A CASE STUDY FOR THE DOMESTIC APPLICATION OF NATURAL VENTILATION IN SYDNEY - A view from the ground up

A. D. Oosthuizen
Ecobuild Pty Ltd
PO Box 19, Bundeena NSW 2230, Australia
Fax: +61 2 9527 6633
E-mail: ecobuild@ozemail.com.au

ABSTRACT

The on-the-ground experience of a domestic design and construct company (Ecobuild Pty Ltd, for which the author is the designer and director), is illustrated as a case study for the application of domestic natural ventilation in the temperate climate of Sydney. Factors limiting the general domestic application of natural ventilation are discussed. Requirements of a domestic ventilation system in Sydney are listed. Examples of domestic natural ventilation designed the company are illustrated. Preliminary results are discussed. The need for domestic IAQ research and standards is stressed.

1 INTRODUCTION

Australians spend approximately 80% of their time at home or at school, 10% at work and less than 3% of time outdoors (S. Brown & P. Newton, 1997). There is an agreement that the greatest source of exposure to airborne pollutants is the indoor environment, with 50-80% of this exposure coming from domestic indoor air.

Adequate research into air infiltration and ventilation rates in Australian dwellings is lacking. Limited evidence indicates that air infiltration rates in new Australian dwellings are below levels considered overseas as essential for good indoor air quality. New ventilation methods and codes to improve IAQ have commenced internationally, but not in Australia where practical research into building ventilation has been lacking in recent years (S. K. Brown, 1997). During the last decades, domestic indoor air pollution has been increasing due to the lowering of house ventilation and infiltration rates to increase energy efficiency, and the increased emission of pollutants from manufactured building materials and finishes (S. K. Brown, 1997). The reduction of standard ceiling heights to 2.4m has decreased indoor air volumes dramatically.

Research into domestic IAQ in Sydney has been limited. No single government authority has responsibility for indoor air quality. No regulations have been developed specifically for domestic indoor air environments (S. K. Brown, 1997). Lack of awareness and understanding in Local Government exists, regarding the importance of domestic IAQ. Local Environmental Plans and Development Control plans largely ignore domestic ventilation. The Royal Australian Institute of Architects, Housing Industry Association and Master Builders Association likewise do not have any specific policy on domestic IAQ and ventilation. Energy efficiency evaluation tools such as NatHERS do not take into account the effect of ventilation on heat loss or gain, other than assumed infiltration rates (J. Ballinger, 1998).

2 EXTERNAL FACTORS INFLUENCING THE INTRODUCTION OF DOMESTIC NATURAL VENTILATION IN SYDNEY

2.1 Local Government Development Controls

Development Control Plans often inhibit the implementation of a natural ventilation system. Dedicated ventilation space such as vertical ducts, stacks and atria are counted as floor space into Floor Space Ratio calculations. In order to provide ventilation space on plan, usable living space must be sacrificed. Height restrictions (especially on sloping sites) severely limit the application of stack ventilation and may result in standard ceiling heights of 2.4m, reducing indoor air volumes. There is local government resistance to the appearance of visible ventilation components.

2.2 Lack of ventilation design

In Australia, houses are mostly designed by builders and draughtsmen, with less than 1% assumed to be designed by architects. 85% of dwellings are project homes. Natural ventilation is currently not a primary consideration in common domestic design and project homes. Current ventilation design techniques may be too complicated and expensive for domestic design, even for most architects.

2.3 Air conditioning and user habits

Inhabitants have increasingly become used to dial up a temperature on the air-conditioner. How to use windows and shading to warm and cool the house, is becoming a forgotten skill.

2.4 Sound transmission

Ventilation ducts may cause sound transmission between rooms in a house. Breathing walls are typically less massive. Special precautions need to be taken in the acoustic design to compensate for the effect of the ventilation system

2.5 Effect of insect screening

In Sydney it is necessary to screen all openings against mosquitoes, sandflies, spiders and other insects. Depending on the type of insect screen, the average reduction in airflow due to screening a ventilation opening may be as much as 80%, depending on the wind speed and dustiness of the screen (R. Aynsley, 1996). Ventilation opening screen size needs to be compensated accordingly.

