1. PURPOSE

The purpose of this case study is to investigate the application of solar passive design principles to a house currently being built in Googong, and to detail the changes made after a consultation with Queanbeyan City Council Sustainable Building Advisory Service (SBAS) for the Googong development. The general principles of solar passive design, and then the way in which they have been applied in this particular build, will be explained. Note that green building goes far beyond passive solar design into embodied energy, choice of building materials and finishes, water efficiency, etc, but this case study is focused on passive solar design.

2. CONTEXT

60% or more of total annual energy consumption in a typical Capital Region household is due to space heating, so much of the discussion in this case study will refer to winter. Unless explicitly noted, you can assume that the reverse is true in summer (eg. it is important to maximise sunlight entry into the house in winter, but minimise sunlight entry in summer).

K&D are building a solar passive house because they have a long-standing professional and personal commitment to sustainability, and want to build for the long-term. The durability and high energy and water efficiency of the building are thus very important, ensuring that the house is inexpensive to maintain and run for themselves and others who may live in the house in the future. Indoor air quality is also an important aspect of the house.
3. SOLAR PASSIVE DESIGN PRINCIPLES

Solar passive design is a method of designing a building to work with its environment to maintain a comfortable internal living environment year-round while using as little conventional energy input (gas, electricity, wood, etc) as possible. There are seven key principles underpinning solar passive design: Orientation, Glazing, Thermal mass, Draught sealing, Insulation, Ventilation and Shading. These principles are best remembered using the mnemonic GOT-DIVS to appropriately group together the principles that rely on each other.

3.1 GOT – Glazing, Orientation, Thermal Mass

Glazing and orientation (careful consideration of solar angles in building orientation) are used in harmony to maximise the quantity of sunlight entering the house in winter (and minimise sunlight entry in summer). Thermal mass inside the house exposed to this sunlight, such as concrete floors or internal brick or stone walls, traps the heat energy from the sunlight\(^1\) that hits it. After the sun sets and the house starts to cool, this heat is released from the thermal mass to the cooling air, which keeps the house at a more constant temperature around the clock. This is the core idea in solar passive design: trapping as much of the heat from the winter sun inside the house as possible.

It is also important to make clever choices regarding glazing and solar orientation to minimise sunlight entry in summer, because thermal mass exposed to sunlight in summer may overheat the building (see figure 2). Windows that are exposed in summer can be shaded – see shading on left.

3.2 DI – Draught Sealing, Insulation

Once the heat from the winter sun has been trapped inside the house, the aim is to keep as much of it as possible inside the building envelope\(^4\) for as long as possible. To achieve this, the building envelope should be tightly sealed so that as little warm air leaks out (and as little cold air leaks in) as possible. Draught sealing of the building joints and building envelope penetrations (plumbing, electrics, fans, downlights, etc) during construction, and ensuring that all openings in the building (doors and windows) are as well sealed as possible, will minimise this loss of heat by convection (movement of air).

Warmth is also lost from the house by conduction through the ceiling, walls, windows, doors and floors whenever there is a temperature difference between inside the building envelope and the outside environment. The temperature difference in Googong on winter nights can be in excess of 20°C, so heat loss through conduction is a very important issue. A high level of bulk insulation\(^2\) throughout the building envelope (e.g. ceiling R5, walls R3) dramatically reduces the rate of conducted heat loss from a building, and is essential in a cold climate like Googong. It is also important to insulate under the roof (R3) if suspended, or to insulate the edge of the slab if slab-on-ground. If installing in-slab heating, under-slab insulation should also be installed. Finally, reflective insulation should also be installed under the roof and in the walls to reflect radiant heat away from the house in summer, which will help to keep it cool.

3.3 VS – Ventilation, Shading

Well-designed ventilation is essential in a healthy, comfortable and energy efficient house. Ventilation is necessary for both air quality and keeping the house cool in summer. A passive cross-ventilation pathway through the house, combined with secure openings, allows the house to be left open overnight in summer to flush the warm air out and take advantage of cooler night air to cool thermal mass.

3.4 FEAT – Features of the House Design

4. FEATURES OF THE HOUSE DESIGN

4.1 Site plan and building envelope orientation

The Googong lot selected by K&D is ideal for their plans. It has a long east-west axis, providing ample northern frontage (see figure 3) to allow windows to maximise incoming sunlight into the house in winter. This orientation is perfect for passive solar design, and the housing envelope has been designed to maximise exposure to the north. The block is gently sloping, which will require some site fill prior to construction, but the building envelope plan avoids over-shading by neighbouring buildings, crucial in passive solar design.

