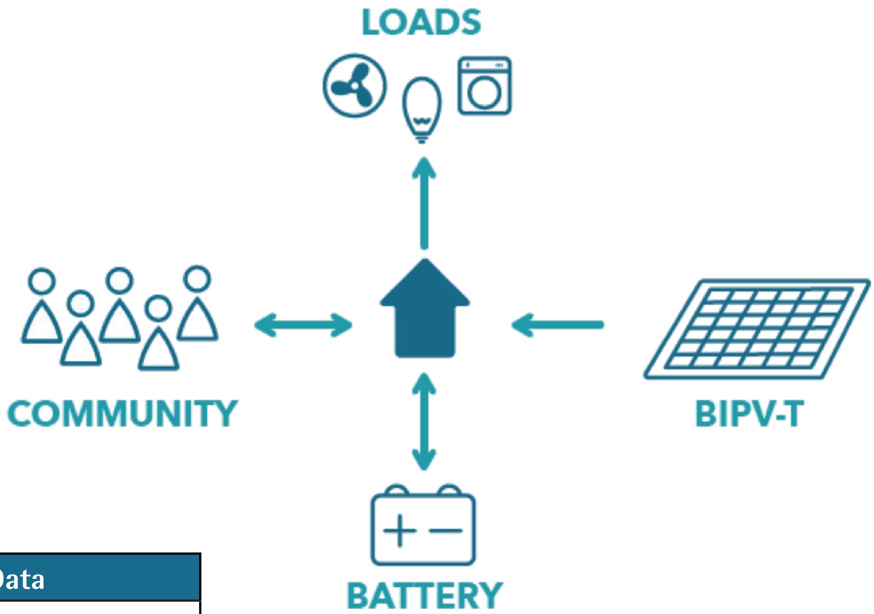


Figure 3.58 - Model Predictive Control Digram

Table 3.32 - E3DC S10 Technical Specifications

E3DC S10 MINI Technical Data	
Dimension (LxWxH)	923mm x 355mm 1005mm
Weight	114kg
Operating Temperature	5°C - 35°C
Nominal Output Power	1.5kW
AC Output Voltage Range	207 V - 259 V
Operating Voltage	230 V
Depth of Discharge	92%
Nominal Storage Capacity	13.8kWh
Useable Storage Capacity	12.7kWh
Phase/s	Single Phase

3.3.4 Simulation Tools

A MATLAB script, included in Appendix A, was developed by a UOW student to determine output of the solar PV system of the course of the year. The script determines the best case (clear sky) power output of the PV, average PV output based on MBR Solar Park 3 year historical weather data and worst case scenario, based on the worst weather conditions from the 3 year weather data. Developing a custom script was beneficial as it allowed UOW to test various PV configurations, weather conditions and PV modules to ensure the optimal amount of solar was implemented on the house. The script would determine the output of the BIPV-T system every hour of the year. The script would run as follows:

1. Declaration of variables including size of PV system, latitude and longitude of the MBR solar park, solar PV tilt and orientation, derate and PV/ inverter efficiencies

2. Determine the clear sky global horizontal insolation that would strike a collector at 0°. This was calculated using the equations from chapter 4 of [1].

3. Determine the clear sky global horizontal insolation that would strike a collector at 10° (this is the tilt angle of the solar on the Desert Rose house).

4. Calculate the ratio of insolation striking the collector at 0° and the insolation striking the collector at 10° (the installation angle of the Desert Rose solar PV).

5. Import the global horizontal insolation and temperature data for the nth day of the year at the MBR solar park from excel (this data was provided by the SDME organisers). Below shows the close comparison between the global horizontal irradiance (GHI) calculated by the MATLAB script and the measured value provided by the SDME organisers.

6. Multiply the insolation curve by the previously insolation ratio to determine the insolation striking a collector at 10° using the real weather data. This gives the average solar PV irradiance curve.

7. Calculate the drop in solar PV efficiency as a result of increased cell temperature using the following equations

$$T_{cell} = T_{amb} + \left(\frac{NOTC - 20°C}{0.8\ kW/m^2}\right)$$

$$Decrease\ in\ P_{max} = Temp\_coeff \times (T_{cell} - 25°C)$$

Where:

- Tcell is solar cell temperature
- Tamb is the ambient temperature
- NOTC is the nominal operating cell temperature
- Temp_coeff is the temperature coefficient for tractile solar roof tiles is -0.42%/°C
- Decrease in Pmax is the reduction in maximum solar output at each time interval due to system inefficiencies

This equation is also used to calculate the benefit of cooling the Tractile solar tiles during the hotter parts of the day.

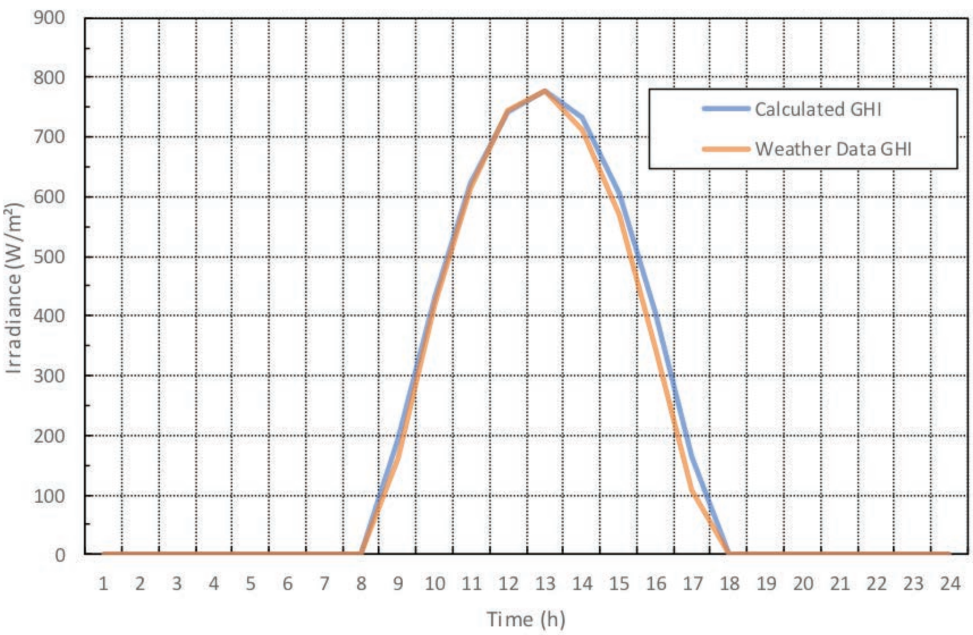


Figure 3.59 - November 14 Irradiance Curves

8. The power output curve of the PV system is determined by considering the decrease in power output due to cell temperature along with a general derate of 15% (due to losses in cables, inverters and module soiling). The equation for the power curve is shown below

$$Power_n(t) = sys_{size} \times measured\ insolation_n\ (t) \times derate \times Decrease\ in\ P_{max}(t)$$

Where:

- Sys size is the rated capacity of the PV system, 10.4 kW
- Measured insolation (t) is the average irradiance that will strike the solar PV at time interval t based on the average MBR solar park weather data
- Derate is the reduction in efficiency (15%) due to losses in the system.
- Decrease in Pmax is the reduction in output power due to solar cell temperatures above 45°C
- n is the day number of the year

Finally, to determine the energy produced throughout the whole day, the power curve was integrated over 24 hours. That is:

$$kWh\ per\ day_n = \int_0^{24} Power_n(t)\ dt$$

Full code is included in Appendix A of this report. To verify the results, online tool PVWatts was used. Based on the PVWatts analysis (using weather data from Abu Dahbi airport), it was estimated that the 10.4 kW Desert Rose system would generate approximately 18,542 kWh per year. Based on the MATLAB script developed by UOW, it was estimated that the system would generate 19,005 kWh per year, only differing by the PVWatts calculation by 2.44%. For a detailed breakdown of the energy analysis, see Section 5 of this report.

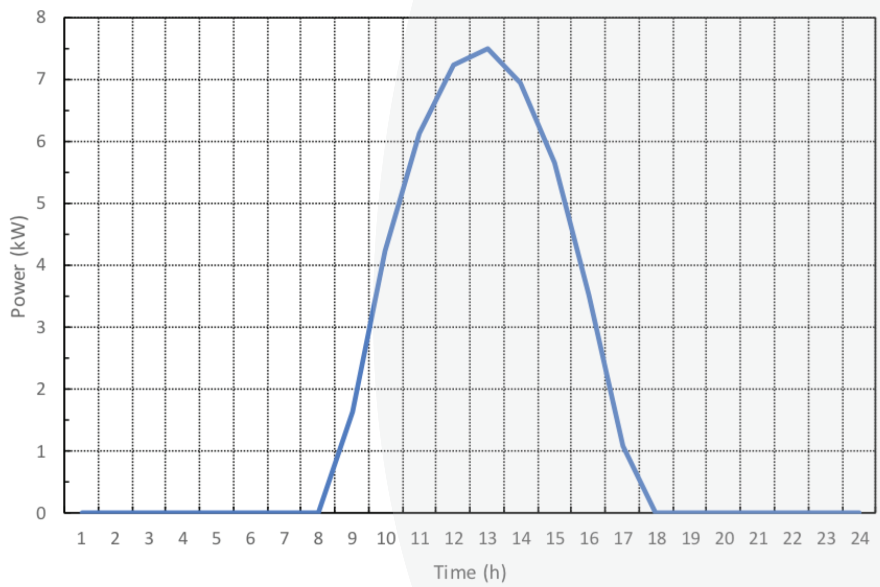


Figure 3.60 - PV Output Power Curve

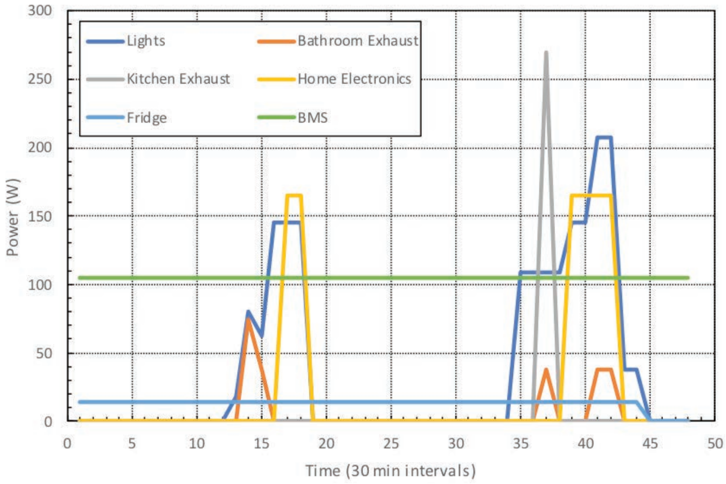
3.3.5 Simulations

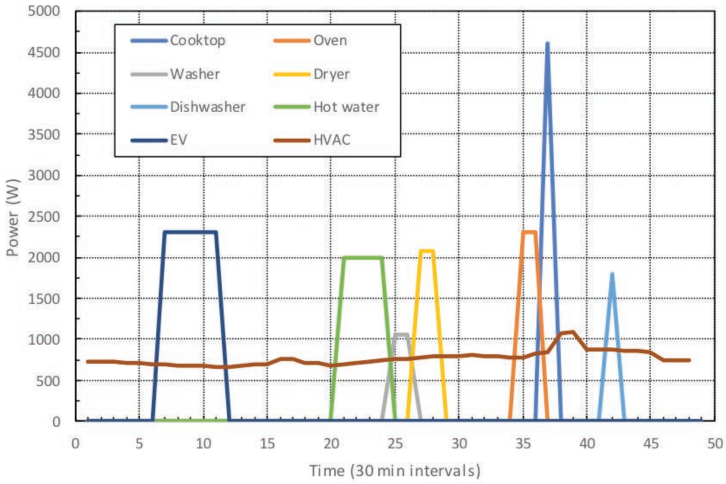
a) Annual Energy Simulation

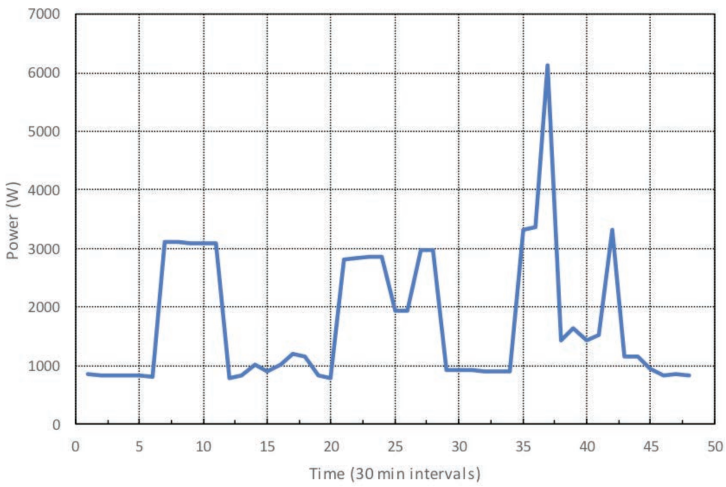
Desert Rose Electrical Consumption

Along with the calculated power output of the Desert Rose solar PV system, detailed daily load profiles are required to determine if the house will achieve net-zero energy. The load profiles were created my summing all individual loads over the course of a day. The average daily load profile for the Desert Rose house is shown to the right.

An individual load profile was created for each day with a different load profile created for weekends, assuming that clothes washing/drying and entertaining guests occurred during these days. Summing over the course of one year gave the total house energy consumption. The HVAC electrical load profile was generated using software package TRNSYS. Additional electrical load profiles were generated using recorded load data from the Desert Rose house. The annual electrical energy consumption of the Desert Rose house is shown below.







Top Right: Figure 3.61 - Desert Rose Small Electrical Loads

Middle Right: Figure 3.62 - Desert Rose Large Electrical Loads

Bottom Right: Figure 3.63 - Desert Rose Combined Electrical Loadcurve

Below: Table 3.33 - Desert Rose Calculated Energy Consumption

Annual Energy Consumption		
Total Energy Annual	**Week Day Energy Annual**	**Weekend Energy Annual**
13923.67 kWh	9687.22 kWh	4236.45 kWh
Daily Average	**Weekday Average**	**Weekend Average**
38.15 kWh	37.12 kWh	40.74 kWh

Desert Rose Annual Energy Production

The following are the results of the electrical energy production simulation for the Desert Rose house. The expected output of the solar PV is calculated using a MATLAB script discussed in Section 4. The script calculated the expected generation from the 10.4 kW of solar every hour for the whole year. The results of the solar PV energy analysis are shown below. The 'Best Case' scenario is calculated using the clear sky irradiance curve. The 'Average Case' is calculated using the average solar irradiance curves of the three-year MBR solar data provided by the SDME organisers. The 'Worst Case' is calculated using the worst solar irradiance data for each day from the three-year MBR solar park historical data.

Based on these results, even during poor weather conditions, the 10.4 kW solar system on the Desert Rose is still able to supply 100% of the household load.

Table 3.34 - Desert Rose Calculated Energy Production

Annual Energy Production		
Best Case (kWh)	Average Case (kWh)	Worst Case (kWh)
21354.50	19005.00	16709.20
Average Daily Energy Production		
58.51	52.07	45.78

Desert Rose Monthly Energy Production and Consumption

The table below breaks down the monthly energy consumption and production of the Desert Rose house. The table also highlights the benefits of being able to cool the Tractile solar tiles with expected efficiency increases. This is particularly significant in the summer months which show an average increase in efficiency as high as 8.6%. This is the equivalent of having an additional 900W of solar installed on the house.