2.6 Effect on fire spread

A well-ventilated house is likely to burn faster and fiercer than a badly ventilated house. This applies especially to stack ventilation. Fire protection measures such as smoke detectors, fire extinguishers and fire escapes becomes more critical.

2.7 Domestic design cost

Builders or draughtsmen, for around $1000, design 99% of houses in Australia. Few homeowners would spend extra on ventilation design. Architects too largely ignore ventilation design, especially where A/C is to be installed. The cost of a ventilation consultant in the design of single houses is considered prohibitive by most homeowners.

2.8 Building cost

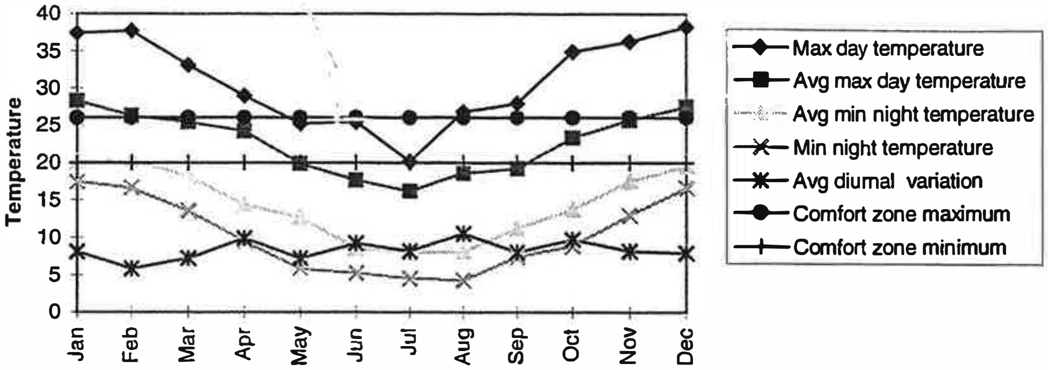
Additional building costs may occur relating to dedicated ventilation components and control systems. Given the lack of standards and general IAQ awareness, there is little motivation to incur additional building costs for natural ventilation.

2.9 Maintenance and running costs

Maintenance cost relating to dedicated ventilation components may increase, like cleaning filters and ducts.

3 SYDNEY CLIMATE (Bureau of Meteorology daily climate data for Sydney Airport)

3.1 Sydney average annual maximum and minimum daily temperatures

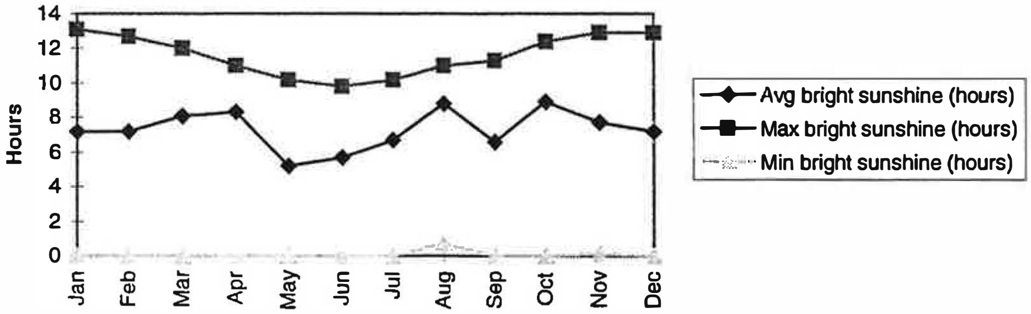


Graph 3.1 Daily temperatures

Average maximum daytime temperatures vary from 28 degrees Celsius in January to 16 degrees minimum in July. Average minimum nighttime temperatures vary from 20 degrees Celsius in January to 8 degrees minimum in July. Temperatures in summer may reach 38 degrees and at night in winter fall to a minimum of 4 degrees.

