Guidelines

# Sustainable Services & Thermal Comfort

## for Residential Buildings
## &
## for Small to Medium Size Commercial Premises

This information and other technical information can be found on our web-site, for the benefit of all designers and Clients. These guidelines may be freely distributed, but without alteration/deletion, and with full acknowledgement of the Author.

(www.understandingenergy.com.au)

In a general document like this cost-effectiveness cannot be readily categorised. Your designer may be able to assist you in investigating the options. Alternatively the technical staff at Healey Engineering can assist.

(last edited 16/7/08)

# Contents

## 1. COMFORT, ENERGY SAVINGS, PAYBACK

The energy cost for a small building will range from $ 50 to $ 15 per square metre a year. This applies to a house and to an office facility. Any scheme that saves a proportion of this energy can pay back only small capital cost items.

"Payback period" concepts also do not formally account for environmental externalities such as pollution created, imported fuels (strategic societal issue) greenhouse gas reduction, and depletion of non-renewable energy resources. An NPV (net present value) calculation is more realistic than payback period, but is still only a more accurate "payback" calculation.

This report looks at comfort and liveability on the basis that staff productivity of comfortable occupants is a much greater cost factor. The discomfort from the many badly-designed houses is something your family should not have to bear.

Conventional solutions (eg: Air conditioning systems) do not automatically bring comfort. Even where theoretically "perfect" conditions are achieved (usually at ridiculous energy cost) comfort may **not** be achieved. Mechanical comfort systems control surrounding air temperature, not comfort.

The sustainable solutions proposed give better working conditions, and allow occupants a greater degree of personal control of comfort, as well as environmental benefits. These are the target, a better long term total investment.

## 2. COMFORT & DISCOMFORT

Usually these sustainability issues are addressed in "Energy Saving" terms. This may be misleading. In most workplaces basic comfort relates to occupant satisfaction and productivity. The salaries paid can be **50 to 200 times** the energy cost in an office building. Lost productivity is far more expensive than the power bill.

Air conditioning systems do not automatically bring comfort. Even where theoretically "perfect" conditions are achieved (usually at ridiculous energy cost) comfort may **not** be achieved.

Air conditioning systems control surrounding air temperature. Even "perfect" conditions mean that 85% of occupants are comfortable. This means that 15% of occupants are not comfortable, and many of those are uncomfortable. This arises from varying metabolisms, types of clothing, physical activity.

Thermal comfort is only partly (one-third) based on air temperature, the remaining 2/3 is radiant heat & "coolth" and air movement. Also thermal comfort is of little use if the occupant is subject to glare.

These notes deal with the largely technical ideas related to design of the building and its facilities. The issue of comfort is tied up with these technical issues. The issues of comfort also extend well beyond what is discussed here. A linear example is the need for a place away from the work desk to eat lunch. Another is to allow a worker to move away from the workplace (usually a PC screen) for brief periods and focus to a distant object. If the blinds are drawn because of heat and glare, this has to be elsewhere (Foyer, verandah?).

# 3. THE BASIC ISSUES

## 3.1 Concepts

Sustainable comfort involves the careful design of the building. This is the integration of shade, sun penetration, insulation, and cross ventilation.

Affordable sustainable comfort in summer comes from the combination of good cross ventilation in mild weather, and night cooling on still nights in warm and hot weather. Air conditioning is then needed on fewer occasions.

Affordable sustainable comfort in winter involves heat gain from solar, preferably by passive gain, alternatively by active solar air collectors. Again this minimises the need for heaters or air conditioners. Then possibly this gained heat may need to be re-distributed to cooler areas of the building (lower floors, south aspect).

Heating or cooling the surrounding building structure is more important for comfort than simply controlling the air temperature. That is why a "naturally" comfortable building is more pleasant than a "heated" or "cooled" building.

## 3.2 Shape, Aspect, Insulation, Ventilation

The most important issue is a sound building design. This could be described as "Shape, Aspect, Insulation, and Ventilation". These need be dealt with by the Architect / Builder first so that the money will be spent on mechanical systems (if any) will be effective.

## 3.3 Building & Energy Codes

Buildings that meet the energy requirements of the Building & Energy Codes (the BCA in Australia) will achieve a basic level of insulation and solar control.

## 3.4 Beyond the Building Codes

The further design of winter passive solar access reduces the active heating requirements and result in more even structural temperatures giving better comfort. There are many opportunities for improvement

Further detailed design can take a building from basic compliance to 6 stars plus.

**(a)** *Passive Solar Gain*
Heat gain by the control of winter passive solar access reduces the active heating requirements and result in more even radiant temperatures giving better comfort.