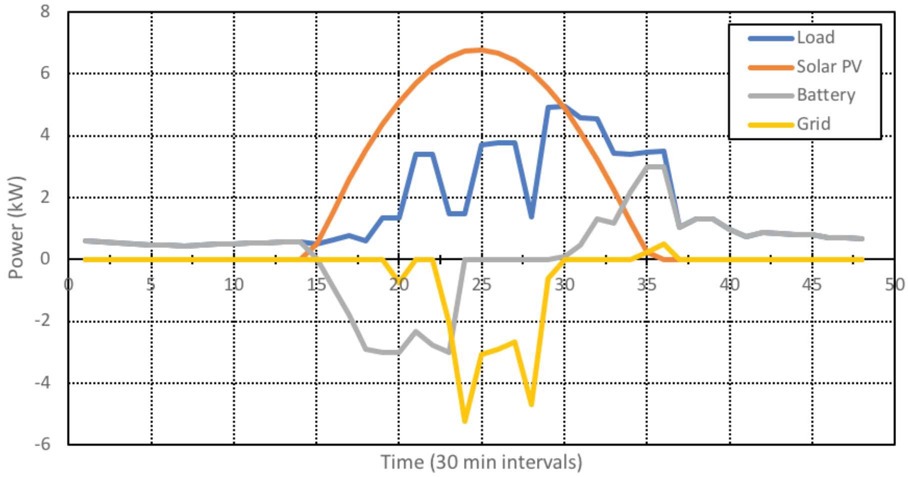
Table 3.35 - Monthly Energy Analysis Examining Cooling of Solar Tiles

Monthly Energy Analysis				
Month	Average Energy Production (kWh)	Average Energy Production w/ Cooling (kWh)	% Increase in Efficiency w/ Cooling	Average Energy Consumption
January	1337.66	1345.48	0.58	1001.31
February	1381.30	1404.73	1.67	926.69
March	1596.33	1640.73	2.71	1064.16
April	1772.60	1873.24	5.37	1124.46
May	1861.97	2011.73	7.44	1214.29
June	1809.17	1960.56	7.72	1289.45
July	1743.18	1900.87	8.30	1377.90
August	1727.25	1889.72	8.60	1263.90
September	1631.50	1764.90	7.56	1313.90
October	1556.23	1645.85	5.44	1275.01
November	1294.84	1328.66	2.55	1059.66
December	1292.94	1306.47	1.04	1012.95

Contest Period Energy Simulation

An in-depth energy analysis was undertaken to determine the expected energy consumption and production for the solar decathlon competition. The analysis was undertaken for the measured periods of the competition (18/11 – 27/11). The load profile for each day was created based on the detailed competition schedule provided by the SMDE organisers. An example of a load profile is shown below. Negative values for battery power indicate the battery is charging and negative values for grid energy indicate the solar inverter is exporting power to the grid.

Table 3.36 - November 19th competition energy profile



Integrating each curve gave the total energy usage for the competition. Using this data, the charging/discharging cycles of the energy storage was calculated and subsequently, the total cost of energy for each day. The results are shown.

Table 3.37 - November 19th Competition Energy Profile

Date	Energy Consumption (kWh)	Energy Production (kWh)	Grid Energy Import (kWh)	Grid Energy Export (kWh)	Total Cost (Shams)	SoC at end of day (%)	Self-Consumption (%)
18-Nov	33.81	45.19	0.00	19.72	0.00	45.78	100.00
19-Nov	39.07	45.04	0.37	11.02	1.41	19.32	99.05
20-Nov	38.05	44.88	2.48	7.09	2.48	39.53	93.48
21-Nov	37.67	44.73	0.60	7.23	0.60	47.99	98.41
22-Nov	26.63	44.59	0.67	22.18	2.01	25.10	97.48
23-Nov	22.13	44.44	2.24	20.30	2.24	55.69	89.89
24-Nov	26.21	44.31	0.50	23.48	1.51	22.22	98.07
25-Nov	35.63	44.17	2.51	7.52	2.51	50.17	92.95
26-Nov	35.88	44.05	0.00	9.33	0.00	45.77	100.00
27-Nov	29.81	43.92	6.17	13.70	13.95	100.00	79.31
Total	**324.89**	**445.32**	**15.55**	**141.57**	**26.70**	**N/A**	**94.86**

3.3.6 Results and Discussion

The following section outlines the results of the energy analysis. Section

a) 'Standard PV systems'

It was one of Team UOW's goals from the beginning of the project to avoid using standard PV systems. Instead, Team UOW decided to integrate an innovative BIPV-T system into the building envelope. The BIPV-T solar tiles cover the entire southern facing portion of the Desert Rose house, therefore, there is no 'Standard PV' installed on the house.

b) BIPV System

The Desert Rose has an extremely unique building integrated photovoltaic-thermal system installed on the house. The system is made up of 104 solar tiles with a combined rated output of 10.4 kW from Australian company, Tractile Solar.

Team UOW have been able to incorporate the solar tiles in the building construction to create a 5-in-1 system. The solar tiles not only produce all of the house's electricity, but they also completely replace the roof construction on the southern facing portion of the house. The unique design means there is no need for roof sheeting. Instead, the interlocking tiles make up the entire roof and are able to withstand extreme weather conditions such as cyclonic winds and hail.

Along with producing electricity, the solar tiles contain water channels that run underneath the tiles which serve three purposes. Firstly, the water channels are connected to the houses hot water unit, which pumps water through the tiles during the hottest parts of the day to produces our domestic hot water.

Secondly, running water through the solar tiles creates a heat exchange effect, cooling the tiles down which can increase the total energy output of the system by up to 10% over the course of a day. This is key in the hot Dubai climate. Finally, by cooling the tiles down, the houses roof construction is essentially cooled down which in turn cools down the building envelope, acting like an insulating active element. Again, this feature is extremely beneficial for the hot Dubai climate.

c) Energy Balance

The results of the energy analysis show that the Desert Rose house will not only achieve net-zero energy but will be a net-positive energy house both during the competition week and annually. That is, the energy generated from the house's BIPV-T system is greater than the energy consumed within the house.

Table 3.38 - Competition Calculated Energy Export and Cost

Annual		
Energy Produced (kWh)	**Energy Consumed (kWh)**	**Excess Energy (kWh)**
19005.00	13923.67	5081.33
Competition		
445.32	324.89	120.44

3.3.7 Energy Payback Analysis

a) Standard PV Systems

Similar to Section 6, there is no need to complete an analysis for 'Standard' PV systems on the Desert Rose house as there is none.

b) BIPV Systems

This analysis will relate to the Desert Rose BIPV-T system. To determine the payback period of the solar PV system, a daily electrical load profile is required along with a solar PV output curve, battery power curve and gird import/ export curves. The load profile used was the Combined electrical load profile presented in Section 3.5. The average PV output curve was calculated using the MATLAB script presented in Section 3.4. Combining all power curves gives the following.

The energy from the solar PV that is used to supply the household loads and charge that battery is considered free energy, therefore, there is no cost associated with it. The only energy that has an associated cost is the grid energy.

The following table shows the energy produced/consumed by each system over the course of a day.

As it is not possible to quantify the value for BIPV-T system in the SDME 'Shams' currency, the following economic analysis will be completed considering Australian dollars. According to Energy Australia [2], the fixed price electricity in Wollongong is AUD \$0.2978/kWh. Additionally, they provide a feed in tarriff for solar energy of AUD \$0.125/kWh in New South Wales [3].

The daily price paid for energy (ignoring connection fees) is therefore:

$$Daily\ cost = (Grid_{import} \times \$0.2978/kWh) - (Grid_{export} \times \$0.125)$$

$$Daily\ cost = (2.2\ kWh \times \$0.2789/kWh) - (10.06\ kWh \times \$0.125)$$

$$Daily\ cost = AUD - \$0.6023$$

$$\therefore Annual\ cost = AUD - \$219.84$$

Considering no solar, the cost would be:

$$Daily\ cost\ no\ solar = (House_{Load} \times \$0.2978/kWh)$$

$$Daily\ cost\ no\ solar = (41.84\ kWh \times \$0.2978/kWh)$$

$$Daily\ cost\ no\ solar = AUD\ \$12.45$$

$$\therefore Annual\ cost\ no\ solar = AUD\ \$4542.75$$

This gives net saving of AUD\$4762.59/yr.

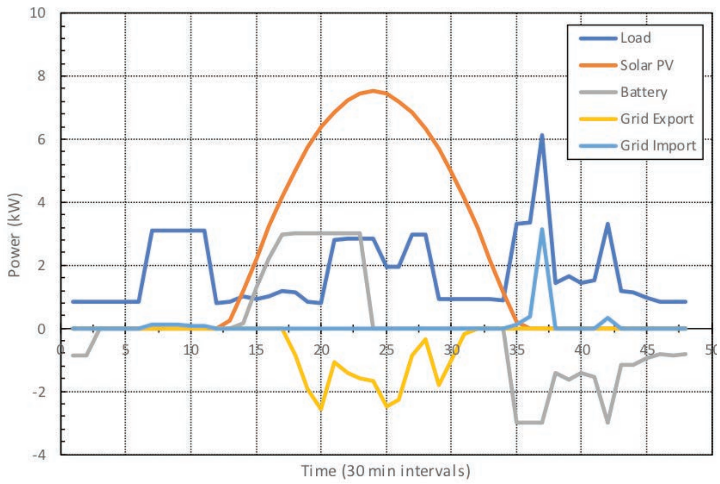


Figure 3.65 - Average Daily Power Exchanges

Table 3.39 - Daily Energy Use and Production

Daily Energy Usage / Production			
Household Load (kWh)	Solar PV Power (kWh)	Grid Import (kWh)	Grid Export (kWh)
41.83	53.24	2.22	10.06

As the Desert Rose will contain a BIPV-T system that replaces the need for a normal roof construction or solar thermal system, the price of these two components must be subtracted from the total capital investment (CAPEX). The equation for the initial CAPEX of the entire system is therefore:

$$CAPEX = C_{Tractile} + C_{ES/Inverter} - C_{Roof} - C_{Solar\ Thermal}$$

Where:

- Ctractile is the cost for the Tractile solar roofing system, plumbing connections and electrical connections (AUD \$30,000 quote).
- CES/Inverters is the cost of the two energy storage systems/ inverter (AUD \$20,000 quote)
- Croof is the cost for a colourbond roof (70m²) in Australia (AUD\$14000 [4])
- Csolar thermal is the cost for evacuated tube solar thermal system (AUD \$3600)
- Therefore, the total capital investment for combined BIPV-T/ energy storage system is \$27000.

Using the simple payback formula (6), the payback period can be determined.

$$Simple\ Payback = \frac{Initial\ CAPEX}{Annual\ Savings}$$

$$Simple\ Payback = \frac{AUD\ \$32,400}{AUD\ \$4762.75}$$

$$Simple\ Payback = 6.80\ years$$

3.3.8 Conclusion

From the energy report, it is evident the 10.4 kW of BIPV-T will meet all of the energy requirements of the Desert Rose house. Based on current estimates, the system will produce 19,005 kWh of energy annually, while only consuming 13,923.67 kWh of energy, making the Desert Rose a net-positive energy house. On average, the house will only require around 2.22 kWh of energy from the grid per day for cooking. This leads to the house being supplied by 94.69% renewables. The payback period considering Australian Residential electricity prices and feed-in tariffs is 6.80 years, much less than the expected 15 year life of batteries and 25 year life of the solar PV.

Project Management

4

4.1 Team Competition Strategy

This section details the strategy and approach that Team UOW is taking to the Solar Decathlon Middle East competition. The organisational structure and project timeline is also detailed along with the course integration and sponsorship schedule.

Team UOW is taking a 'human centred' design strategy which places the occupant at the heart of the solution rather than as a problem. We believe this is the key to innovating long lasting and high impact solutions to sustainable, environmental and health challenges. This strategy takes us into the homes of people who we envision will live in Desert Rose houses.
By walking in the shoes of the occupant we gather an understanding of their needs and wishes, and we seek to encompass these in a sustainable, environmental and healthy manner.

4.1.1 Competition Approach

Team UOW is taking a bold and original approach to the SDME 2018. By constructing a house that is designed for the ageing demographic, Team UOW is taking up the challenge set by the U.S. Department of Energy (DoE) and the Dubai Electricity and Water Authority (DEWA) goals "to contribute to the knowledge and dissemination of industrialized, solar and sustainable housing". We believe that the healthy homes for the elderly approach has the greatest practical potential to achieve significant economic, environmental and health benefits across the Middle East and the Australian built environment.

This approach led us to adopt the design philosophy of "architecture that celebrates human life rather than itself" with a motto of creating 'A House for Life'. Team UOW's vision for the Desert Rose is that someone approaching retirement age will move into a house able to adapt to their needs as they continue to age. Should the occupants develop a disability such as arthritis, mobility issues, or dementia then the Desert Rose is designed to be easily adapted to meet those needs so that the residents can enjoy the highest quality of life possible. Team UOW's design principles have merged the Middle Eastern cultural influence with that of an Australian culture and have met the needs of someone living with dementia and aged related disabilities.

4.1.2 Team UOW Organisational Structure

Team UOW has two primary executive committees: the Governance Committee; and Management Committee. The Governance Committee is responsible for the overall project direction and approval of expenditures, and the Management Committee is responsible for the overall management and organisation of the team and its members. Further to this Team UOW have five primary sub-teams that consist of the Building Services Team, Communications Team, Design and Construction Team, Liveability Team, and Operations Team. These teams are student led and consist of decathletes within a series of smaller teams as shown in the Team UOW Organisational structure provided as Figure 4.1.

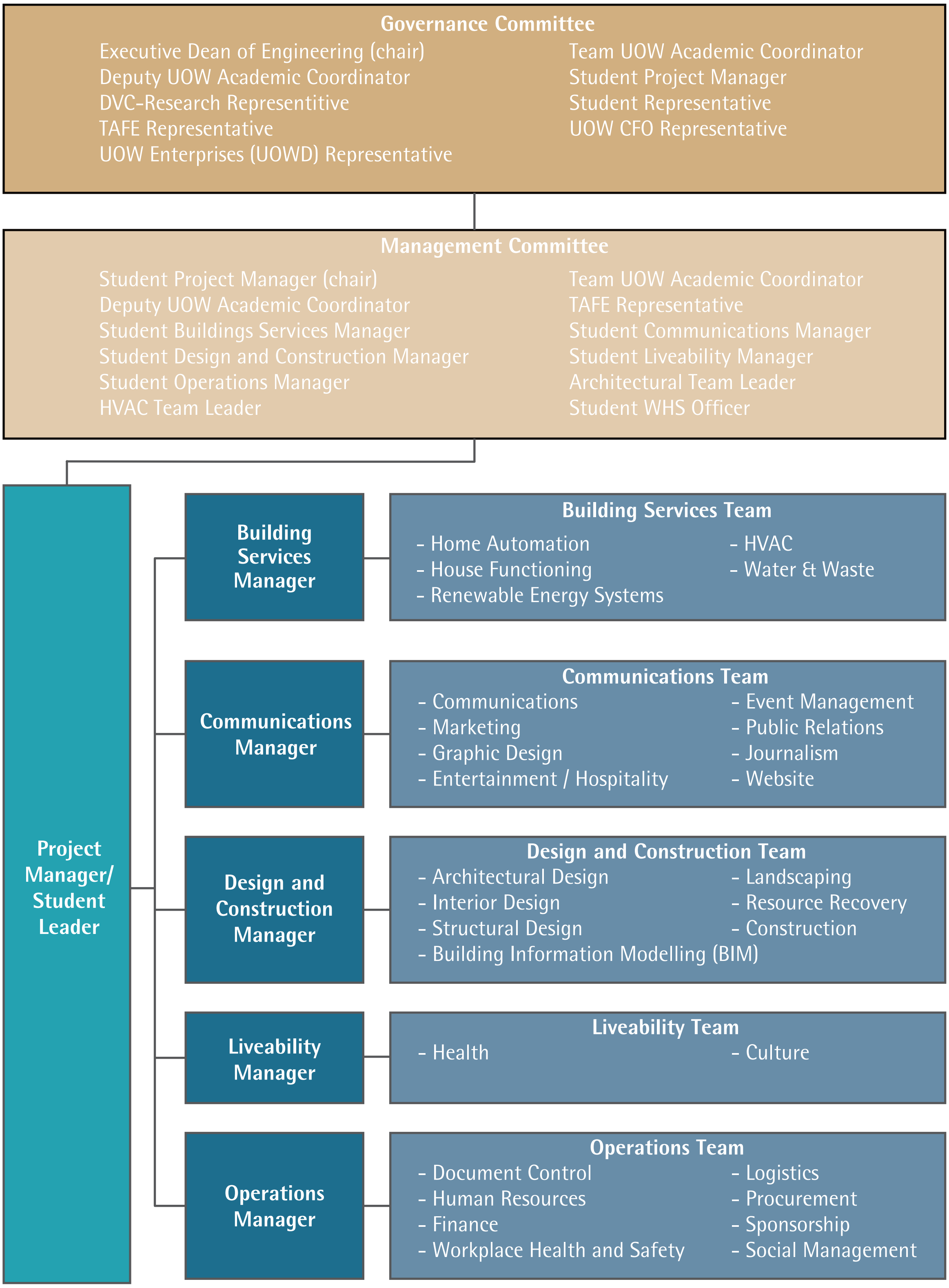


Figure 4.1 - Team Organisational Chart

4.2 Project Schedule

In order to successfully complete our project Team UOW has divided our Desert Rose into eight primary phases. These phases consist of:

Phase 1 – Design: Period where every aspect of the Desert Rose will be designed and detailed.