Average diurnal temperature variation is roughly 8 degrees, with the maximum variation of 11 degrees in August and the minimum 6 degrees in February.

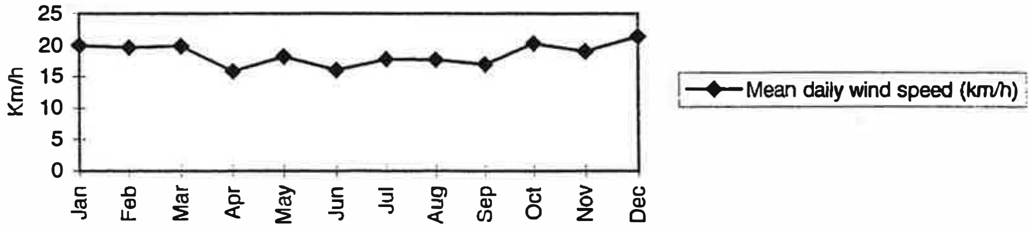
3.2 Sydney average daily sunshine



Graph 3.2 Daily sunshine

Sunlight is available on average for roughly a 7 hours of the day. Exclusive reliance on solar assisted ventilation is therefore limited in relation to the 24hr ventilation requirement of houses. Solar assisted ventilation measures may be coupled with heatbanks to lengthen the period of effectiveness after direct sunlight has passed (G. Baverstock, 1986).

3.3 Sydney mean daily wind speeds

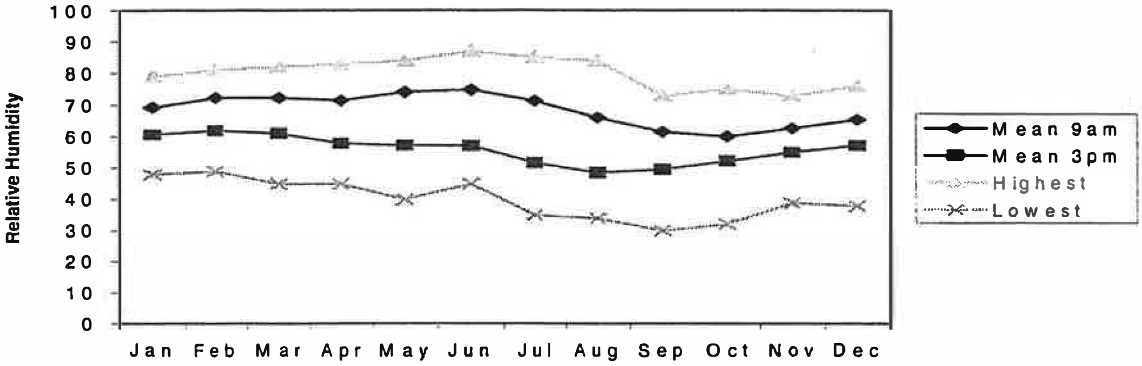


Graph 3.3 Daily wind speeds

Wind direction varies on a both daily and seasonal basis. Nighttime southerly breezes in summer changes to westerly in the winter. Daytime northeasterly breezes in summer vary to southerly and westerly in winter. Daytime wind calms are rare. Conditions for cross ventilation during the day, resulting from external differential air pressure, are good.

Night calms occur regularly (up to 40%), predominantly in summer (September to April). The minimum night calms (20%) occur in the winter months of June, July and August. Due to the significant proportion of night calms, cross ventilation, relying on external differential air pressure resulting from wind is limited for night ventilation, especially in summer. Stack ventilation, relying on the internal temperature gradient, may be more appropriate for nighttime ventilation.