The garage has been placed to the west of the house, which means the house has no windows facing west\(^4\), an advantage in summer. The garage is not linked to the interior of the house by a door so as to maximise indoor air quality, which is especially important to minimise respiratory health issues.

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\(^1\)Infrared radiation, aka heat energy, makes up about 50% of the energy in sunlight – the other half is mostly visible light, and a little ultraviolet light, neither of which contribute to heating.

\(^2\)Building envelope: the exterior of the living environment – namely the ceiling, external walls (including external garage walls – the garage is effectively an outside space because of the leakiness of typical garage doors), external windows, external doors, and floor.

\(^3\) – colloquially called “pink batts”, although they come in many colours and materials, and also as loose fill substances and boards.

\(^4\)The upper floor also has no west-facing windows by design.
4.2 Floor plan – clever use of orientation and glazing

Central to passive solar design is the idea that the house should not require minimal heating or cooling. Integral to this idea, windows are essential for allowing sunlight into the building in winter, and in doing so contribute both heat and light to the interior. However, windows also have two major drawbacks – they are very poor insulators that lose heat rapidly, especially on winter nights; and, if windows are exposed to sunlight in summer they can rapidly overheat the house. So, cleverly balancing the use of windows in the design is essential.

Most windows should be on the northern face of the house to maximise incoming sunlight in winter, while windows should be minimised to the east, west and south, and this is what K&D have done.

This design makes very clever use of glazing. There are ample north-facing windows in the living-dining area (see figure 6) to allow sunlight access to the thermal mass of the concrete slab floor in winter. There are also north-facing windows in each of the main bedrooms. These rooms should all be very warm and comfortable during the day in winter, and should need minimal heating to stay warm at night.

Also, K&D have decided to install highly efficient triple glazed windows with thermally broken framing. Although expensive, this is an excellent investment in the comfort and efficiency of their future home, and necessary in a true passive solar design. For further protection from the cold on winter nights, it would also be a good idea to install insulating internal window coverings, such as multilayered curtains sealed in all directions, or bracketed honeycomb blinds.

4.3 Floor plan – shading

As has been noted above, there are no west-facing windows in the house, although there are some to the east which will need shading. The large living-dining room window will be shaded by the roof of the alfresco, and the lounge room, rumpus room and bedroom two windows will be externally shaded to prevent overheating in summer. The downstairs northern windows will also be shaded by a pergola with retractable shading so as to be useful in summer but not get in the way of solar access to the windows in winter.

4.4 Floor plan – ventilation

On summer nights, when it is important to open the house up as much as possible and allow the cool air in, the predominant direction of the breeze at Googong is from the east to south-east. K&D’s house has allowance for passive ventilation from the east on both floors – through the lounge room window and dining room door downstairs, and the rumpus room window upstairs. The air can exit from any of the windows/doors to the north on both floors.

Combining these openings with secure screens means that they could potentially be left open overnight to enable the warm air to be fully flushed out of the house, and to help cool the thermal mass of the slab.

4.5 Other passive design features – draught sealing and insulation

The family have decided to make sure that the building is properly draught sealed during construction, which is essential in passive solar design, although not standard in the Australian building industry. Construction joints, such as between the floor, walls and ceiling, penetrations through the building envelope, such as plumbing, and other gaps, such as those between window framing and wall framing, will be properly sealed, and the external walls will be wrapped in a water vapour-permeable airtight membrane. This will minimise heat lost through gaps in the building envelope while avoiding moisture build-up in the house (which can lead to sick building syndrome).

The house will also have a high level of insulation. The external ceiling (upstairs and downstairs) will be insulated to the R5 insulation standard recommended for this climate zone. The roof will be under-laid with reflective insulation/anti-con to help keep the ceiling cavity cooler in summer and prevent condensation issues in winter. The internal ceiling (between upstairs and downstairs) will be insulated with R4 batts, which will help to retain heat downstairs at night, and also give some degree of acoustic insulation. The external walls will be insulated with R2.5 earthwool batts (R3 total with the wall included), and the wall to the garage will be rightly treated as an external wall and insulated the same way.

The concrete slab downstairs floor will also be insulated on the edges (R2.14) and underneath (R1.7 insulation and waffle pod design combining for roughly R2.2), a great idea in a climate like Googong where the surrounding ground can have a significant effect on the temperature of the slab from summer to winter.