**(b)** *Double Glazing*
Double glazing and "smart glass" should be considered.

**(c)** *Air Leakage*
Massive heat loss, discomfort, and drafts can occur from even subtle leaks. The time to experiment to detect them is on a windy day. Close all doors and windows, then stand in an open doorway; you may be surprised by the draft. Sources are:

- weather board framed construction
- suspended timber floors – gaps between boards, and gaps at the wall

- drainage holes in windows
- no weather stripping on doors
- fans without shut-off dampers
- short-glazing on lavatory windows
- gap at the wall ceiling joint
- vent holes in light fittings (down light tubs, recessed fluoro lights)
- (and more!)

**(d)** *Other Issues*
Controlled cross ventilation, night cooling, efficient air-conditioning, smart central air con and vent control, heat transfer ducts, de-stratification, and wall and floor insulation are discussed further.

## 4. INSULATION SYSTEMS

### 4.1 Roof-Ceiling Insulation

Bulk fibre insulation (fibreglass, wool, acrylic etc) is the most effective. More effective (and expensive) with a foil reflective layer. Batts are easier to manage than loose material.

Foil sheet insulation (alone: usually multiple foil sheets separated by an insulating air gap) is reasonably effective in summer (controlling radiant heat) but much less so in winter compared with bulk fibre. Consider this insulation for a retrofit in difficult locations (under floor, high roof).

Going beyond the recommended "building code" level of insulation improves performance, and is valid, but often there are more cost-effective ways to spend the money.

### 4.2 Floors & Walls

**(a)** *Suspended Floors*
Floor insulation under raised floors is often neglected and not required in the codes in many climate zones. In every situation and climate zone a significant qualitative improvement can be made by insulating the under floor. At the same time air leaks can be checked for. No, carpets are not effective, only a partial solution.

**(b)** *Double Brick*
In some climate zones the recommended "building code" level of insulation does not require bulk insulation in "double brick & cavity" walls. Double brick walls do not perform anywhere near their claimed performance. This is because much of the thermal mass is ineffective, and the calculated "R values" are simplistic and do not account for real life. We advise that 25 mm rigid or semi-rigid insulation boards or batts installed (during construction) give a significant boost to qualitative comfort in that building. This occurs because the internal leaf of the brick wall acts as affective thermal mass when insulated.

# 5. DIRECT SOLAR GAIN

## 5.1 Solar Gain – Residential

Direct solar gain is usually desirable, but care must be taken that glare (say TV viewing) is not prominent.

The energy collected by passive solar gain features is both delivered to the occupants, and stored in the thermal mass. Buildings with low thermal mass can utilise less solar gain, which is otherwise wasted or overheats the building. Buildings with larger thermal mass can accept greater solar gain, and deliver it to the next day.

The balance of solar energy with losses can be calculated (by us) highlighting potential overheating, and need for double glazing or better insulation.

## 5.2 Solar Gain – Office Buildings

**(a)** *Office Tenancies*
Heat gain from direct solar radiation is not very useful when directed into the working spaces, as it is accompanied with glare. Also in temperate Climate zones the need for heating in active office zones ceases mid-morning even on a cold day.

**(b)** *The Total Building*
The above indicates that the solar windows need be biased slightly to morning collection (say 15 degrees E of N), but not too far E as to give a solar gain problem in summer. Direct solar radiation can be brought in from north-facing windows (or glass blocks) into "circulation" spaces such as corridors, foyers, meeting rooms, utility areas and lunchrooms. The air con RA grilles can be best located close to these solar collection areas.

## 5.3 Shading & Sun Control

All windows need control of the sun heat and glare. Buildings without sun control end up with ridiculous ineffective schemes of multiple internal blinds, reflective treatments, tinting, and are still plagued with glare and radiant heat of the hot glass.

The heat calculations for the commonly used "sun control" internal blinds are (at best) optimistic. Sun control must be external, before the heat gets through the glass.

**(a)** *Residential*
A guide to shading is as follows: Where rooms are air conditioned, if the sun falls directly on windows for more than 1 hour per day, then shading needs review. If the direct solar is unavoidable then window reflective or tinting film should be installed.

**(b)** *Office Buildings*
In particular in poorly-shaded offices the 2 meters near the window are only useful as circulation space and filing cabinets. If these were honestly calculated (eg: half the rental returns for that zone) then we would not see the silly "international style" all-glass office buildings. These buildings are described as "all glass buildings without windows" as the multiple blinds are always drawn closed.

## 6. CROSS VENTILATION

Cross ventilation is mainly needed in warm weather; hence the air flow needs to occur at high level. Low level airflows cause drafts and blow papers off the table. The design of our windows and doors usually blocks this airflow above the 2100 lintel height, keeping the pocket of hot air that needs to be removed.

Internal doors need to go to ceiling height, or more effectively, and open-able transom window/panel above the door should be provided, giving security, privacy, and controlled ventilation.