3.4 Humidity



Graph 3.4 Relative humidity

Relative humidity at 9am peaks in June at 74.9% and is lowest in October at 60%. 3pm Relative humidity peaks in February at 61.9% and troughs in August at 48.5%. In general the mean relative humidity is well above an assumed comfort zone high of 50% relative humidity. These humidity levels may require an increased ventilation flow rate to provide cooling comfort to the occupants in summer, prevent winter condensation, and mould and dustmite growth in summer.

4 SYDNEY DOMESTIC VENTILATION REQUIREMENTS

4.1 House occupancy patterns

Australians spend more than half their time in the indoor environment of their homes (refer 1 INTRODUCTION). Domestic indoor air quality should therefore be of the greater concern, as compared to workplace and outdoor air quality. Unlike most other indoor space, residences are mostly fully occupied at night, and often unoccupied during weekday mornings and early afternoons. Occupancy patterns vary depending on the family demographics.

4.2 Day ventilation

Family homes are often locked up during the day, when the parents are at work and the children at school. Ventilation ceases as all doors and windows are closed for security. Because of low infiltration rates in recent domestic construction, the indoor air quality may be poor by the time the inhabitants return home. This situation could be rectified by a natural ventilation system independent from the doors and windows, providing at least a base line indoor air change.

Due to the almost complete lack of daytime calms, cross ventilation could be an effective method of natural daytime ventilation. Breezeways and openings strategically placed on the windward and leeward side of the home could be effectively used for summer cooling and air flushing utilizing the prevailing sea breezes. Supplementing the cross ventilation with stack ventilation to further remove warm air from the home can enhance this effect.

During winter days, the cold prevailing southerly and westerly winds provide ample external differential air pressure for cross ventilation, with external openings reduced to compensate for the strength and low temperature of the winds. This however results in air displacement by diffusion, increasing the amount of air needed to achieve a complete indoor air change. In winter this will place additional demand on space heating and is therefore not likely to be energy efficient. Stack ventilation (especially in combination with passive solar design and heatbanks) with low external air intakes and high exhausts, may result in vertical air displacement, requiring less external air to achieve an indoor air change, thereby improving energy efficiency by reducing the demand of indoor space heating.

4.3 Night ventilation

Night ventilation is important, as it is the period the home is most likely to be fully occupied. Bedroom ventilation at night is especially important during the hours of sleep.

In summer, up to 40% of nights is calms, lacking sufficient breeze to drive cross ventilation. Humidity is typically high. Overheating and a build up of humidity of the interior may occur, even with windows open. Stack ventilation with appropriately sized and located openings, may provide better cooling and air change.

Prevailing winter nighttime westerlies are typically cold. Nighttime cross ventilation is typically limited by the occupants to preserve indoor heat. Stack ventilation coupled with heat releasing heatbanks, arguably requiring less external air than cross ventilation, may provide adequate fresh air at minimum expense to energy efficiency.

4.4 Condensation

Current external finishes frequently cause an air and vapour tight barrier, which may lead to condensation problems, often exacerbated by the general lack of wall and floor insulation. Construction elements such as walls, floors and roofs could be air permeable (while being waterproof yet vapour permeable), avoiding conditions that would allow condensation to occur.

4.5 Pollutant emissions

Locally manufactured building components, materials and finishes frequently have high VOC emission characteristics (S. K. Brown, 1997). Most homes still have wall to wall carpeting. Given the low air infiltration rates common in resent domestic construction, the need for a ventilation system removing these indoor air pollutants becomes more critical.

4.6 Air change standards

Quantitative air change standards for domestic ventilation is limited to "...an aggregate opening or openable size not less than 5% of the floor area of the room required toe be ventilated;..." (Building Code of Australia, 1996).