Phase 2 – Construction: Period when the house will be physically built.

Phase 3 – Demonstration: Upon completion of construction the Desert Rose will have 3 key public demonstrations, the first is a trade night for technical trades, the second a sponsorship night, and the third a week long public display alongside our existing award winning Illawarra Flame house.

Phase 4 – Calibration: The Desert Rose will be tested and the building services will be fine tunned to achieve maximum performance.

Phase 5 – Transportation: The Desert Rose will be packed into shipping containers and transported to Dubai.

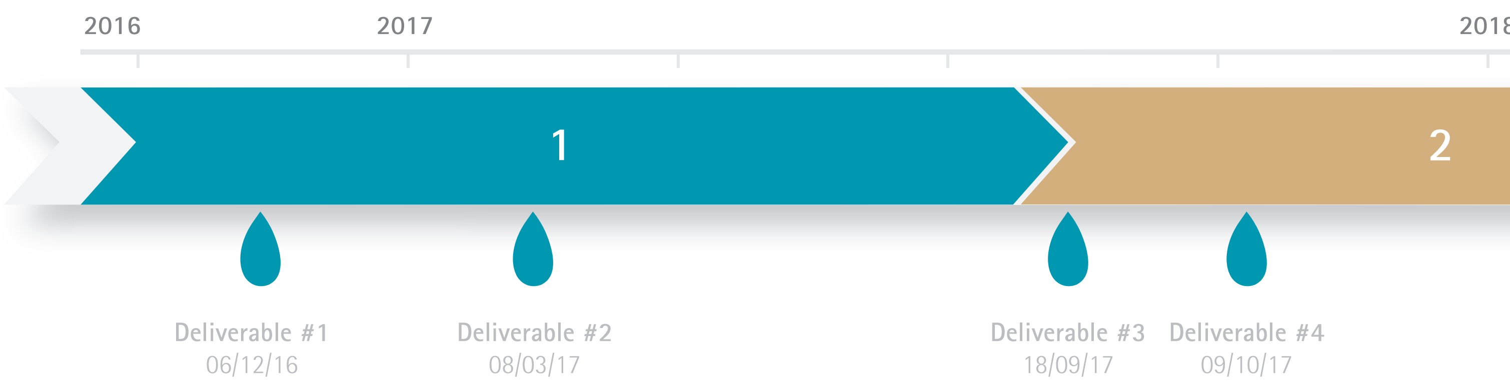
Phase 6 – Pre-Assembly: Team UOW will inspect the Desert Rose on arrival in Dubai for any damages during transport. This phase is a contingency in case any significant damage to the Desert Rose is experienced.

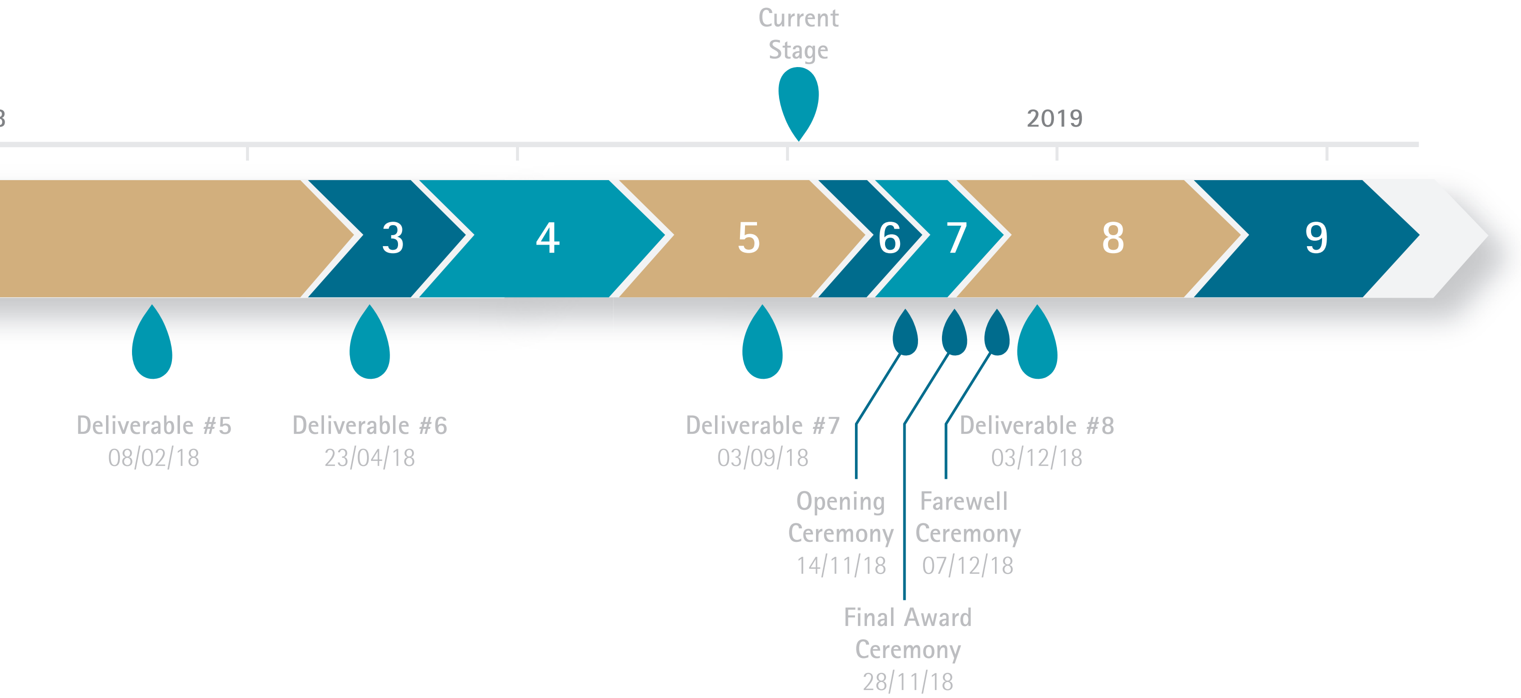
Phase 7 – Competition: The Solar Decathlon Middle East 2018 competition.

Phase 8 – Disassembly and Transportation: The Desert Rose will be disassembled and transported back to Australia.

Phase 9 – Assembly and Demonstration: The Desert Rose will be reassembled in Australia with another week long public display.

An overview of the Desert Rose project timeline and when these phases are scheduled is given below in Figure 4.2.




Current
Stage
2019
3
4
5
6
7
8
9
Deliverable #5
08/02/18
Deliverable #6
23/04/18
Deliverable #7
03/09/18
Deliverable #8
03/12/18
Opening
Ceremony
14/11/18
Farewell
Ceremony
07/12/18
Final Award
Ceremony
28/11/18

Dinner Party Menu

5

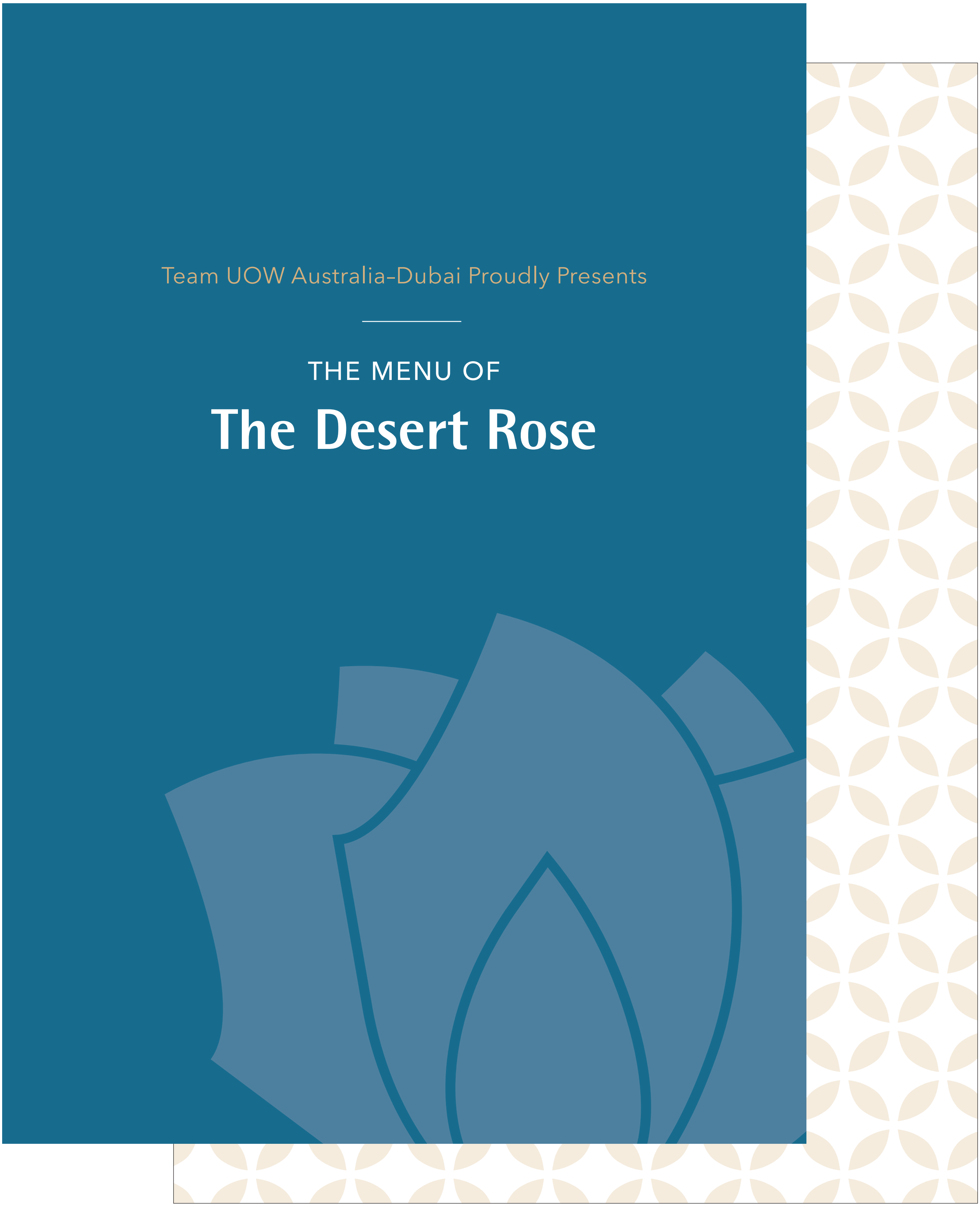


Figure 5.1 - Menu Cover Page and Inside Cover

At the start of 2018 I was given the opportunity to take my **passion for cooking** overseas, all the way to Dubai, to be a part of the Solar Decathlon competition. After a brief meeting and understanding of the ideas behind the Desert Rose House, I began my own journey of discovery and found a new passion for sustainability and dementia care. How to improve a person's lifestyle who is living each day with dementia.

As a chef I thought to myself, **how can I help** these people and how can I create menus based around these ideas. I started researching and discovered vitamins and minerals which help prevent the deterioration of the brain i.e. help prevent dementia. My menus have been based around these food groups which contain these vitamins and/or minerals. Each major protein in my menu items contains a major vitamin, for example Barramundi contains fish oil and magnesium. My menus will hopefully showcase home cooking which is not only rich in nutritional value but easy to cook as well.

Another thought which crossed my mind in the development stage of these menus was 'which avenue am I going to take cuisine wise?' Did I want to showcase just Australian food? Or did I want to show versatility? I chose to showcase the **versatility of Australian chefs** and how well we handle cooking different cuisines, being from the multicultural country that we are and the influences these cultures have on our food culture. Over the three nights I am showcasing foods from Native Australia, Modern Asia and The Middle East.

I have set myself the challenge of cooking three different cuisines which are of **restaurant quality in a home environment.** I have done this to show that no matter what country you are from, there are ways in which we can all do our part to help prevent the deterioration of our brains and to help better the lifestyle of people currently living with dementia. This starts with our diets and cooking simple meals from our home kitchen.

Alex

Figure 5.2 - Menu Page One

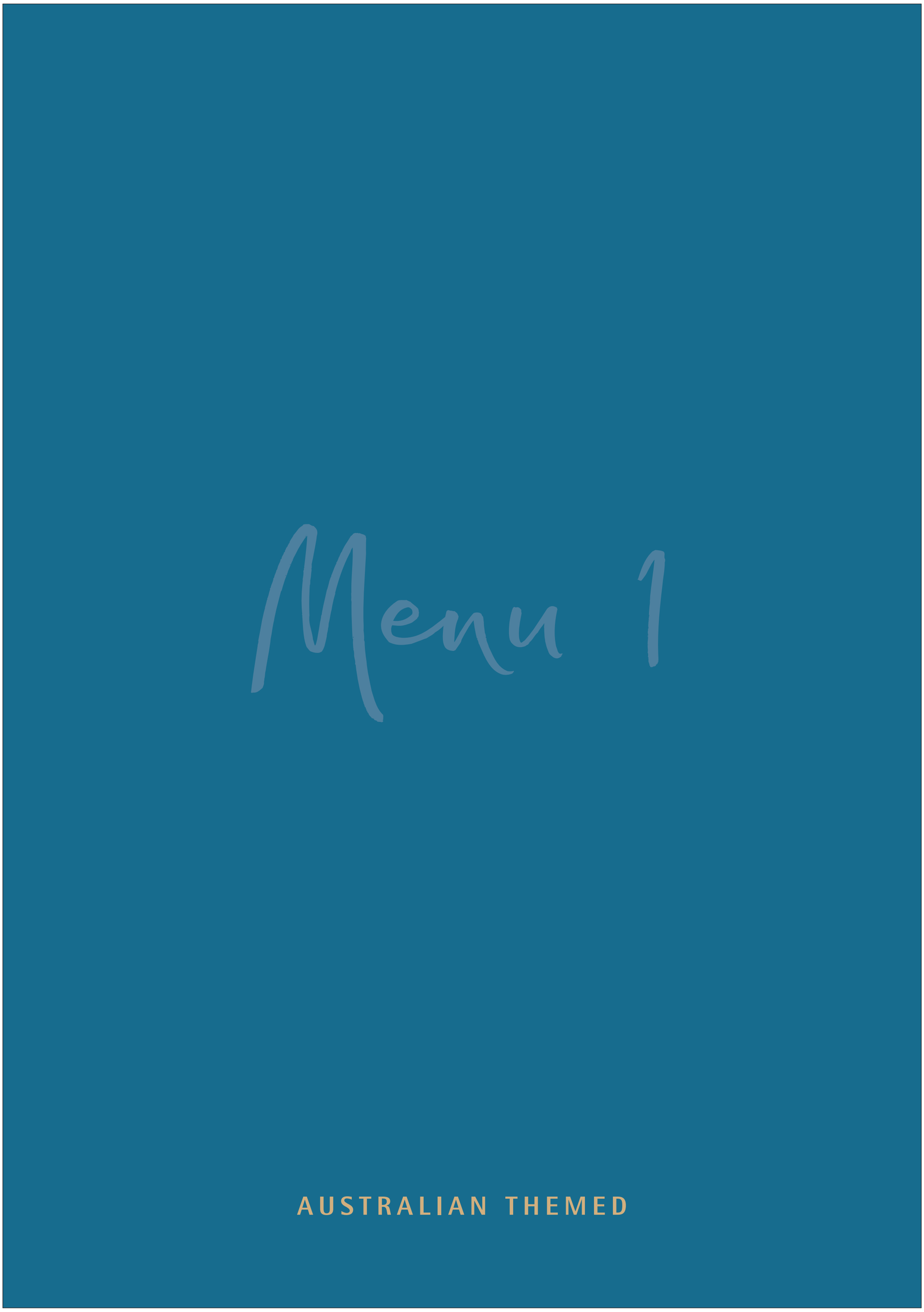


Figure 5.3 - Menu Page Two

ENTREE

Native Thyme and Pepperberry Meatballs
with Spiced Avocado and Nahm Jim Dressing

MAIN

Crispy Skin Lemon Myrtle Barramundi
with Native Thyme and Pepperberry Mayo,
Roast Beetroot and Goats Cheese Salad

DESSERT

Kaffir Lime Pavlova with Poached Seasonal Fruits
and Wattle Seed Cream

DRINKS

Lemon Aspen Lilly Pilly Cordial – Entree and Main
Native Tea and Coffee – Dessert

Figure 5.4 - Menu Page Three

NATIVE THYME AND PEPPERBERRY MEATBALLS WITH SPICED AVOCADO AND NAHM JIM DRESSING

Ingredients

1.6kg Wagyu Mince
1 tbsp Pepperberries, crushed
1 tbsp Native Thyme
2 Eggs
½ cup Bread Crumbs
4 Chillies, de-seeded
4 Garlic Cloves
40g Coriander Root
20g Palm Sugar
40g Fish Sauce
4 Ripe Avocados
2 Lemons (zest and juice)
2 tbsp Ground Cumin
Olive Oil
Salt and Pepper to taste
20g Lime Juice
1 Eshallot

Serves 8

Figure 5.5 - Menu Page Four

METHOD

1. Preheat oven to 200°C and line a baking tray with baking paper.
2. Place Wagyu mince, eggs, breadcrumbs, pepperberries and native thyme in a large mixing bowl and combine until all ingredients are mixed in well together.
3. Form meatballs and weigh out to 50g per ball and set aside.
4. To make Nahm Jim dressing:
   Finely dice chillies, eshallot, garlic cloves and coriander and grind in mortar and pestle, add sugar and grind again.
   Add fish sauce and cut with the lime juice.
   Place in a container and set aside.
5. Peel avocados and dice into a bowl. Add lemon juice, a pinch of salt and cumin. Smash with a fork until avocado is pureed and ingredients are well combined. Pass through a sieve to remove lumps. Place cling wrap over the mix cartouche style and place in fridge.
6. Heat a frying on a medium-high heat with olive oil.
   Place meatballs in to seal on top and bottom.
   Place in baking tray and finish off in oven for 8-10mins.
7. Once meatballs are cooked through, pull out and place on baking paper to drain.
8. To plate, smear avocado and place 4 meatballs per person in the smear. Swirl Nahm Jim around the plate.
   Garnish with fresh thyme and salt flakes.