The combination of proper draught sealing and a high level of insulation will combine to retain heat inside the house to a much greater extent than a standard build. This in turn means that the house will require minimal heating to be warm and comfortable in winter, and should also stay cool in summer as long as the windows are adequately shaded.

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Figure 4: the downstairs floor plan.

Figure 5: the upstairs floor plan.

Figure 6: north-facing glazing in the living area and main bedrooms.
4.6 Other passive design features – heating and hot water heating

Given the solar passive design of K&D’s home, they have decided to use a heat recovery ventilation (HRV) system to keep the house warm in winter while also maintaining excellent air quality. HRVs replace the stale air inside a house with fresh air from outside, but in doing so they transfer most of the heat from the outgoing air to the incoming air to keep the heat inside the house. The HRV will be connected throughout the house to bathroom exhaust fans, the kitchen rangehood, etc so that it is the only ventilation penetration in the building envelope.

The family have had the house and HRV system modelled to ensure that the HRV will effectively replace the stale air inside a house with fresh air. The HRV will be connected throughout the house to bathroom exhaust fans, the kitchen rangehood, etc so that it is the only ventilation penetration in the building envelope.

The family have had the house and HRV system modelled to ensure that the HRV will effectively replace the stale air inside a house with fresh air.

Example of forward-thinking design and planning: with a slab on ground floor, it would be infeasible to install hydronic heating post-construction, but installing the pipework in the walls during construction adds to the adaptability of the house in the future.

The hot water heating will be a Sanden water heat pump – they are highly efficient, and also very quiet. A high-efficiency water heat pump combined with solar photovoltaic panels can result in high hot water heating efficiency and low GHG emissions.

K&D intend to install solar photovoltaic panels after a year of living in the residence so that they can size their installation according to their demand for electricity. If possible, we will also follow up with the family around this time to assess the energy consumption of their home.

5. POST-CONSULTATION CHANGES TO THE PLAN

The house was in an advanced stage of planning when K&D consulted the Sustainable Building Advisory Service – plans had been drawn up, although given that they had not yet been through the development application process, the plans were not set in stone.

K&D did not make major changes to their design post-consultation, however the consultation did help them to refine a few important details including:

- window placement and size – the size of a number of windows was increased (north-facing living-dining room windows) or reduced (stairwell, rumpus, bedroom windows), or removed altogether (lounge room);
- the importance of window framing – the windows they subsequently chose for the house are some of the most insulative on the market;
- connecting all sources of ventilation to the HRV to increase air-tightness of the building envelope;
- the nature of supplementary heating (changed from a flued gas space heater to hydronic heating – a better complement to the solar passive design – and then to no supplementary heating at all after K&D did further research);
- the importance of shading eastern windows;
- the size of the front door (reduced – doors are generally not highly insulated, and large doors can be very heavy).

6. SUMMARY OF SUSTAINABLE FEATURES

K&D’s house is an excellent example of a well-planned solar passive design. Crucial design features include:

- a suitable site which allows for correct solar orientation to maximise access to sunlight in winter and minimise incoming sunlight in summer;
- careful placement of glazing – maximum exposure to the north, minimal exposure to the east, west and south;
- careful choice of windows – triple-glazed with thermally broken framing to allow the sunlight in but reduce heat loss through conduction as much as possible;
- retracted external shading for exposed northern and eastern windows during summer;
- use of thermal mass (an insulated slab-on-ground floor) inside the building envelope to store heat during winter and help to maintain a more consistent temperature in the house year around;
- draught sealing during construction to maximise heat retention in the building envelope;
- a high level of insulation in all directions to maximise heat retention in the building envelope;
- allowance for passive ventilation pathways for summer cooling overnight;
- highly efficient heat recovery ventilation to complement the passive solar design and help to retain heat in the building envelope with minimal use of electricity;
- hot water heating by highly efficient (and quiet) water heat pump;
- provision for future installation of solar photovoltaic panels.
7. CONCLUSION

K&D have decided to build a solar passive house so as to improve the comfort, efficiency and indoor air quality of their new home with the long-term in mind. Their design incorporates the features that facilitate their lifestyle, and a pleasing aesthetic, while also being highly efficient, and adaptable to their potentially changing needs over time. They have shown that with careful thought about what you want from your house now and in the future, some patient research, and consultation with sustainable housing professionals, it is possible to build a comfortable, fully functional and highly efficient solar passive house in Googong.