4.7 Heating and cooling requirements (Refer Graph 3.1)

Perceived domestic thermal comfort depends on temperature, radiation, wind speed and humidity, and the dress and activity level of the inhabitants (C. Pidcock, 1996). A daytime comfort zone of 3 degrees above (26 degrees), and 3 degrees below (20 degrees) room temperature is assumed for discussion purposes. On average, cooling (-2 degrees) is required during the day for 4 months (November to February), and heating (+4degrees) is required for 4 months (June to September). Nighttime cooling may be required on midsummer nights when nighttime calms are frequent. Nighttime heating (+12degrees) at an assumed 20-degree comfort minimum is required for 9 months (March to November).

4.8 Energy efficiency

Australia wide 39% of domestic energy usage results from space heating and cooling (Australian Greenhouse Office, 1999). There has been no research in relative domestic energy usage for heating versus cooling in Sydney. From **Graph 3.1** it would appear that in Sydney marginally more energy would be expended on heating, relative to cooling.

This puts pressure in winter on the natural ventilation system not to leak too much heat from the home, resulting in higher energy usage. Air displacement, rather than diffusion, would require less external air to provide the same IAQ, and hence should be more energy efficient. Stack ventilation, designed for air displacement, therefore seems more appropriate for domestic winter ventilation.

In order to provide natural cooling in summer days, breezeways capitalizing on the prevailing cool sea breezes may be most appropriate, but in practice is limited by excessive air speed, given the normally brisk sea breeze. For the calm summer nights, stack ventilation may be more successful in exhausting hot air and humidity from the indoor air and to provide adequate airflow speed for cooling, possibly alleviating the need for air-conditioning or mechanical ventilation.

5 EXAMPLES OF APPLIED NATURAL VENTILATION IN SYDNEY

5.1 New house

Building name:	House Gschwind, Maianbar (Sydney)
Year of completion:	1997
Type of building:	House
Design and construction:	Ecobuild Pty Ltd