Figure 5.6 - Menu Page Five

CRISPY SKIN BARRAMUNDI, NATIVE THYME AND PEPPERBERRY MAYONNAISE WITH ROAST BABY BEETROOT AND GOATS CHEESE SALAD

Ingredients

8x 150-160g Barramundi Fillets (skin on)
8 Baby Beetroot, peeled and halved
100-150g Goats Cheese
400g Balsamic Vinegar
100g Brown Sugar
200-300g washed Roquette
200g Olive Oil (100g for Salad Dressing)
2 Egg Yolks
10g White Vinegar
5g Dijon Mustard
1 pinch Native Thyme
1 pinch Crushed Pepperberries
Salt and Pepper to taste
250-300g Vegetable Oil

Serves 8

Figure 5.7 - Menu Page Six

METHOD

Mayonnaise

1. Combine egg yolks, white vinegar, Dijon mustard, native thyme and pepperberries in a bowl.
2. Whilst whisking, very slowly add the vegetable oil making sure not to split it. Once all oil is combined and mayonnaise is thick, season with salt and pepper to taste.

Barramundi

1. Preheat oven to 200°C
2. Score skin of the barramundi and rub salt in. Place on a lined tray and set aside.
3. Add balsamic vinegar and brown sugar to a medium saucepan. Stir sugar over medium heat until it is dissolved. Bring to the boil and then place on low until liquid is reduced by a half. Place in jar and set aside to cool.
4. Add baby beetroot to a tray and coat generously in olive oil, pinch of native thyme, season and roast in oven for 10-15 mins or until soft. Pull out and set aside to cool.
5. Heat fry pans with a generous amount of olive oil until almost smoking. Place barramundi carefully skin side down and cook until skin releases from the pan. Sprinkle with lemon myrtle and finish off in the oven for 5-10mins.
6. Assemble salad in a bowl with roquette, baby beetroot and crumbled goats cheese. Coat with a touch of olive oil and mix through.
7. Assemble on a plate. Smear mayonnaise on base, place fish on top, salad on the side and balsamic glaze around the outside.

Figure 5.8 - Menu Page Seven

KAFFIR LIME PAVLOVA WITH POACHED SEASONAL FRUITS AND WATTLE SEED CREAM

Ingredients

6 Egg Whites
875g Caster Sugar
2 tsp Corn Starch
½ tbsp Lemon Juice
½ tbsp Vanilla Extract
500mL Pure Cream
500g Water
1 stick Cassia Bark
2 Star Anise
1 Chilli, sliced
1 punnet Blueberries
½ punnet Strawberries
1 tbsp Wattle Seeds
2 Kiwi Fruit
1 punnet Raspberries

Serves 8

Figure 5.9 - Menu Page Eight

METHOD

Poached Fruits

1. In a medium saucepan, bring 500g sugar, water, chilli, star anise, and cassia bark to a boil.
2. Strain sugar syrup and place back on the heat to simmer.
3. Add fruits and simmer for 2 minutes. Take off heat and set aside to cool in fridge.

Pavlova

1. Preheat oven to 130°C. Line a baking tray with baking paper.
2. Whisk egg whites at a medium speed with wattle seeds until soft peaks form. Gradually add sugar and beat on high speed for 10 minutes or until stiff peaks form.
3. Using a spatula, fold in lemon juice and vanilla extract. Once combined, fold in corn starch and mix well.
4. Using a piping bag, pipe meringue into 8 shapes onto lined baking tray using a Wilton 1M tip.
5. Bake at 130°C for 75 minutes then turn oven off. Without opening the oven door, let meringue sit in oven for another 30 minutes. Transfer to cooling rack and cool at room temperature.
6. Once cooled, plate on some scattered poached fruits, place meringue on top and pipe on Chantilly cream. Squeeze finger lime over fruits and garnish Pavlova with some more wattle seeds and fresh mint.

Figure 5.10 - Menu Page Nine

Figure 5.11 - Menu Page Ten

ENTREE

Duck Breast Soba Noodles
with Mushroom Dashi Broth, Crisp Garlic and Eshallots

MAIN

Miso Marinated Barramundi, Aonori Mayonnaise
with Cucumber and Papaya Salad

DESSERT

Sweet Coconut Sushi rolls, Mixed Seasonal Fruit Compote,
Tempered Chocolate and Wattle Seed Cream

DRINKS

Yuzu Lemonade – Entree and Main
Tea and Coffee – Dessert

Figure 5.12 - Menu Page Eleven

DUCK BREAST SOBA NOODLES WITH MUSHROOM DASHI BROTH, CRISPY GARLIC AND ESHALLOTS

Ingredients

4x 250g Duck Breast (skin on)
1L Water
200mL Mirin-Fu
200mL White Grape Juice
1 sheet Dried Kombu
30g Bonito Flakes
270g Organic Soba Noodles
1 clove Smoked Garlic
4 sprigs Shallots
250g Bean Sprouts
200g Shiitake Mushrooms
100g Dried Wakame
300mL Thin Soy Sauce
50-100mL Mushroom Soy Sauce
1 tsp salt

Serves 8

Figure 5.13 - Menu Page Twelve

METHOD

Dashi Broth

1. Place water, soy and kombu sheets in a pot and bring to the boil.
2. In another small saucepan, combine mirin-fu and white grape juice. Bring to the boil and add to pot.
3. Once boiled, turn off heat and add the bonito flakes.
   Sit for 20mins and then strain broth through muslin cloth.
   Stir in mushroom soy sauce 20mL at a time until taste is balanced.

Duck Breast

4. Preheat oven to 200°C.
   Add wakame to some water to rehydrate it.
5. Score the skin of the duck breast and rub with salt.
   Place skin side down in a fry pan and cook on low heat for 10mins or until fat has rendered and the skin is golden brown.
   Flip breasts and set aside.
6. Bring to the boil water in a pot and cook soba noodles until al dente. Strain and add a touch of oil to prevent them sticking together.
7. Thinly slice shiitake mushrooms and remove stalk. Fry off in a touch of grapeseed oil and garlic. Once cooked add a touch of mushroom soy sauce to de-glaze the pan. Allow mushrooms to soak up the sauce.
8. Set up pot of boiling water, dashi broth in pot to heat, cut duck breasts in half and place on a tray skin side down on a greased oven tray and thinly slice shallots. Place breasts in the oven and cook for 2mins to reheat them. Quickly blanch noodles to reheat.
9. To plate, place noodles. Add the mushroom dashi broth, wakame and shiitake mushrooms and bean sprouts.
   Fan 1 half of the duck breast over each serve and season with salt.

Figure 5.14 - Menu Page Thirteen

MISO MARINATED BARRAMUNDI, AONORI MAYONNAISE WITH CUCUMBER AND WAKAME SALAD

Ingredients

500g Shiro Miso Paste
195g Mirin-Fu
100g White Grape Juice
248g Caster Sugar
165g Sushi Vinegar
150g Yuzu Juice
8x 160-200g Barramundi Fillets (skin on)
2 Telegraph Cucumbers
20g Dried Kombu
300g Grapeseed Oil
150g Rice Vinegar
5g Grated Ginger
15g Kikkoman Soy Sauce
100g Vegetable Oil
1 pinch Dried Aonori
4 sprigs Shallots, finely sliced
30g Dehydrated Wakame, rehydrated

Serves 8

Figure 5.15 - Menu Page Fourteen

METHOD

Yuzu Miso

1. Cook off mirin-fu (165g) and white grape juice in a pot.
   Add miso paste on a medium heat and stir until smooth.
   Add sugar and once dissolved set aside to cool. Once cooled, add sushi vinegar and yuzu juice and stir until combined.

Barramundi

1. Preheat oven to 200°C. Check barramundi fillets for any bones, portion into 80g pieces and place in a tray.
   Cover with yuzu miso and stand in fridge until ready for use.
   Keep some yuzu miso in a bottle for plating.
2. Combine grapeseed oil, vegetable oil, rice vinegar, aonori, remainder mirin-fu, grated ginger and soy sauce in a bowl.
   Once well combined, add vinaigrette to a bottle.
3. Cut cucumbers into thirds and using a mandolin, slice cucumber lengthways as thinly as possible.
   Combine in a bowl with kombu, wakame and shallots.
4. Line a baking tray with baking paper and place barramundi fillets on top. Place in the oven and cook for 8-10mins.
5. Once fish is cooked through, pull out of oven and plate.
   2 pieces of barramundi per serve. Add a generous amount of vinaigrette to salad bowl and mix through.
   Place salad next to the fish and dress fish with yuzu miso.

Figure 5.16 - Menu Page Fifteen

SWEET COCONUT SUSHI ROLLS, MIXED SEASONAL FRUIT COMPOTE, TEMPERED CHOCOLATE AND WATTLE SEED CREAM

Ingredients

400g Caster Sugar
250g Water
2 sticks Cassia Bark
2 Star Anise
250g Sushi Rice
400g Coconut Cream
4 large Strawberries
1 punnet Blueberries
1 Kiwi Fruit
1 handful Mint Leaves for garnish
125g Belgian Chocolate
250-300g Pure Cream

Serves 8

Figure 5.17 - Menu Page Sixteen

METHOD

1. Bring coconut cream and 150g caster sugar to the boil in a saucepan, then simmer for 2-3 minutes. Place in fridge to cool.
2. In a pot, add sushi rice and wash off excess starch. Cover with water until it reaches your knuckles with a flat hand on top. Bring rice to the boil, turn temperature to low and cover for 8 minutes. Turn off heat and leave for another 8 minutes, still covered.
3. In another pot, bring 250g caster sugar, water, cassia bark and star anise to the boil, simmer for 5 minutes and strain. Once finished, place back on the heat to simmer and add prepared fruits to simmer for 2mins. Place in fridge to cool.
4. Combine rice in a tray with coconut cream and agitate with a wooden spoon until a gluey consistency is formed. Gradually add the coconut cream until desired taste is achieved. Cool rice in fridge.
5. Once rice is cold, form the desired sushi roll shapes.
6. Melt chocolate in a bowl over a boiling pot. Using baking paper, cut desired lengths and heights and wrap the sushi rolls in chocolate. Cut the paper to match the height of the rolls. Set in fridge.
7. Whip cream with a small amount of caster sugar and wattle seeds.
8. Assemble sushi rolls on a serving plate, 3 rolls per serve. Add poached fruits to the top and garnish with mint leaves. Place wattle seed cream.

Figure 5.18 - Menu Page Seventeen

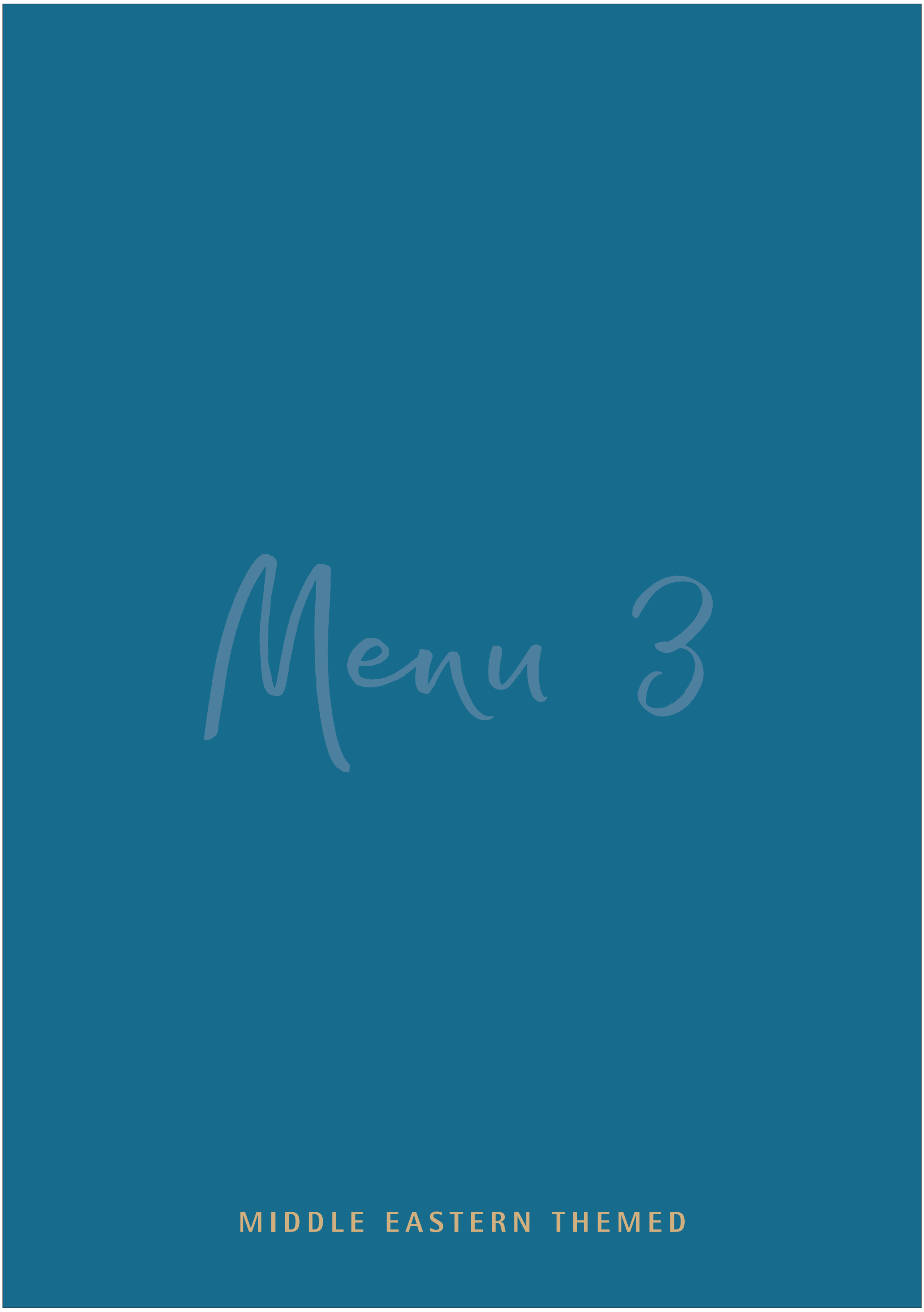


Figure 5.19 - Menu Page Eighteen

ENTREE

Lamb Kofta Skewers
with Housemade Black Hummus
and Tzatziki Dipping Sauces

MAIN

Stuffed Aubergines in Housemade Tahini Sauce
Served with Sumac Spiced Spinach and Toasted Flatbread

DESSERT

Rose infused Milk Pudding with Crushed Pistachios,
Candied Pomegranate Seeds and Rosewater Syrup

DRINKS

Middle Eastern Limonana – Entree and Main
Hibiscus Tea or Coffee – Dessert

Figure 5.20 - Menu Page Nineteen

LAMB KOFTA SKEWERS WITH BLACK HUMMUS AND TZATZIKI DIPPING SAUCES

Ingredients

400g Canned Chickpeas
3 cloves Fermented Garlic
15 cloves Smoked Garlic
½ tsp Squid Ink
1 Fresh Lemon (juice and zest)
3 tbsp Extra Virgin Olive Oil
60g Black Tahini
1 Lebanese Cucumber
¾ cup Flat Leaf Parsley
½ tsp Ground Cinnamon
½ tsp Ground Cardamom
1 tsp White Vinegar
500g Greek Yoghurt
½ tsp White Pepper
1.2kg Ground Lamb Mince
50g Pine Nuts
50g Walnuts
1 small Red Bell Pepper
1 small Jalapeño Pepper, de-seeded
1 tsp Ground Cumin
½ tsp Ground Cloves

Serves 8

Figure 5.21 - Menu Page Twenty

METHOD

Hummus

1. Drain chickpeas and reserve the juice.
2. Combine chickpeas, fermented garlic, 3 cloves smoked garlic, squid ink, black tahini, 2tbsp olive oil and lemon zest and juice in a food processor. Blitz on high until smooth, using reserved chickpea juice if consistency is too thick.
   Strain through a sieve and refrigerate until ready for use.