Security of openings is essential. A sufficient number of high level windows need be secure to allow the cross ventilation to be open all night.

Sample photos of (highlight) transom windows courtesy of:
www.loewen.com/home.nsf/windows/transom

## 7. WINDOWS & GLAZING

In the temperate climates double glazing and/or "lowE" glass and "smart" glass are not cost effective on an energy-saving calculation alone. They are justified if the additional factors are considered:

- The elimination of condensation
  (this occurs on residential building windows on winter mornings)
- Acoustic control.

For colder climates exotic glass systems may be cost-effective, bearing in mind that "lowE" glass is for control of heat loss in winter by radiation.

Many "lowE" glass has ALSO a low coefficient of solar gain. This is an additional factor different to "lowE", but this is not made clear in the manufacturers' literature.

If solar gain in summer is the issue there are effective transparent (non-tinted) solar films that have low reflection (< 16%), neutral colour, and high solar co-efficient.

## 8. LIGHTING

This is an involved technical area. Ask about effective lighting systems

- Artificial Lighting & Task Lighting
- Light Levels & Task Lighting
- Types of Luminaires
- Occupant Controls
- Automatic Controls
- Solar switching and occupant sensors

Consider also skylights into dark passages.

## 9. BUILDING PLANNING

Ask about optimising the building planning – "what are the energy issues":

- Thermal Zones, Surface Area, Operating Hours

## 10. LOW ENERGY COMFORT SYSTEMS

These systems use ventilation fans to provide air movement. These are not "standard" exhaust fan but must be selected for low energy and low noise. For every 1 unit of energy a night cooling fan can deliver 15+ units of cooling energy.

### 10.1 Night Cooling

Night cooling is simply providing a sea breeze at night on those hot nights without any natural air movement that often occur in this climate zone. If the outside air at night is cooler than inside of the building then exhausting air from the house with an extract fan will induce cooler air to enter the house, giving immediate cooling from temperature and air movement.

If the building has reasonable thermal mass and good insulation then the overnight cooling is stored in the structure and the cooling effect can continue into the next day.

It is a rare night that the outside is hotter than the inside. If these are the only nights that you operate the air conditioning then the house and lifestyle are very sustainable.

An air conditioner must NOT be operating when the night cooling is operating in that area. The remote switching with the "options card" can be interlocked at virtually no cost to the night cooling fan.

In commercial premises we automate the air inlets (motorized dampers) and the fan for night cooling. In the residential situation we recommend that the occupants manually open windows to let in cool air. This allows the occupant to direct the cooling most effectively to suit the location of the occupants.

The on/off controls are typically set to allow the occupant to set the "start", but the system turns "off" by itself on a temperature sensor to prevent over cool the house on the milder nights. Various control combinations can be discussed at the time of documentation.

### 10.2 Heat Transfer Ducts

In 2-storey buildings the warm air can stratify resulting in a warmer first floor. A simple destratification method is a small low energy fan taking a modest warm airflow from a heated room, to a cooler room, usually a place where the solar gain does not reach directly.

- from (say) the highest point in the foyer/stairwell to a ground floor room
- from a north facing warm (say) lounge room to a southern aspect bedroom, bathroom, or passage

### 10.3 Solar Air-Heat Collectors

These can be individual roof-top solar collectors (looking like hot water collectors) or can be a Trombe Wall on a north wall of a building.

The solar heated airflow is used to directly heat and ventilate the cooler areas (eg: southern rooms) of the building. The system uses all outside air, not re-circulated air. When this warm air enters the building it gently "pressurises" the building reducing cold air infiltration in winter. The warmth of the airflow is stored in the building internal walls (thermal mass) stabilising its warming effect for many hours after the sun has set.

In more sophisticated systems an electronic controller varies the speed of the fans. The fans are controlled from a temperature sensor in the solar airflow and one in the building. The speed of the fans can be varied via an electronic VSD controller, reducing airflow and fan energy on days of lower solar contribution. The system is fully automatic, operating fans, closing and opening motorised dampers. In all cases experience is needed in the design of fans, ductwork, controls, to minimise energy use.

In addition the Trombe Wall can be used in summer to act as a solar chimney. The induced draft (thermal buoyancy) effect of draws air away from the building, creating ventilation, even night cooling, without the use of the fans.

## 11. Controls for Mechanical Systems

Natural cross-ventilation, combined with night cooling, destratification (heat transfer ducts) and then air conditioning has the potential to conflict. The windows need be closed when air conditioning is operating. As long as the air conditioning is not operating at the time that the windows are open or that the night cooling fan is operating then the systems are compatible.

For this reason we recommend that the air conditioning be given (at least) a central on/off controller. This is totally practical, a small cost but must be ordered with the air conditioners, a condition of their purchase.