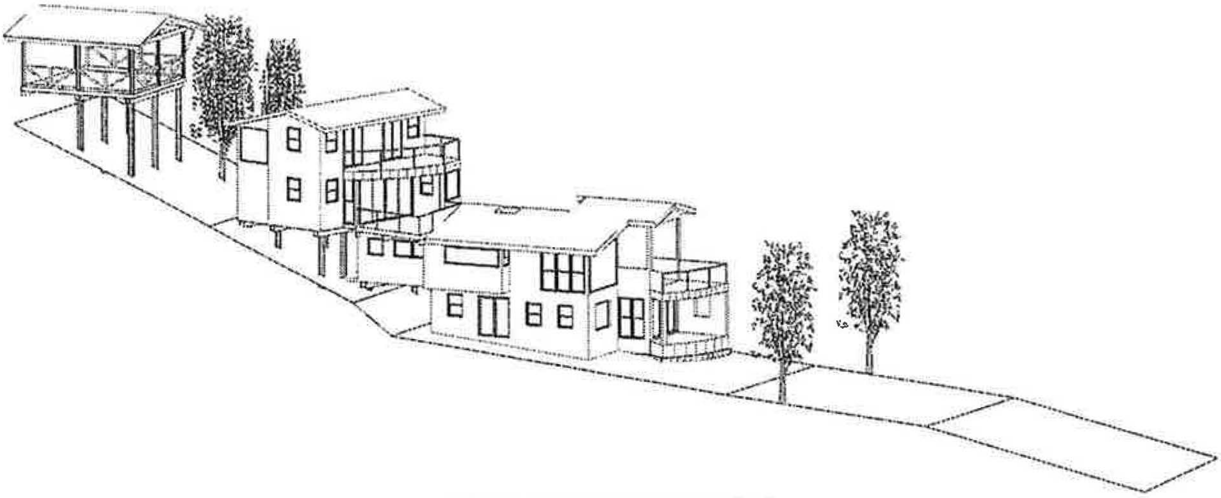


Figure 5.1 House Gschwind

5.1.1 Principle of natural ventilation

The house is divided into two living **zones** and a transitional zone linking the two living zones. All three zones are double storey height. The elevation of each zone is one storey higher than the other. Each double storey living zone can be independently **stack and/or cross ventilated**, as well as joined together serially to stack ventilate all zones together. The bottom living zone and the transitional zone can be joined together to create a **breeze way** by catching summer breezes utilizing the porch as a **wind scoop** and channeling it by cross ventilation through the living zone to exhaust through the wide entry way of the transitional zone. The top living zone is one room deep with all rooms having openings on at least two opposing sides for maximum cross ventilation ability. **Passive solar design** has been applied to each zone, allowing full solar access in winter, while excluding sun in summer. Fully **insulated heatbanks** in the form of concrete floors and massive walls were employed in the bottom living zone, providing a heat release time lag of 7 hours. The concrete floors have off peak **in slab heating** installed. All floors (R1.5), walls and roofs (R2.5) have **full insulation.** Both stack and cross ventilation **rely on the opening of windows** and sometimes the doors. Full length double hung windows allow **external air intake openings low** down to the floors, while louvers, roof windows and elevated double hung windows allow **air exhausts at maximum relative height to the air intakes.** Opening the wide entry and opposing porch doors, the breezeway is made operational. Opening the full-length double hung windows at the top, allow conventional cross ventilation. To improve **air infiltration rates** and reduce the possibility of **condensation** in the event of all doors and windows being closed, **breathing wall- and (some) floor construction** have been employed. Only **non-VOC emitting building materials and finishes** were applied. **Insect screening** has been applied to all external openings. To compensate, **aggregate opening sizes** have been set at a minimum of 10% of respective room floor areas. Local government development control **height restrictions** made it impossible to employ rooftop air exhaust stacks or chimneys. Similarly, **ceiling heights** in the bedrooms were forced down to 2.4m, in order to allow 2.7m minimum ceiling in the living spaces.

5.1.2 Operation of natural ventilation system

The general operation of the natural ventilation system is dependent on the opening of doors and windows by the inhabitants. **Stack and/or cross ventilation** is possible in all three zones, whether independently or combined, providing abundant combinations for maximum air change or as is required by the specific conditions. **Air infiltration,** when all doors and windows are closed, is achieved by breathing wall and floor construction. (Radon levels in Sydney are low.) **Summer night time cooling** is achieved through stack ventilation of the two living zones, independently or as a whole system, by drawing in cool air from the cool, permanently shaded underbelly of the house and exhausting the warmer internal air through high exhaust openings. Due to the high incidence of night calms, cross ventilation could not be fully relied on. **Summer daytime cooling** is performed as for nighttime on wind still days, or when the wind is unfavourable. When the prevailing cool north easterly sea breeze is blowing, the breezeway using the porch as windward wind scoop, and the wide entry as opposing leeward exhaust, can be opened, **flushing** the house with cool air and providing additional air flow speed for a physical cooling effect. The upper living zone is one room deep with opposing external openings on at least two sides, to allow maximum cross ventilation utilizing the see breeze. Alternatively, it too can be stack ventilated, drawing in cool air from the underbelly of the house. **Winter nighttime warming** is achieved by stack ventilation, by drawing in external air low down over the preheated passive solar-, or off-peak electrically heated, heat banks (floors) and exhausting the air higher up by means of the resultant internal temperature gradient. The resultant air displacement, rather than diffusion, lessens the amount of external air needed to provide the same IAQ, minimizing the energy requirements for space heating. This lessens the reliance on the cold prevailing night winds for cross ventilation. **Winter daytime warming** is achieved by passive solar design allowing the sun to heat the internal heatbanks. Stack ventilation, as per above, transfer the heat throughout the living zones.

5.1.3 Overall performance:

Owner's verbatim quote: "The improvement of air quality in this house compared to any previous houses we have lived in, is remarkable. We can return to the house after several weeks' absence, when the house was completely locked up, and the air is fresh and pleasant even before we open a window. The thermal comfort of the house is excellent."