Tzatziki

1. Blitz cucumber with pinch of salt in food processor.
   Strain and squeeze excess liquid through muslin cloth.
2. Mix 5 smoked garlic cloves, 1tsp white vinegar and 1tbsp olive oil until combined. Add the cucumber and stir in yoghurt and white pepper. Season to taste and refrigerate until ready for use.

Lamb Kofta

1. Preheat oven to 180°C. Place the nuts into a food processor and blitz until finely chopped. Transfer to a fry pan and toast over medium heat until nuts are golden brown and fragrant. Place into a large mixing bowl.
2. Combine onion, garlic, bell pepper, jalapeño pepper and parsley in a food processor until finely chopped but not pureed. Strain vegetables to remove excess liquid.
3. Add vegetables, lamb mince and dried spices to nuts and combine thoroughly. Separate mince into 50g portions and form into small sausage shapes onto pre-soaked skewers.
4. Seal off koftas in a grill pan over a high heat and place on a lined baking tray in the oven for 10mins.
5. To serve, smear tzatziki and place 3 skewers on each plate. Add 2 small scoops of hummus and sprinkle with smoked paprika. Garnish with fresh coriander leaves.

Figure 5.22 - Menu Page Twenty-One

STUFFED AUBERGINES IN HOUSEMADE TAHINI SAUCE SERVED WITH SUMAC SPICED BABY SPINACH AND TOASTED FLATBREAD

Ingredients

7 Garlic Cloves
8 tbsp Tahini
2 Lemons, juiced
4 tbsp Greek Yoghurt
4 Eggplants
300g Minced Lamb
4 400g Tinned Diced Tomatoes
3 tbsp Tomato Paste
1 Brown Onion, finely diced
4 Flatbreads, toasted and broken into pieces
2 small Red Onions, finely sliced
700g Baby Spinach
2 tbsp Sumac
2 Lemons, juiced
1 bunch Flat Leaf Parsley, finely chopped
6 tbsp Pine Nuts, toasted

Serves 8

Figure 5.23 - Menu Page Twenty-Two

METHOD

Tahini Sauce

1. Grind 5 garlic cloves and salt using a mortar and pestle to form a paste. Add tahini and lemon juice and stir until combined. The tahini will form a thick, dry texture. Gradually add water until sauce becomes smooth but not runny.
2. Stir in yoghurt and season to taste.

Eggplant and Spinach

1. Preheat oven to 200°C. Peel eggplants length ways in strips 1-2cm apart to leave a stripy effect all the way around the eggplant. Slice length ways about 1cm thick. Add to a conical strainer and rub with salt over a bowl to draw moisture out. Once moisture is drawn out, pat with paper towel to remove salt and moisture. Roast in oven for about 30-40mins. Once cooked, lay over paper towel to drain excess oil.
2. Fry the red onions in a little olive oil over very low heat for 20mins until softened and almost caramelised.
   Add the spinach leaves and cook until they are just wilted. Turn off heat and set aside.
3. In a separate fry pan, sauté brown onion off, then add mince and cook until brown and soft.
4. Fry off 2 finely chopped garlic cloves in a medium pot until almost cooked. Add tomatoes, 500ml of water and tomato paste. Simmer for 20mins or until thickened.
5. To assemble, add tomato sauce as the base. Roll up 1tsp of mince in 1 slice of eggplant and add to plate. Repeat 6 times per plate. Spoon tahini sauce over the eggplant and sprinkle pine nuts. Top with parsley and any leftover mince.
6. Reheat spinach, sprinkle with sumac and squeezed lemon juice. Stir through and season. Plate a generous amount so there's one plate between two.

Figure 5.24 - Menu Page Twenty-Three

ROSE INFUSED MILK PUDDING WITH CRUSHED PISTACHIOS, CANDIED POMEGRANATE AND ROSEWATER SYRUP

Ingredients

1kg Milk
500g Caster Sugar
3 tbsp Cornflour mixed with water
½ tsp Vanilla Extract
260g Rosewater
Small handful Dried Rose Petals
1 stick Cinnamon
1 small sprig Saffron
1 handful Pomegranate Seeds
20g Pistachios, toasted and crushed

Serves 8

Figure 5.25 - Menu Page Twenty-Four

METHOD

Rosewater Syrup

1. Bring 200mL rosewater, 200g caster sugar, rose petals, saffron and cinnamon stick to the boil until sugar is dissolved. Drop to a simmer for 5mins or until syrup thickens. Strain and set aside in fridge to cool.

Milk Pudding

1. In a saucepan, gently heat the milk and remaining sugar on low heat, stirring regularly. Just before milk boils, stir in cornflour mix and continue stirring until milk thickens.
   Add vanilla and remaining rosewater and stir.
2. Once mixture reaches a thick consistency, pour the mixture into individual glasses and leave to cool. Once cooled, set in fridge for one hour.
3. Add 100g caster sugar and just a touch of water to a pan. Cook until caramel is formed and add pomegranate seeds. Sugar should coat seeds. Take off heat and cool.
4. To serve, spoon rosewater syrup over pudding and garnish with pomegranate seeds, crushed pistachios, rose petals and mint leaves.

Figure 5.26 - Menu Page Twenty-Five

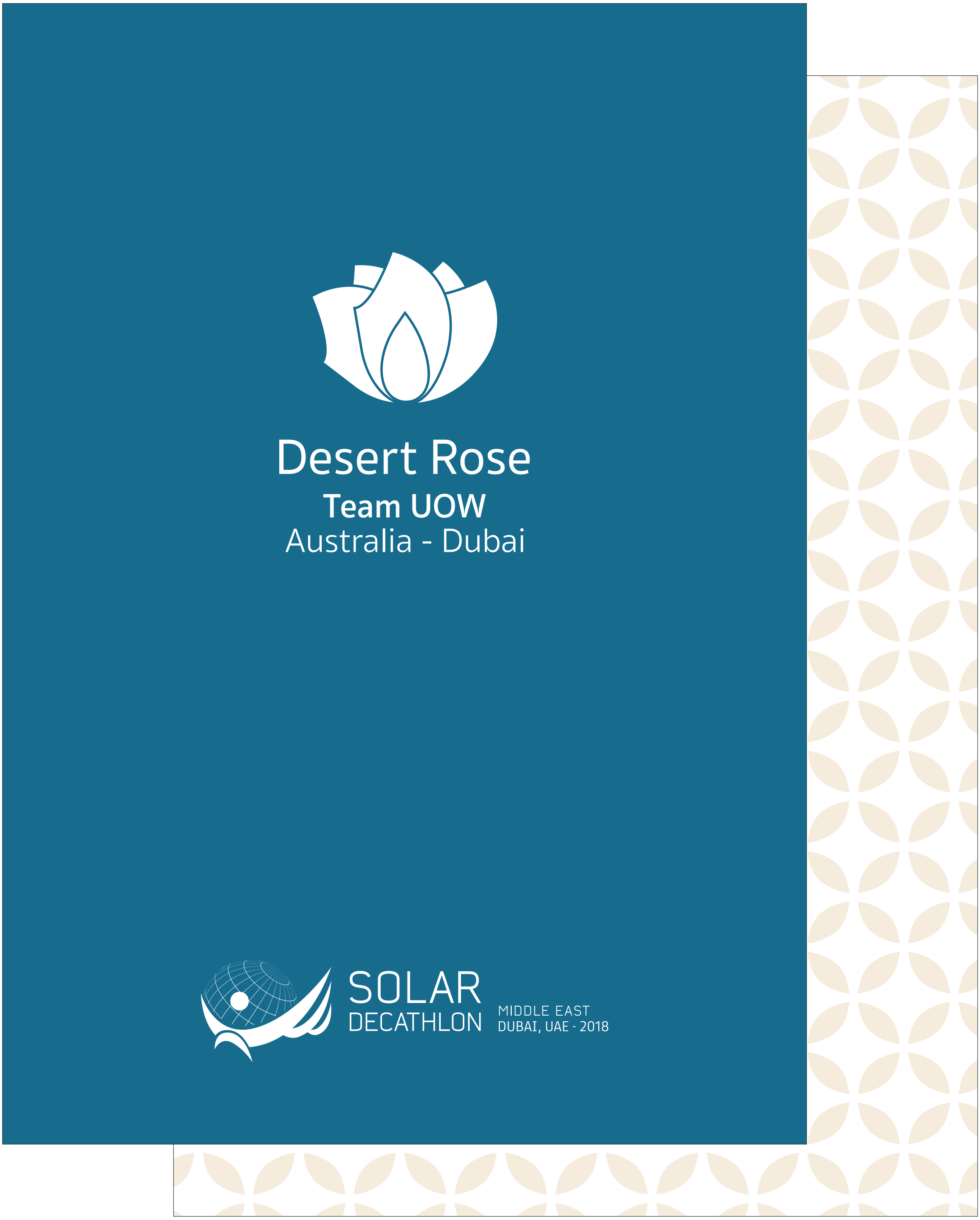


Figure 5.27 - Menu Inside Cover And Back Cover

6

Collaborating Institutions & Sponsoring Companies

6.1 Institutions

Team UOW consists of three collaborating institutes, the University of Wollongong Australia, University of Wollongong in Dubai and TAFE NSW.

- Team UOW is led by the University of Wollongong's Faculty of Engineering and Information Sciences (EIS) and the Sustainable Buildings Research Centre (SBRC). The UOW Faculty of EIS is recognized as one of the leading engineering faculties in Australia and is a member of the prestigious "Group of Eight + 2" top Engineering Faculties in the country. The Go8 universities win ~86% of all Australian competitive R&D funding. Of particular relevance to the SDME project is the Sustainable Buildings Research Centre (SBRC), which is a multi-disciplinary facility that brings together a wide range of researchers to holistically address the challenges of making our buildings more sustainable and effective places in which to live and work. The SBRC is located at UOW's Innovation Campus (iC) which is home to a number of leading research institutes and corporations, and home to the previous Solar Decathlon Illawarra Flame House which stands on our Sustainability Street.
- The University of Wollongong in Dubai (UOWD) was established in 1993 and is one of the UAE's oldest and most prestigious universities. UOWD supports a range of academics recruited locally and internationally and provides undergraduate and postgraduate courses in Business, Engineering and Information Sciences. UOWD's local knowledge and expertise in sensors, smart rotating solar panel, energy and heat simulation in the Simulation and Smart Systems Research Centre provides a perfect partnership.
- TAFE NSW is the leading provider of vocational education within our local region. TAFE has extensive facilities and expertise providing a wide spectrum of educational courses that encompass every facet of building construction and maintenance services and also nursing and aged care. TAFE NSW played a pivotal role in the design and construction of the Illawarra Flame house by providing expertise in the building industry, training and support of Solar Decathletes and the workshop and tools used for the construction of the house.

6.2 Sponsors

Team UOW's Leadership Team is responsible for investigating and approaching suitable potential sponsoring companies. Team UOW's Governance Committee provides the final approvals. Formal agreements have been signed with a number of official sponsors including:

3D Fire Design - Provided the design of our fire system.
Actech – supplies the concrete industry with a wide range of products and supplied us with concrete chairs for our second skin wall.
Architectural Hardwood Joinery (AHJ) - a local joiner who uses recycled hardwood to produce goods. They have provided our doors and window frames.
Arens International – provides solutions for natural ventilation and has provided electric window actuators.
Autodesk – produces a large variety of CAD software and has provided us in-kind licences for the design of our project.

Aspire – is a local events caterer and provided catering to many events hosted by Team UOW

Beacon Lighting – provides a wide range of lighting and ceiling fans and has supported us with lamps, ceiling fans and pendant lighting.

Beaumont Tiles – provides a wide range of tiles and has supported us with tiles for our wet areas.

Betta Wardrobes & Shower Screens – provided our bedroom wardrobes.
Big River Group – provides a wide range of timber products and has supported us with battens, plywood, timber flooring and other timber materials.
BlueScope Steel - BlueScope is the largest steel manufacturing company in the Illawarra region. As a Gold Pillar sponsor in Team UOW's 2013 Solar Decathlon victory, they were very excited to come on board as a sponsor providing all structural frames and various other materials and design support.

BlueScope Win Community Partners – is a foundation that supports local initiatives and has provided cash sponsorship to support the project.

Bremick - provided all of our bolts, nuts and washers to secure our structural

UNIVERSITY OF WOLLONGONG
AUSTRALIA · DUBAI · HONG KONG

NSW GOVERNMENT TAFE NSW

Desert Rose
Team UOW
Australia - Dubai

steel frame.

Bradford – is a subsidiary of CSR and is one of Australia's largest suppliers of insulation of glasswool insulation.

Buildex – are a manufacturer of fasteners and has provided all of our screwed fasteners.

Cardno – is a large consultancy firm and the local office provided support on our structural design.

Cement Australia – is Australia's leading cement supplier and has provided all of the cement for our second skin wall.

CMG AV -provide audio, visuals and lighting for events and supported events at during our public open week.

Coates Hire - is Australia's largest equipment hire company and has provided various construction and event equipment.

Complete Plumbing and Fire – are a local company that specialise in fire protection and assisted in the installation of our fire system.

Daikin - is a world leader in air conditioning systems. They are committed to supporting Team UOW through in-kind and monetary support. This includes HVAC system components and specialised support.

Davey – is an Australian pump manufacturer and provided the one of our firefighting pumps.

DCTech – provides ridged insulation products and air tight membranes and has provided our XPS insulation.

Denso - provides concreting materials and has sponsored our carbon fibre reinforcement

Dulux – is large paint supplier and supplied all of the painting products for the Desert Rose

Dux – is a local hot water manufacturer and has provided a heat pump hot water system.

Edmiston Jones GBB - this locally based architectural firm is working closely with our team to guide us towards a smart, stunning and sustainable design. Director/Architect Mark Jones and his team have continued their support since Team UOW's 2013 Solar Decathlon China victory and are committed to achieving the greatest outcome.

Electrolux – is a leading brand of appliances and has provided us with some of our appliances.

Element Consulting Engineers - newly established this firm offers structural consulting to our region. Director and founder, Scott Redwood, led the Construction team during the Solar Decathlon China 2013. Now as a graduate his keen interest in the competition and sustainable construction has led his support of the new Solar Decathlon.

Eleni Lighting – produces architectural lighting solutions and supplied us with our cornices.

Enduroframe - as a subsidy of BlueScope Steel, Enduroframe is providing our innovative, custom-made structural frame.

Engineers Australia – is the peak body for engineers in Australia and has providing cash sponsorship and access to their networks.

Enware - is a commercial tapware provider specialising in innovative solutions for aged care and medical facilities. They are supporting us in offering innovative tapware not yet released to the market, toilets and basins.

Flagstaff – provides waste support facilities and assisted the team in handling of the construction waste and recycling.

Green Edge Automation - provided controls for the HVAC system.

Gyprock – is a subsidiary of CSR and one of the largest suppliers of plasterboard.

Hager - manufacturer of electrical distribution systems worldwide. Hager are a proud in-kind sponsor of our battery and car charging systems along with electrical protection, switches and sockets and automation elements.