A semi-automatic control for night cooling is recommended, though a totally manual operation is quite common. A more sophisticated control is available for both the systems, discussed in their sections, bringing remote control and automatic features.

# 12. Active Heating & Cooling Systems

## 12.1 Air Conditioning

The small and medium sized building is often suited to individual small split air conditioning systems. These bring the energy benefit of only operating the rooms you are in or are planning to use.

With these benefits, the split units can be accidentally left on unnecessarily for long times. The temperature controls can be set to silly temperatures in the belief that setting a higher thermostat makes the unit work harder than 100%. These issues can be resolved with care, or with automatic systems. Being careful is effective, though a partial automation is suggested.

The type of split unit recommended is the inverter-style units. These are usually only available in small units, but ducted units are available in addition to the "high wall" and "cassette" styles of unit. These typically are at least "4+ star" energy rating, though many are closer to "6 star". This rating can be verified by you, or by us, at the web page www.energyrating.gov.au.

The inverter system energy savings take a number of years in a residence (three years in an office) to pay for the moderate extra cost. An significant additional benefit is that they control temperature and humidity better than the on-off action of the non-inverter units.

Before the purchase is made of the units, a decision must be made to either purchase a standard inverter unit, or add an "options card", or select a more sophisticated control. After the purchase most units cannot be retrofitted with these features.

We recommend that the "options card" configuration. This is a $100 (or less) circuit card built into the unit that allows a remote switch to turn the units on or off without altering the temperature settings and time clock settings in the IR remote control of the unit. As an example the on off of all units could be set at the front door of the house, when people leave or arrive. A more complex feature would be to link with a micro-switch in (say) the main windows in the living areas to switch off AC when the room is opened up.

A limited number of brands have units with remote temperature controls, monitoring with a PC, other features at significant extra cost. These are not necessary for a residential installation, but can be reviewed.

## 12.2 Standard Air Conditioning Systems

With a good building, standard systems can be reasonably effective, or can still be very mediocre. All the hard work in designing an optimum building can be wasted.

Some aspects of off-the-shelf systems need extra design and thought. See the notes following.

## 12.3 Optimising Standard Systems

Depending on your air conditioning system, various features can be applied to the system to significantly improve efficiency. An (incomplete) checklist follows:

- Local controls (don't start on time clock) (ie like UWA)
- Local override – if not needed
- Local override – if needed after hours

- Fan speed control
- Economy cycle (above 20 kW of cooling only)
- Common setpoint
- Lock out heating on one, cooling on the other.
- One unit per thermal or occupancy zone
- T/stats – no temp adjusters
- Zoning of Thermal Zones
- Splits vs Ducted
- Occupant Controls
- Automatic Controls
- Transport Energy – Air Systems
- Transport Energy – Water Systems
- Variable Speeds for Variable Loads

## 13. Low Energy Heating Systems

Ask about low energy (active & semi passive) heating systems

- Ducted Solar Air Heaters
- De-Stratification
- Warm Air Transfer
- Trombe Walls
- Water Heat Piped Solar

## 14. Low Energy Cooling Systems

Ask about low energy cooling systems

- Evaporative Cooling
- Night Cooling
- Indirect Evaporative Cooling

## 15. Hot Water

Before asking whether solar/gas or solar/electric are best, consider the basic rule. Place the hot water tank close to the frequently used hot water outlet, which in Residences is the kitchen tap. Then consider how far it is to the other usage points, particularly the showers. Over 15 m distance and you may need another hot water unit. Do not use a "ring main" under any circumstances, as these use more energy than installing a second unit.

Solar hot water boosted by either gas or electric is usually cost-effective. Yes, they do need boosting in the temperate of cold climates. A time switch or a one-shot switch makes sense with an electric booster, but is not essential.

For the second unit maybe an instantaneous unit is suited. Both gas and electric are available with "proportional" control, not the old "on/off" models.

## 16. SOLAR & WIND ENERGY POWER SYSTEMS

In the cities and suburbs (ie: on the electric mains "grid") commercial buildings and suburban houses a "grid-connect" photovoltaic (PV) solar electric power system is technically simple, reliable, virtually off-the-shelf installation. "Grid-connect" wind power systems are also feasible.

These "grid-connect" systems are expensive even with the Solar Rebate. The rebate is available to a limited range of installations. Get advice before you proceed. These are usually installed without batteries, and can be installed with batteries at significant additional cost.

For remote locations ask about renewable energy power systems,

- Hybrid with Gas or Diesel (50% to 75% solar)
- Solar Dominant with Manual Backup (70% to 90% solar)
- Solar Only – with plug-in power unit for backup (90% plus solar)

Renewable power sources include:

- Solar
- Wind
- Mini-Hydro

Ask about

- Fuel Cells
- Cost & payback
- Solar rebates / subsidies

end