Empirical evaluation has not been performed to date, nor has the energy efficiency of the house been measured. Performance of the ventilation system is dependent on the correct settings of the ventilation system by the occupants, given the changing internal and external conditions. No sign of condensation has been visible, including on the glazing during winter.

5.2 Current design:

Building name:	Cluster housing development, Dolans Bay (Sydney)
Expected year of completion:	2000
Type of building:	Houses (4)
Design:	Ecobuild Pty Ltd

Figure 5.2 House Dolans Bay

5.2.1 Principle of natural ventilation

The house is divided into **five double storey zones**. Four zones on the corners of the building are separated by a cross-shaped intermediate zone, separating/linking the four corner zones. The four corner zones each have **dedicated stack ventilation**, independent of doors and windows, and other zones. In addition, with these zones being one room deep only, doors and windows can be used to provide **cross ventilation**. The central transition zone has independent stack ventilation through a central double volume atrium. In addition the transition zone can operate as a 2.7m wide breezeway, bisecting the house. **Air intakes** are underneath the cool underbelly of the house, through **carbon air filters**. The **air is preconditioned** in basement chambers before being fed low down into each room of the different zones. The rooms have opposing **exhaust vents** located at maximum height relative to the room intake, from where it is exhausted through the dedicated stack chimneys, operating by means of **thermal gradient** and supplemented by wind and solar effects as available. **Passive solar design** is applied to each zone to drive the internal temperature gradient, allowing full solar access in winter, while excluding sun in summer. Fully **insulated heatbanks** in the form of concrete floors and massive walls are employed. The concrete floors have off peak **in slab heating** installed. All floors (R1.5), walls and roofs (R2.5) have **full insulation**. To improve **air infiltration rates** and reduce the possibility of **condensation** in the event of all doors and windows being closed, **breathing wall construction** is employed. Only **non-VOC emitting building materials and finishes** are applied. **Insect screening** has been applied to all external openings. To compensate, **aggregate screen opening sizes** have been set at a minimum of 20% of respective room floor areas.

5.2.2 Operation of natural ventilation system

The natural ventilation system is to be **fully computer controlled and operated**, based on **inhabitant control** of indoor air temperature. Each of the **five zones** is to be **independently controlled**. Vents are to be automatically operated by the control system. The **ducted stack ventilation** system is to operate independently of the doors and windows and whether the house is occupied or not, allowing optimum and continuous 24 hour ventilation. In addition by the inhabitants opening windward and leeward doors and windows, single space **cross ventilation** is possible. The transition zone can act as a 2.7m wide **breezeway**, longitudinally bisecting the house. **Air infiltration**, when all doors and windows are closed and the stack ventilation system is disabled, is to be achieved by breathing wall construction, thereby minimizing conditions for **condensation** to occur. (Radon levels in Sydney are low.) **Summer night time cooling** is to be achieved through independent stack ventilation of all the zones, by drawing in cool air, through low room intake vents, from the basement air-preconditioning chambers and exhausting the warmer internal air through high room exhaust openings connected to stack ventilation chimneys. Due to the high incidence of night calms, cross ventilation could not be fully relied on. **Summer daytime cooling** is performed as for nighttime on wind still days, or when the wind is unfavourable. When the prevailing cool northeasterly sea breeze is blowing, the breezeway doors of the transitional zone can be opened, **flushing** the house with cool air and providing additional airflow speed for a physical cooling effect. The upper parts of the living zones is one room deep with opposing external doors or windows on at least two sides, to allow maximum cross ventilation utilizing the see breeze. **Winter nighttime warming** is achieved by stack ventilation, drawing in air from the (heated) pre-conditioning air chambers in the basement, over the heated floors and exhausting the air high up in the room into the stack chimney. The resultant air displacement, rather than diffusion, is expected to lessen the amount of external air needed to provide the same IAQ, minimizing the energy requirements for space heating. This lessens the reliance on the cold prevailing night winds for cross ventilation. **Winter daytime warming** is achieved by passive solar design allowing the sun to heat the internal heatbanks (floors). Stack ventilation, as per above, transfer the heat throughout the living zones. Low VOC pollutant emitting materials and finishes are specified.