Holyoake - supplier of air management solutions to Australia and New Zealand. They have provided our HVAC vents and dampeners.

Ice-Tech Air – are local air-conditioning and refrigeration engineers and have assisted us with the design and installation of our HVAC system.

Illawarra Woodworking School – manufactured our custom-made dining table.

Ivory Egg – provides training and products for control automation and assisted us with the BMS of the Desert Rose.

Koala – is an Australian manufacturer of mattresses and supplied our mattress.

Lambert Kitchens – is a local cabinetry manufacturer and assisted us with our kitchen.

Laminex – produces laminated products and supplied the materials for our kitchen and bathrooms.

Lincoln Sentry – supply a range of cabinetry and architectural hardware and provided our soft close mechanisms for our kitchen cupboards.

Level Master – manufactures adjustable pier heads and supplied the pier heads for the Desert Rose decks.

Lysaght - are a subsidiary of BlueScope and has provided our steel frame for the flooring system, parts of the roof and our flashings.

MarKarno – Provides detailed steel work and constructs buildings and has provided us with cash support and glass powder.

NASH – is Australia's National Association of Steel-Framed Housing and has provided us access to their standards.

NuGreen Solutions – is an Australian energy services company and has supplied us with LED downlights and associated DALI ballasts.

Orrcon Steel – are a subsidiary of BlueScope and has provided all of our hot rolled steel components.

Phase Change Material Products Limited - manufactures PCM and sponsored our PCM material.

Piranha Eyewear - Specialise in sunglasses and safety eyewear and have provided Team UOW with safety glasses for a desert environment.

Pixalux – is a local manufacturer of light panels and provided our RGB splashback and artificial skylights.

Proctor Group - provides innovative building envelope solutions and will be supplying Team UOW with our airtight membrane.

Prime Pumps – is a local supplier of pumps and have provided one of our fire fighting pumps.

Progenia - newly established this firm offers sustainable construction and project management services to our region. Director and founder, Scott Redwood, led the Construction team during the Solar Decathlon China 2013. Now as a graduate his keen interest in the competition and sustainable construction has led his support of the new Solar Decathlon.

Pryda – manufactures a truss and frames and provided us with cleats for our steel frame connections

Prysmian – manufactures electrical cables and has provided us with cabling for the Desert Rose.

Reece – is one of Australia's largest plumbing suppliers and has provided all of our water pipes, fittings and kitchen sink.

Remondis – is a world-renowned recycling company and has assisted us with the recycling of our construction waste.

Scope Home Access – are local builders that work with occupational therapists to provides homes and renovations for elderly people or people living with a disability. They have provided us expertise in the design of the Desert Rose.

Sekisui Foam Australia – manufactures varies foam products and has supplied our ridging ducting and sound insulation.

Siemens - develops and produces electrical and automation components worldwide. As a major in-kind sponsor Siemens has provided HVAC control and fire detection elements for the Desert Rose.

Soil Co – is local manufacturer of mulch and soils and has provided us with mulch for our open week display.

South Coast Party Hire – is a local hire and event decorator and provided marquees and décor for our public open festival.

SpanSet – is a local manufacturer of heights safety equipment and supplied us with our harness laynyards.

SJB Architects - Australian based architects who provided support in graphical rendering.

SterilAire - Australian company that develops HVAC cleaning technology and has provide a UV light HVAC system.

Sydney Build Expo – Is an annual expo held locally and provided exhibition space for us to communicate our project.

Sureguard Safety Australia SSA – manufactures safety helmets and has provided these for Team UOW.

Suttle Shades – is a local blinds, shutters and awnings company and has provided our blinds.

Taylor Brammer – is a local landscaping architecture firm and has assisted with our landscaping design.

TES – Thermal Energy Solutions provided us with our innovative ROTEX heat exchanger hot water system.

TDF – are local floor layers and installed our floating floors.

Tractile - produces innovative solar roofs and is sponsoring our BIPV-T tiles.

Victaulic – provides and innovative pipe connection solution and provided us with connections for our systems.

Viridian - is a subsidiary of CRS and is Australia's largest supplier of glass and manufactures right here in Australia. They have provided all our window glazing and the innovative Microshade.

VisuaLive 3D - designs and creates software for Microsoft Hololens that will support our communications objectives. They have provided software licences for their product.

Waples - Australian marketing group focused on regional clients and are offering marketing and strategic planning training and support.

Warrigal – A local leading provider of aged care has provided cash support and expertise.

Weathertex – provides innovative cladding materials and has supported us on our external wall materials.

Winning Appliances – is a local supplier of appliances and has supported us with various appliances

Oasis Sponsors

Sunlight Sponsors

Friends Sponsors

Buildex®

Bradford™ more than insulation

MarKarno construction made easy

Electrolux

Arens® INTERNATIONAL

Waples

UNIVERSITY OF WOLLONGONG AUSTRALIA
/NNOVATION CAMPUS

Tractile

Edmiston Jones

BREMICK

Orrcon Steel

PROCTOR GROUP AUSTRALIA pga

dc tech

URSA

HOLYOAKE AIR MANAGEMENT SOLUTIONS

ahj architectural hardwood JOINERY

Beacon LIGHTING

NuGreen Solutions

Warrigal

UglyFish PROTECTION WITH ATTITUDE.

Denso® LEADERS IN CORROSION PREVENTION & SEALING TECHNOLOGY

SEKISUI FOAM AUSTRALIA

Waterdrop Sponsors

Waterdrop Sponsors continued

Team Uniform Design

7

The long sleeved shirts seen below show the construction uniform of the team. The shirts feature the Desert Rose logo on the front and the SDME logo on the sleeve. Two high-visibility reflective strips sit across the torso and arms.

Figure 7.1- Team UOW Construction Uniform

The hard hats seen below form another part of the construction uniform of the team. The hard hats are white to adhere to SDME requirements, and also feature the Desert Rose logo on the front.

Figure 7.2- Team UOW Hard Hat

The shirts seen below are official Team UOW t-shirts. They have been designed using the team primary uniform colour, black, with the Desert Rose logo on the front and the SDME logo on the right arm.

Figure 7.4 - Team UOW T-Shirts Version 1

Figure 7.5 - Team UOW T-Shirts Version 2

The images below show the formal apparel of Team UOW. A simple black dress shirt, in team colours, with the Desert Rose and SDME logos on the front.

Figure 7.6 - Team UOW Female Dress Shirts

Figure 7.7 - Team UOW Male Dress Shirts

The images below show the casual apparel of Team UOW. A short sleeved polo shirt in team colours, with the Desert Rose and SDME logos on the front and a black cap for sun protection with the Desert Rose logo on the crown.

Figure 7.8 - Team UOW Polo Shirts and Hat

Figure 7.9 - Team UOW in Official Uniform. Taken 22/09/2018

Dissemination Activities

8

8.1 Presentations

Date	Presentation Name/Topic	Group/Organisation	Audience	Location	Attendance Numbers	Presenter
10/04/2018	Advocating for Net-Zero Energy Sustainable Houses through the International Solar Decathlon Competition	3rd World Congress on Civil, Structural, and Environmental Engineering (CSEE'18) Budapest, Hungary	External - International	Budapest, Hungary	25	Tim McCarthy
19/07/2018	Desert Rose and the Solar Decathlon	Australian Industry Group and I3Net-Industry Breakfast	External - Domestic	UOW - Innovation Campus	100	Clayton McDowell
20/07/2018	Desert Rose and the Solar Decathlon	Innovation Campus - Sunset Social	External - Domestic	UOW - Innovation Campus	250	Clayton McDowell
21/07/2018	Desert Rose Reveal	Team UOW	External - Domestic	UOW - Innovation Campus	85	Luca Faidutti, Brendan Banfield, Paul Cooper, Clayton McDowell
11/08/2018	UOW Open Day - Desert Rose	UOW Wollongong	UOW/ External - Domestic	UOW	15	Yeganeh Baghi & Cameron Porter/ Luca Faidutti & Ross Prandalos
14/08/2018	Desert Rose and the Solar Decathlon	Engineers Australia – UOW Alumni	UOW/ External - Domestic	UOW	95	Clayton McDowell
04/09/2018	Desert Rose and the Solar Decathlon	Aged and Community Services Australia (ACSA)	External - Domestic and International	International Convention Centre, Sydney	100	Clayton McDowell
06/09/2018	The Desert Rose Student Experience	Deputy Vice Chancellor (Academic) - Strategic Retreat	UOW - Domestic	Sebel Kiama	30	Meg Cummins & Cameron Porter
06/09/2018	Desert Rose and the Solar Decathlon	Master Builders' Association	External - Domestic	UOW - Innovation Campus	30	Clayton McDowell
17-19/09/2018	Desert Rose	Australian Engineering Conference 2018	External - Domestic	International Convention Centre, Sydney	100	Emily Ryan & Clayton McDowell
25/09/2018	Desert Rose	Australian Sustainable Energy Council	External - Domestic	University of Technology, Sydney	50	Brendan Banfield

8.2 Events & Exhibitions

Date	Event / Organisation	Audience	Exhibition Type	Location	Attendance Numbers
15-16/03/2018	Sydney Build Expo	External- Domestic	Exhibition Stall	Hordern Pavillion, Sydney	11,839
02/05/2018	Team UOW - Trade Night	External- Domestic	Exhibition Stall	Desert Rose Construction Site	150
8-10/05/2018	Air Conditioning, Refrigeration and Building Services (ARBS) Exhibition	External- Domestic	Exhibition	International Convention Centre, Sydney	8,840
09/05/2018 - 22/06/2018	Team UOW 'Education Hub' Tours	External- Domestic and International	Educational Exhibition and Tour	TAFE	280
19/07/2018	Australian Industry Group and i3Net: Desert Rose Industry Breakfast	External- Domestic	Tours of the Desert Rose	UOW Innovation Campus	100
20/07/2018	UOW Innovation Campus - Sunset Social	External- Domestic	Tours of the Desert Rose	UOW Innovation Campus	250
21-22/07/2018	Team UOW Australia-Dubai: Desert Rose Festival Celebrating Sustainability	External- Domestic and International	Festival, stalls and Tours of the Desert Rose House	UOW Innovation Campus	950
26/07/2018	Official Unveiling of the Desert Rose House	External- Domestic	Ceremony and Tours of the Desert Rose House	UOW Innovation Campus	100
13/09/2018	Google Sidewalks Lab	External- Domestic and International	Exhibition Stall	UOW Innovation Campus	80
17-19/09/2018	Australian Engineering Conference 2018	External- Domestic and International	Exhibition Stall	International Convention Centre, Sydney	1,200
17/09/2018	Sustainable Houses Day	External- Domestic	Exhibition Stall	Illawarra Flame House	90

Team UOW have been working hard over the last two years to promote the Solar Decathlon Middle East 2018 and the Desert Rose House. This includes various presentations, conferences, seminars, exhibitions and events to both domestic and international audiences. Over the last two years, Team UOW have given 78 presentations; held exhibition stalls at 26 different conferences, events and exhibitions; and organised and hosted 7 public events.

Our most successful dissemination activities since Deliverable 6 were:

- Hosted an exhibition stall at the Sydney Build Exhibition - attended by over 11,000 people, during this two-day event Team UOW gave virtual tours of the Desert Rose House using the Microsoft Hololens. We shared the Desert Rose and Solar Decathlon story to many people in the building industry from across Australia.
- Hosted an exhibition stall at the Australian Engineering Conference - attended by over 1,200 people, during this four-day event Team UOW gave virtual tours of the Desert Rose House to conference attendees and school children. We also displayed videos of our construction. Two representatives of Team UOW also presented during the conference in the 'Grand Plan for Australia' session.
- Organised and hosted the Desert Rose Reveal - a series of events promoting Team UOW and the Desert Rose House. This started with the Sponsors Evening, where our sponsors were invited to join the Team to celebrate and have a tour of the house. This was followed by an Industry Breakfast gathering people from the local region involved in the building industry to share ideas and tour the house. The following evening we were the feature for the Sunset Social, inviting local businesses and UOW alumni to visit the Desert Rose House and discuss health and wellbeing in our region. Over the weekend we ran the 'Festival Celebrating Sustainability' which included informative sustainability talks, stall holders promoting sustainable practices, and tours of the Desert Rose House. The week ended with the Official Unveiling of the Desert Rose House by the Deputy Premier of New South Wales and attended by other local politicians and dignitaries who also had the opportunity to visit and tour the house. During the Desert Rose Reveal we attracted over 1,300 people from the public to tour the house and learn more about the Solar Decathlon competition. These events were widely publicised on traditional media channels and both ours and our supporters' social media channels.

Project Media Appearances

9

Table 9.1 - Dissemination Activities - Project Media Appearances

	Date	Type	Name of Publication or Web	URL
1	06/10/2016	Web	UOW Media - 'Dementia Friendly Solar Powered Home Compete in World Energy Olympics'	http://media.uow.edu.au/releases/UOW222372.html
2	23/11/2016	Web	Aged Care Guide - 'Supporting Dementia Living While Looking After the Planet'	https://www.agedcareguide.com.au/talking-aged-care/supporting-dementia-living-while-looking-after-the-planet
3	19/12/2016	Web	Architects Edmiston Jones GBB (Architectural firm) - 'Desert Rose - Solar Decathlon update'	https://aej.com.au/desert-rose-solar-decathlon-update/
4	19/12/2016	Social Media	Architects Edmiston Jones GBB (Architectural firm) - Facebook post	https://www.facebook.com/pg/edmiston.jones/posts/?ref=page_internal
5	01/01/2017	Web	Australia Solar Council - '2018 Solar Decathlon'	https://www.solar.org.au/industry-news/2018-solar-decathlon/
6	30/03/2017	Newspaper - Digital and Print	Illawarra Mercury - (local newspaper) - 'UOW makes the finals of the Solar Decathlon Middle East, held in Dubai'	http://www.illawarramercury.com.au/story/4564631/house-of-the-future-uows-desert-rose-is-heading-to-dubai/
7	31/03/2017	Web	Illawarra Mercury (local newspaper) - 'Could this be what Aussie houses look like in the future?'- Facebook Post	https://www.facebook.com/pg/Illawarramerc/posts/?ref=page_internal
8	31/03/2017	Social Media	Dementia Australia (national body for Dementia in Australia)- Facebook Post	https://www.facebook.com/pg/DementiaAustralia/posts/?ref=page_internal
9	19/4/2017	Social Media	Architects Edmiston Jones GBB (Architectural firm)- Facebook Post	https://www.facebook.com/pg/edmiston.jones/posts/?ref=page_internal
10	17/05/2017	Web	Fight Dementia- 'University of Wollongong students take dementia-friendly home to Dubai'	https://www.fightdementia.org.au/dementia-news/issue-08/dementia-friendly-house
11	13/07/2017	Social Media	Innovation Campus (UOW)- Facebook Post	https://www.facebook.com/pg/innovation.campus.wollongong/posts/?ref=page_internal
12	18/08/2017	Web	Medianet- 'Thousands expected at UOW Open Day tomorrow'	http://www.medianet.com.au/releases/141337/
13	26/08/2017	Web	ReNew Magazine Issue 141	https://renew.org.au/renew-magazine/renew/renew-issue-141/
14	04/09/2017	Web	Innovation Campus (UOW)- 'Team UOW strives for gold'	http://innovationcampus.com.au/news/team-uow-strives-for-gold/
15	Sept-17	Print Magazine	Purpose in Action - Building the Future	
16	01/09/2017	Web	Places to go in Wollongong	http://www.placestogoinwollongong.com/events/9586989-Building-Desert-Rose-Innovative-Dementia-Friendly-Ecohome/
17	05/09/2017	Newspaper - Digital	The Fifth Estate (Australia's leading newspaper for sustainability)- 'How a dementia-friendly net-zero home will help older people stay put'	https://www.thefifthestate.com.au/innovation/residential-2/how-a-dementia-friendly-net-zero-home-will-help-older-people-stay-put/95185
18	10/09/2017	Web	SBRC - 'Desert Rose: A House for Life'	https://sbrc.uow.edu.au/collaborations/sustainability-street/index.html
19	26/09/2017	Web	Renew Magazine - 'A net zero energy home'	http://renew.org.au/current-issue/a-net-zero-energy-home