5.2.3 Overall performance:

Building has not commenced. The development application is pending with Sutherland Shire Council.

6 PRELIMINARY SUBJECTIVE RESULTS AND DISCUSSION

No empirical testing has been performed on House Gschwind. The stated results are based on the subjective perceptions of the inhabitants of House Gschwind and previous stack ventilated houses designed and built by the company. **Stack ventilation** appears to be an efficient way of domestic natural ventilation in Sydney, provided it is operated correctly by the inhabitants, especially if stack air intakes and exhausts is a function of the doors and windows. If stack inlet and exhaust openings are opened too wide, excessive air flows may occur, depending on prevailing conditions. On the other hand if stack exhaust openings are shut, unreleased thermal stratification may lead to the upper levels of the stack over heating. Given that stack exhausts may be three storeys above the intakes, inhabitants rarely bother to adjust the exhaust relative to the intake openings. The stacks may therefore rarely be used optimally. **Cross ventilation** capability of the houses is rarely used by the inhabitants, who instead rely almost exclusively on stack ventilation. The **breezeways** are likewise rarely utilized, except for the few very hot days in summer when the breeze is not too strong. The inhabitants rate the **thermal comfort** of the houses as very good. The houses remain cool in summer, and warm in winter. No need for further cooling in summer has been expressed, and winter heating is avoided all together during the day, with some mid winter night and early morning heating required. In general houses, built by the company, with insulated ground floors as heatbanks, appear to have a superior thermal performance to insulated lightweight construction exclusively. In winter with airflow rates diminished and heating switched off, upper storeys may be warm while leaving bottom storeys cold. This effect seems to be mediated by placing heatbanks in the lower storeys. The **energy efficiency** of the houses has not been tested.

7 CONCLUDING REMARKS

Preliminary research indicates that the current understanding of domestic IAQ in Sydney is poor. There is urgent need for baseline research into domestic IAQ. There is general unawareness in domestic designers, builders and owners about IAQ issues, including ventilation. This recalcitrance appears to encompass all levels of government as well, leading to a lack of domestic ventilation standards and regulations. Natural domestic ventilation currently appears to occur by default, rather than by design. Domestic natural ventilation should be seen as integral, and not adjunct, to the ecologically sustainable and energy efficient design and construction of dwellings.

REFERENCING

1. Brown S., P. Newton (1997). Air pollution exposure descriptors in Australia. Unpublished CSIRO BCE document.
2. Brown S. K. (1997). Indoor Air Quality. Australia: State of the Environment, Technical Paper Series (Atmosphere).
3. Ballinger J. A., (1998). NatHERS User Training Course. Unisearch, Industry and Technology Group.
4. Aynsley R. (1996). Natural ventilation in passive design. Technology Note 2, Environment Design Guide, The Royal Australian Institute of Architects.
5. Bureau of Meteorology, Climate and Consultancy Section, New South Wales Regional Office, Requested daily climate data for Sydney Airport AMO.
6. Baverstock G., S. Paolino, (1986). Low energy buildings in Australia. Graphic Systems, Western Australia.
7. Building Code of Australia, (1996). Part 3.8.5 VENTILATION, Clause 3.8.5.2 Ventilation requirements.
8. Pidcock C., R. Cowdroy, (1996). Perceived comfort. Design Guide Note 12, Environment Design Guide, The Royal Australian Institute of Architects.
9. Australian Greenhouse Office, Energy Efficient Strategies et al., (1999). Study of greenhouse gas emissions from the Australian residential building sector to 2010. Final Report. 21 February 1999.