Figure 9.1 - See Table 9.1 Entry #1

Figure 9.2 - See Table 9.1 Entry #1

	Date	Type	Name of Publication or Web	URL
20	01/10/2017	Magazine - Digital and Print	Renew Magazine - 'Desert Rose: 'Cool Performance'	https://shop.ata.org.au/wp-content/uploads/woocommerce_uploads/2017/09/ReNew_141_low_res.pdf
21	01/12/2017	Web	Electrical Connection - 'Ivory Egg Invests in the Future of Renewable Energy by Sponsoring the University of Wollongong Solar Decathlon Team'	https://electricalconnection.com.au/ivory-egg-invests-in-the-future-of-renewable-energy-by-sponsoring-the-university-of-wollongong-solar-decathlon-team/
22	04/12/2017	Social Media	Ivory Egg (KNX supplier) - Ivory Egg Invests in the Future of Renewable Energy- Facebook Post	https://www.facebook.com/pg/ivoryeggLtd/posts/?ref=page_internal
23	11/12/2017	TV	WIN News Illawarra- 'Dementia house' (featured on live TV and later shared to Facebook)	https://www.facebook.com/WINNewsIllawarra/videos/2003233139693419/
24	11/12/2017	Social Media	WIN News Illawarra (local TV news) - 'Dementia house' – Facebook Post	https://www.facebook.com/WINNewsIllawarra/videos/2003233139693419/
25	11/12/2017	Radio	ABC Illawarra Radio - 'Desert Rose – Construction Launch'	
26	11/12/2017	Social Media	ABC Illawarrra (local radio station) - '97.3 ABC Illawarra is at Wollongong TAFE' – Facebook Post	https://www.facebook.com/search/str/97.3+abc+illawarra+is+at+TAFE/keywords_blended_posts
27	11/12/2017	Web	UOW - 'Hands and minds get to work building a home for all ages'	https://media.uow.edu.au/releases/UOW241376.html
28	11/12/2017	Newspaper - Digital and Print	The Australian - 'Students Take on Housing Challenge'	http://www.theaustralian.com.au/higher-education/high-wired/top-global-online-education-award-to-aussies/news-story/ee5a4680074d123758fcd2e7948ab27d
29	11/12/2017	Newspaper - Digital and Print	Illawarra Mercury - 'Wollongong students building 'age-friendly' sustainable house'	http://www.illawarramercury.com.au/story/5112684/wollongong-students-building-age-friendly-sustainable-house/?cs=300
30	11/12/2017	Web	Aged Care Insite (peak body in Aged Care) - 'Dementia-friendly 'house for life' in the works'	https://www.agedcareinsite.com.au/2017/12/dementia-friendly-house-for-life-in-the-works/
31	11/12/2017	Social Media	Aged Care Insite (peak body in Aged Care)- Facebook Post	https://www.facebook.com/agedcareinsite/
32	11/12/2017	Web	Redbook - 'Desert Rose rises from the ground'	https://www.redbook.com.au/car-news/desert-rose-rises-from-the-ground-110176?csn_tnet=true
33	December 2017	Web	Architects Edmiston Jones (architectural firm)- 'Desert Rose Emerges'	https://aej.com.au/desert-rose-emerges/
34	11/12/2017	Web	Member for Parliament - 'Local students to build on solar success'	http://www.garethwardmp.com.au/media/local-students-build-solar-success/
35	11/12/2017	LinkedIn	Paul Deverell - 'Desert Rose House officially launched'	https://www.linkedin.com/pulse/desert-rose-house-officially-launched-paul-deverell/

Figure 9.3 - See Table 9.1 Entry #29

Figure 9.4 - See Table 9.1 Entry #33

	Date	Type	Name of Publication or Web	URL
36	12/12/2017	TV	WIN News Illawarra (featured on Live TV and later shared to Facebook) 'Desert Rose'	https://www.facebook.com/WINNewsIllawarra/videos/2004705829546150/
37	12/12/2017	Social Media	WIN News Illawarra (local TV news) - 'Desert Rose' – Facebook Post	https://www.facebook.com/WINNewsIllawarra/videos/2004705829546150/
38	12/12/2017	Newspaper	Illawarra Mercury - 'Students Building House for all Ages'	
39	12/12/2017	Web	Construction Sales - 'Construction has commenced on a solar-powered, dementia-friendly home in Wollongong named 'Desert Rose'	https://www.constructionsales.com.au/editorial/details/desert-rose-rises-from-the-ground-110176/
40	12/12/2017	Web	Innovation Campus - 'A home for all ages'	http://innovationcampus.com.au/news/a-home-for-all-ages/
41	13/12/2017	Web	UOW - 'Engineering studies a ticket to the world'	https://media.uow.edu.au/news/UOW241540.html
42	14/12/2017	Social Media	Scope Home Access (experts in aged care design and supplier of mobility equipment) – Facebook Post	https://www.facebook.com/pg/Scope-Home-Access-567055230066877/posts/?ref=page_internal
43	15/12/2017	Web	Furnishing International- 'Hands and minds get to work building a house for all ages'	http://furnishinginternational.com/desert-rose-house/
44	18/12/2017		Narooma News (local newspaper) - 'Engineering studies a ticket to the world for Dan Simpson of Narooma'	https://www.naroomanewsonline.com.au/story/5127332/engineering-studies-a-ticket-to-the-world-for-dan-simpson-of-narooma/
45	29/12/2017	Web	Ivory Egg - 'Ivory Egg invest in the future of renewable energy'	https://www.ivoryegg.com.au/news_items/ivory-egg-invest-in-the-future-of-renewable-energy
46	03/01/2018	Web	Gulf News - 21 teams compete in the Solar Decathlon Middle East'	https://gulfnews.com/news/uae/education/21-teams-compete-in-the-solar-decathlon-middle-east-1.2151380
47	04/01/2018	Web	The Senior - 'Desert Rose blooms for dementia'	https://www.thesenior.com.au/news/desert-rose-blooms-for-dementia/
48	07/02/2018	Web	Architects Edmiston Jones GBB (architectural firm) - 'Desert Rose Rises'	https://aej.com.au/desert-rose-rises/
49	07/02/2018	Social Media	Architects Edmiston Jones GBB (architectural firm) - Facebook Post	https://www.facebook.com/edmiston.jones/?__xts__[0]=68.ARBXCpSF8iQI6fEedpaAH8iM4
50	21/02/2018	Newspaper - Digital and Print	Illawarra Mercury - 'UOW/TAFE Design Team to Take Part in Illawarra Memory Walk'	https://www.illawarramercury.com.au/story/5238545/dementia-is-a-deeply-personal-issue-for-uow-decathlon-team/
51	01/03/2018	Social Media	Innovation Campus (UOW) – Facebook Post	https://www.facebook.com/pg/innovation.campus.wollongong/posts/?ref=page_internal
52	04/03/2018	Social Media	Memory Walk & Jog (photos available)	https://www.facebook.com/memorywalkandjog/
53	02/04/2018	Magazine	Tertangala - 'A House For Life'	
54	05/04/2018	Social Media	Tractile (BIPVT supplier) – Facebook Post	https://www.facebook.com/pg/tractilesmarterroof/posts/?ref=page_internal

Figure 9.5 - See Table 9.1 Entry #29

Figure 9.6 - See Table 9.1 Entry #46

	Date	Type	Name of Publication or Web	URL
55	13/04/2018	Social Media	Scope Home Access (experts in aged care design and supplier of mobility equipment) – Facebook Post	https://www.facebook.com/pg/Scope-Home-Access-567055230066877/posts/?ref=page_internal
56	20/04/2018	Web	Zawya - '21 University Teams from 15 Countries Show Smart Sustainable Home Models for the 1st Round of the Solar Decathlon Middle East'	https://www.zawya.com/mena/en/story/21_university_teams_from_15_countries_show_smart_sustainable_home_models_for_the_1st_round_of_theSolar_Decathlon_Middle_East-ZAWYA20180420073734/
57	30/04/2018	Web	UOW Engineering and Information Sciences	https://news.eis.uow.edu.au/executive-dean-launches-inaugural-eis-alumni-newsletter/
58	03/05/2018	Social Media	Innovation Campus (UOW) – Facebook Post	https://www.facebook.com/pg/innovation.campus.wollongong/posts/?ref=page_internal
59	03/05/2018	Radio	ABC Radio Sydney - Evenings with Chris Bath	http://www.abc.net.au/radio/sydney/programs/evenings/evenings/9701616
60	04/05/2018	TV	UOW TV (UOW TV channel) - Facebook Post and Video	https://www.facebook.com/uowtvmultimedia/?hc_ref=ARQPQV58I_jMyes2EpTi6jzj7TDueUmVkkoCH06eECjCE61L-W3uIgQWMPOtcYrFvQM
61	04/05/2018	Social Media	Enduroframe (structural steel frame supplier) – Facebook Post	https://www.facebook.com/pg/enduroframe/posts/?ref=page_internal
62	08/05/2018	Social Media	Scope Home Access (experts in aged care design and supplier of mobility equipment) – Facebook Post	https://www.facebook.com/Scope-Home-Access-567055230066877/
63	May 2018	Web	Architects Edmiston Jones GBB (architectural firm) - 'UOW up for the challenge- Dubai Solar Decathlon'	https://aej.com.au/uow-up-for-the-challenge-dubai-solar-decathlon-2018/
64	May 2018	Web	The Stand (UOW Publication) - 'A House for All'	https://stand.uow.edu.au/a-house-for-all/
65	May 2018	Web	Enware (tapware supplier) - 'Enware Supporting University of Wollongong in their Desert Rose - A House for Life Project'	https://www.enware.com.au/news/enware-supporting-university-of-wollongong-in-their-desert-rose-a-house-for-life-project/
65	15/05/2018	Web	Illawarra Mercury - 'TAFE and UOW progress on track for the Solar Decathlon challenge with the Desert Rose'	https://www.illawarramercury.com.au/story/5381996/a-solar-house-creating-interest/
66	24/05/2018	Social Media	Enduroframe (structural steel frame supplier) – Facebook Post	https://www.facebook.com/pg/enduroframe/posts/?ref=page_internal
67	25/05/2018	Social Media	Proctor Group Australia (construction material suppliers) – Facebook Post	https://www.facebook.com/pg/proctor.australia/posts/?ref=page_internal
68	05/06/2018	Social Media	Enware (tapware supplier) – Facebook Post	https://www.facebook.com/enwareaustralia/
69	18/06/2018	Social Media	WIN News Illawarra (local TV station) – Facebook Post and Video	https://business.facebook.com/pg/WINNewsIllawarra/community/
70	01/07/2018	Web	UOW Deputy Vice Chancellor Academic Newsletter – 'Student profile: Luca Faidutti shares what drives his success'	https://www.uow.edu.au/dvca/newsletter/2018-06/index.html
71	01/07/2018	Social Media	Enduroframe (structural steel frame supplier) – Facebook Post	https://www.facebook.com/pg/enduroframe/posts/?ref=page_internal

Figure 9.7 - See Table 9.1 Entry #40

Figure 9.8 - See Table 9.1 Entry #52

	Date	Type	Name of Publication or Web	URL
72	03/07/2018	Web	UOW Universe Publication – 'Desert Rose Reveal Event'	https://universe.uow.edu.au/community/desert-rose-reveal-event/
73	03/07/2018	Web	UOW Engineering and Information Sciences Publication – 'Desert Rose House Festival Week'	https://news.eis.uow.edu.au/event/desert-rose-house-festival-week/
74	04/07/2018	Web	Research and Innovation news issue - ' Desert Rose House Reveal'	
75	05/07/2018	Social Media	Architects Edmiston Jones GBB (architectural firm) - Facebook Post	https://www.facebook.com/pg/edmiston.jones/posts/?ref=page_internal
76	05/07/2018	Social Media	Innovation Campus (UOW) – Facebook Post	https://www.facebook.com/pg/innovation.campus.wollongong/posts/?ref=page_internal
77	06/07/2018	Social Media	Innovation Campus (UOW) – Facebook Post	https://www.facebook.com/pg/innovation.campus.wollongong/posts/?ref=page_internal
78	12/07/2018	Web	Tractile - 'Desert Rose House Reveal'	http://go.pardot.com/webmail/ 447892/782724661/0fb593aaae70df0731f4bf 425d389a43869039ead29cc789008dc69cfee2fc3f
79	12/07/2018	Newsletter	EIS Alumni News - 'Putting Hearts Into Homes'	https://www.youruowcommunity.edu.au/emailviewonwebpage.aspx?erid=9045249&trid=df31a981-fdad-41a6-9b09-8eeacfd43b09
80	15/07/2018	Social Media	Enware (tapware supplier) – Facebook Post	https://www.facebook.com/pg/enwareaustralia/posts/?ref=page_internal
81	16/07/2018	Social Media	Coasties Big Shed (recycled hardwood supplier) – Facebook Post	https://www.facebook.com/CoastiesBigShed/
82	16/07/2018	Newspaper - Digital and Print	Illawarra Mercury – 'Enjoy a sneak preview of the 'Desert Rose' house at UOW's Innovation Campus'	https://www.illawarramercury.com.au/story/5528591/first-look-at-wollongongs-dementia-friendly-solar-powered-house-design/
83	16/07/2018	Web	UOW – 'Desert Rose House Festival Week'	https://news.eis.uow.edu.au/event/desert-rose-house-festival-week/
84	17/07/2018	Social Media	Architects Edmiston Jones GBB (architectural firm) - Facebook Post	https://www.facebook.com/pg/edmiston.jones/posts/?ref=page_internal
85	17/07/2018	Newsletter	ATA - Wollongong Branch - 'DESERT ROSE: INDUSTRY BREAKFAST'	
86	19/07/2018	Web	Architects Edmiston Jones GBB (architectural firm) - 'Desert Rose: Industry Breakfast'	https://aej.com.au/desert-rose-industry-breakfast/
87	19/07/2018	Web	Innovation Campus Publication – 'A Festival Celebrating Sustainability / DRH Construction Update'	http://newsletter.internetrix.com.au/t/ViewEmail/j/E9389CA46AFBDF102540EF23F30FEDED/E8AD1AF6CED5A4ABFE6194DE962A274B
88	19/07/2018	Web	HVAC&R News / AIRAH - 'Aussie Innovators Set to Shine on World Stage'	http://www.hvacrnews.com.au/features/aussie-innovators-set-to-shine-in-solar-decathlon/
89	19/07/2018	Social Media	Waples Marketing Group (Marketing firm) – Facebook Post	https://www.facebook.com/pg/waplesmarketing/posts/?ref=page_internal

Figure 9.9 - See Table 9.1 Entry #72

	Date	Type	Name of Publication or Web	URL
90	19/07/2018	Social Media	Daikin (air conditioning supplier) – Facebook Post	https://www.facebook.com/pg/DaikinAustralia/posts/?ref=page_internal
91	20/07/2018	Social Media	Tractile (BIPVT supplier) – Facebook Post	https://www.facebook.com/pg/tractilesmarterroof/posts/?ref=page_internal
92	20/07/2018	Social Media	9 News Illawarra '2018 - Solar Decathlon Competition- Desert Rose' – Live TV and later posted to Facebook	https://www.facebook.com/9NewsIllawarra/videos/2079414125658179/
93	20/07/2018	Web	9 News Illawarra (local TV station) - Facebook Post	https://www.facebook.com/9NewsIllawarra/videos/2079414125658179/
94	21/07/2018	Radio	ABC Radio Illawarra – 'Interview with Project Manager'	
95	21/07/2018	Social Media	Tony Di Milia Flooring (flooring supplier) – Facebook Post	https://www.facebook.com/pg/tonydimiliaflooring/posts/?ref=page_internal
96	21/07/2018	Social Media	Illawarra Woodworking School (dining table manufacturer) – Facebook Post	https://www.facebook.com/pg/Illawarrawoodworkschool/posts/?ref=page_internal
97	22/07/2018	Social Media	Illawarra Woodworking School (dining table manufacturer) – Facebook Post	https://www.facebook.com/pg/Illawarrawoodworkschool/posts/?ref=page_internal
98	22/07/2018	Newspaper - Digital and Print	Illawarra Mercury - 'Team UOW hosts sneak preview of the 'Desert Rose' house at the Innovation Campus'	https://www.illawarramercury.com.au/story/5540229/desert-rose-house-opens-its-doors-to-the-public/#slide=1
99	23/07/2018	Newspaper - Digital and Print	South Coast Register (local newspaper) - 'Focus on Dementia and Energy'	https://www.southcoastregister.com.au/.../focus-on-dementia-and-energy/
100	23/07/2018	Newspaper - Digital and Print	Parkes Champion Post (local newspaper) - 'Focus on Dementia and Energy'	https://www.parkeschampionpost.com.au/story/5541935/focus-on-dementia-and-energy/
101	23/07/2018	Web	Mudgee Guardian - 'Focus on Dementia and Energy'	https://www.mudgeeguardian.com.au/story/5541935/focus-on-dementia-and-energy/
102	23/07/2018	Social Media	Scope Home Access (experts in aged care design and supplier of mobility equipment) – Facebook Post	https://www.facebook.com/pg/Scope-Home-Access-567055230066877/posts/?ref=page_internal
103	24/07/2018	Social Media	Innovation Campus (UOW) – Facebook Post	https://www.facebook.com/pg/innovation.campus.wollongong/posts/?ref=page_internal
104	July 2018	Web	The Stand (UOW Publication) - 'Access for all'	https://stand.uow.edu.au/access-for-all/
105	26/07/2018	Newspaper - Digital and Print	Illawarra Mercury - 'Official opening of the 'Desert Rose' house at the UOW Innovation Campus'	https://www.illawarramercury.com.au/story/5550188/desert-rose-house-to-bloom-in-dubai/
106	26/07/2018	Web	UOW - 'Desert Rose House to bloom in Dubai'	https://media.uow.edu.au/releases/UOW249827.html
107	26/07/2018	TV	9 News Illawarra (local TV station) – Facebook Post and Live TV	https://www.facebook.com/pg/9NewsIllawarra/posts/?ref=page_internal

Figure 9.10 and Figure 9.11 - See Table 9.1 Entry #98

	Date	Type	Name of Publication or Web	URL
108	26/06/2018	Web	Desert Rose House to Bloom in Dubai	https://www.illawarramercury.com.au/story/5550188/desert-rose-house-to-bloom-in-dubai/
109	26/07/2018	Social Media	Sharon Bird - MP	https://www.facebook.com/pg/sharon.bird.mp/posts/?ref=page_internal
110	26/07/2018	Social Media	9 News Illawarra	https://www.facebook.com/pg/9NewsIllawarra/posts/?ref=page_internal
111	27/07/2018	Web	ABC News (National news network) – 'Students Create Dementia-Friendly House of the Future'	http://www.abc.net.au/news/2018-07-27/desert-rose-house-designed-for-people-with-dementia/10025914
112	27/07/2018	TV	WIN News Illawarra – Live TV 'Desert Rose launch - University of Wollongong'	
113	27/07/2018	Social Media	Enware (tapware supplier) – Facebook Post	https://www.facebook.com/pg/enwareaustralia/posts/?ref=page_internal
114	27/07/2018	Social Media	UOW – Facebook Post	https://www.facebook.com/pg/UOW/posts/?ref=page_internal
115	27/07/2018	Social Media	ABC Illawarra (National news network) – 'Wollongong 'not forgotten', deputy premier declares' – Facebook Post	https://www.facebook.com/pg/abcillawarra/posts/?ref=page_internal
116	27/07/2018	Social Media	John Barilaro (Deputy Premier New South Wales)- 'Pushing the Boundaries: Yesterday I officially launched 'Desert Rose' - Australia's first dementia-friendly, solar-powered house.' – Facebook Post	https://www.facebook.com/JohnBarilaroMP
117	31/07/2018	Social Media	Scope Home Access (experts in aged care design and supplier of mobility equipment) – Facebook Post	https://www.facebook.com/pg/Scope-Home-Access-567055230066877/posts/?ref=page_internal
118	01/08/2018	Web	Cancer Council Australia - 'The Solar House Challenge, With Laura'	Digital Newsletter.
119	02/08/2018	Web	Innovation Campus (UOW) - 'Desert Rose to bloom in Dubai'	http://innovationcampus.com.au/news/desert-rose-to-bloom-in-dubai/
120	03/08/2018	Web	Enware (tapware supplier) – Facebook Post	https://www.facebook.com/pg/enwareaustralia/posts/?ref=page_internal
121	06/08/2018	Web	Enware (tapware supplier) – Facebook Post	https://www.facebook.com/pg/enwareaustralia/posts/?ref=page_internal
122	16/08/2018	Social Media	Scope Home Access (experts in aged care design and supplier of mobility equipment) – Facebook Post	https://www.facebook.com/pg/Scope-Home-Access-567055230066877/posts/?ref=page_internal
123	20/08/2018	Social Media	Enware (tapware supplier) – Facebook Post	https://www.facebook.com/pg/enwareaustralia/posts/?ref=page_internal
124	20/08/2018	Web - Audio	Aged Care Insite – 'Inside Australia's Dementia-Friendly, Sustainable-Energy House' (audio record of interview and article)	https://www.agedcareinsite.com.au/2018/08/inside-australias-dementia-friendly-sustainable-energy-house/
125	24/08/2018	Newspaper - Print and Digital	Illawarra Mercury - 'Tesla Tiny House Visits Wollongong, Shellharbour' (photo featuring Team UOW members)	https://www.illawarramercury.com.au/story/5604888/tesla-tiny-house-visits-the-illawarra/

Figure 9.12 and Figure 9.13 -
See Table 9.1 Entry #108

	Date	Type	Name of Publication or Web	URL
126	27/08/2018	Social Media	Enware (tapware supplier) – Facebook Post	https://www.facebook.com/pg/enwareaustralia/posts/?ref=page_internal
127	September 2018	Web	UOW Publication - 'The Future Of: Aged Care Featuring Professor Victoria Traynor'	https://www.uow.edu.au/research/newsletter/2018/UOW251342.html
128	12/09/2018	Social Media	Enware (tapware supplier) – Facebook Post	https://www.facebook.com/pg/enwareaustralia/posts/?ref=page_internal
129	September 2018	Web	BlueScope Steel (steel supplier) – 'Desert Rose is taking shape'	https://www.bluescopeillawarra.com.au/community/bluescopewin-partnership/2018/07/desertrose/?filter=&page=1
130	October 2018	Magazine	UOW Publication - 'Putting Hearts into Homes'	https://www.uow.edu.au/alumni/outlook/UOW248796.html
131	1/10/2018	Digital Newsletter	HVAC & R News - ' Desert Showdown'	http://www.airah.org.au/Content_Files/HVACRNation/2018/10-18-HVAC-001.pdf
132	05/10/2018	Digital Newsletter	EIS - 'UOW and Desert Rose Top the 10 Big Ideas at the Engineers Australia Conference '	https://news.eis.uow.edu.au/uow-and-desert-rose-top-the-10-big-ideas-at-the-engineers-australia-conference/
133	05/10/2018	Web	Australian Ageing Agenda	https://www.australianageingagenda.com.au/2018/10/05/noticeboard-pac-celebrates-construction-milestones-at-the-terraces/
134	10/10/2018	Web	NuGreen Solutions - 'NuGreen are proud to sponsor the Desert Rose House for life project '	https://nugreen.com.au/nugreen-are-proud-to-sponsor-the-desert-rose-house-for-life-project/
135	16/10/2018	Digital Magazine	Create - Engineers Australia	https://www.createdigital.org.au/house-life-build-homes-age/
136	23/10/2018	Web	Illawarra Mercury	
137	04/11/2018	Newsletter	Dubai Government Media Office - 'MD&CEO visits Solar Decathlon Middle East 2018 at Mohammed bin Rashid Al Maktoum Solar Park '	http://www.mediaoffice.ae/en/media-center/news/4/11/2018/dewa.aspx
138	05/11/2018	Web	Urdupoint	https://www.urdupoint.com/en/middle-east/dewa-md-visits-solar-decathlon-middle-east-20-473090.html
139	07/11/2018	Web	The National UAE - 'students compete for dh10m solar prize in Dubai'	https://www.thenational.ae/uae/students-compete-for-dh10m-solar-prize-in-dubai-1.788812
140	08/11/2018	Newsletter	Innovation Campus - 'Team UOW Making us Proud'	http://newsletter.internetrix.com.au/t/ViewEmail/j/2B8B25A36933558D2540EF23F30FEDED/DCE84AD55AE6F5F8405DC10595964AA8
141	13/11/2018	Web	Goulburn Post - 'Building for a Brighter Future'	https://www.goulburnpost.com.au/story/5752293/building-for-a-brighter-future/
142	14/11/2018	Web	Mirage News - 'Team UOW Hard at Work in Dubai, Racing to the Finish Line'	https://www.miragenews.com/team-uow-hard-at-work-in-dubai-racing-to-the-finish-line/
143	14/11/2018	Newspaper - Digital and Print	GulfNews UAE - 'Solar decathlon: No electricity bill for this smart home in Dubai '	https://gulfnews.com/uae/environment/solar-decathlon-no-electricity-bill-for-this-smart-home-in-dubai-1.60362131

Figure 9.14 - See Table 9.1 Entry #130

Figure 9.15 - See Table 9.1 Entry #140

	Date	Type	Name of Publication or Web	URL
144	14/11/2018	Web	UOW Media -'Team UOW Hard at Work in Dubai, Racing to the Finish Line'	https://media.uow.edu.au/releases/UOW253314
145	14/11/2018	Social Media	GulfNews UAE - 'Desert rose among 15 student-designed 'green' housing prototypes on show at Solar Decathlon event in Dubai '	https://twitter.com/gulf_news/status/1062925140458127360
146	15/11/2018	Newspaper	GulfNews UAE - 'No electricity bill for this smart home in Dubai '	
147	15/11/2018	Social Media	97.3 ABC Illawarra - 'The Desert Rose team was visited His Highness Sheikh Ahmad bin Saeed Al Maktoum '	https://www.facebook.com/pg/abcillawarra/posts/?ref=page_internal
148	16/11/2018	Social Media	9 News Illawarra - Desert Rose Dubai	https://www.facebook.com/9NewsIllawarra/videos/314068472520210/
149	16/11/2018	TV	9 News Illawarra - Desert Rose Dubai	
150	16/11/2018	Social Media	Innovations Campus UOW	https://www.facebook.com/pg/innovation.campus.wollongong/posts/?ref=page_internal
151	17/11/2018	Web	HVAC & R News - 'Desert Rose: Open for Inspection!'	https://www.hvacrnews.com.au/news/desert-rose-open-for-inspection/
152	Nov/Dec	Web and Print	UOW Outlook - 'Residents Bloom in Desert Rose House'	https://www.uow.edu.au/alumni/outlook/UOW252827.html
153	20/11/2018	Web	Zawaya	https://www.zawya.com/mena/en/press-releases/story/Creative_ideas_and_innovative_solutions_from_28_universities_attract_the_public_to_Solar_Decathlon_Middle_East_in_Dubai-ZAWYA20181120102855/
154	21/11/2018	Social Media	Scope Home Access	https://www.facebook.com/pg/Scope-Home-Access-567055230066877/posts/?ref=page_internal
155	23/11/2018	Web	Faces of UOW - Tumblr - 'Emily and Clayton'	http://facesofuow.tumblr.com/post/180394609405/clayton-after-completing-my-bachelor-of
156	25/11/2018	Social Media	Tractile	https://www.facebook.com/pg/tractilesmarterroof/posts/?ref=page_internal
157	26/11/2018	Web	Future Homes - 'Visit 15 green homes @ Solar Decathlon Middle East in Dubai '	https://toaderpasti.com/15-green-homes-solar-decathlon-middle-east-dubai/
158	28/11/2018	Web	GulfNews UAE - 'FutureHAUS bags top prize in Dubai Solar Decathlon'	https://gulfnews.com/uae/government/futurehaus-bags-top-prize-in-dubai-solar-decathlon-1.60629386
159	29/11/2018	Newspaper	Illawarra Mercury - 'Joint UOW-TAFE NSW house finishes second in international design and construction competition '	https://www.illawarramercury.com.au/story/5785098/age-friendly-desert-rose-house-blooms-in-dubai/?cs=300
160	29/11/2018	Web	Paul Scully MP's Media Release - 'Congratulations to the Desert Rose House'	https://paulscullymp.com.au/news/media-releases/congratulations-to-the-desert-rose-house-team-it-s-time-to-bring-the-competition-to-wollongong/?fbclid=IwAR1yEm-9irSiCjaq9PEMk6bbzDDLgEh6CUejcCGm8t

Figure 9.16- See Table 9.1 Entry #151

	Date	Type	Name of Publication or Web	URL
161	29/11/2018	Web	Mirage News - 'Desert Rose Blooms After Taking out Second Place'	https://www.miragenews.com/desert-rose-blooms-after-taking-out-second-place-with-sustainable-age-friendly-house/
162	29/11/2018	Newsletter	Khaleej Times - 'Solar home by US students wins Dh900,000 in UAE'	https://www.khaleejtimes.com/nation/dubai/solar-home-by-us-students-wins-dh900000-in-uae
163	29/11/2018	Web	Arabian Industry - 'Virginia Tech wins Solar Decathlon Middle East '	https://www.arabianindustry.com/technology/news/2018/nov/29/virginia-tech-wins-solar-decathlon-middle-east-6008483/
164	30/11/2018	Newspaper	Illawarra Mercury - 'Age-Friendly Desert Rose house blooms in Dubai'	
165	Nov 2018	Newsletter	EIS UOW - 'Advanced and Scholar Students' Networking Lunch - Desert Rose Presentation '	
166	Dec 2018	Web	Edmiston Jones - 'Desert Rose Returns'	https://aej.com.au/desert-rose-returns/
167	01/12/2018	Print Magazine	Ecolibrium - 'A Night to Shine'	https://www.airah.org.au/Content_Files/EcoLibrium/2018/12-18-Eco-002.pdf
168	02/12/2018	Social Media	Tractile	https://www.facebook.com/pg/tractilesmarterroof/posts/?ref=page_internal
169	04/12/2018	Social Media	UOW - 'Huge congratulations to Team UOW Australia-Dubai for placing second overall in the Solar Decathlon Middle East 2018 and bringing home nine trophies! '	
170	04/12/2018	Newsletter	EIS - 'Desert Rose blooms after taking out second place with sustainable, age-friendly house '	https://news.eis.uow.edu.au/desert-rose-blooms-after-taking-out-second-place-with-sustainable-age-friendly-house/
171	05/12/2018	Web	Building Connection - 'Team UOW Australia-Dubai wins second place in Solar Decathlon '	https://buildingconnection.com.au/2018/12/05/team-uow-australia-dubai-wins-second-place-in-solar-decathlon/
172	07/12/2018	Newsletter	ASBEC - 'Sustainable Housing- Desert Rose House wins 2nd place '	
173	07/12/2018	Web	Construction Sales - 'Desert Rose blooms in Dubai'	https://www.constructionsales.com.au/editorial/details/desert-rose-blooms-in-dubai-116029/
174	07/10/2018	Web	New Atlas - 'Sustainable and modular FutureHaus wins 2018 Solar Decathlon Middle East '	https://newatlas.com/futurehaus-2018-solar-decathlon-middle-east/57499/ https://newatlas.com/futurehaus-2018-solar-decathlon-middle-east/57499/#gallery
175	10/12/2018	Web	Architecture & Design - 'Tractile triumphs in the Dubai Desert'	https://www.architectureanddesign.com.au/suppliers/tractile/tractile-triumphs-in-the-dubai-desert
176	12/12/2018	Web	Mirage News - 'Engineering, business achievements in the spotlight at summer graduations '	https://www.miragenews.com/engineering-business-achievements-in-the-spotlight-at-summer-graduations/
177	12/12/2018	Web	UOW Media - 'Solar Decathlon sparked Emily's passion for sustainability '	https://media.uow.edu.au/news/UOW254531.html

	Date	Type	Name of Publication or Web	URL
178	21/12/2018	Web	Sustainability Tribe - 'Innovative Solar Powered Homes at Solar Decathlon Middle East 2018 '	http://www.sustainabilitytribe.com/innovative-solar-powered-homes-at-solar-decathlon-middle-east-2018/
179	21/12/2018	Magazine - Print and Digital	ReNew - 'Desert Rose'	https://renew.org.au/renew-magazine/solar-batteries/desert-rose/?fbclid=IwAR2vFQ68K7SP-CSWoP1HdzQ-56MKdF4aJ1u5CK4J8h0JWNiGXrK_wSNkgro
180	Dec 18	Magazine	Purpose in Action - 'Enabling a Better Quality of Life '	
181	05/02/2019	Web	Friday Magazine UAE - 'Heeding Dubai's call, these international students collaborate to build homes of the future '	https://fridaymagazine.ae/life-culture/self-improvement/heeding-dubai-s-call-these-international-students-collaborate-to-build-homes-of-the-future-1.2300918
182	Feb 19	Magazine	Ecolibrium - 'Flower Power'	

Figure 9.17 and Figure 9.18 - See Table 15.1 Entry #181