

A low-angle, upward-looking photograph of a modern glass skyscraper. The sun is shining brightly from the left, creating a lens flare and casting a warm glow over the scene. The sky is blue with scattered white clouds.

**ENERGY IN BUILDINGS
50 BEST PRACTICE INITIATIVES**

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ACKNOWLEDGEMENTS

The Clean Energy Finance Corporation (CEFC) gratefully acknowledges the contributions of the following organisations to this handbook:

AIRAH	Investa
AMP Capital	ISPT
ASBEC	Lendlease
Australian National University	Master Builders' Association
Cbus Property	Monash University
Clean Energy Council	Office of Environment & Heritage
Climate Works	Planet Ark
Coles	Property Council of Australia
Dexus	QIC
Energy Efficiency Council	Sustainable Melbourne Fund
Frasers Property	Stockland
Goodman	Swinburne University
GPT Group	University of Melbourne
Green Building Council of Australia	University of Queensland
Housing Industry Association	Vicinity Centres
	Walker Corporation



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INTRODUCTION

Technology, economics and policy are rapidly transforming energy markets and the broader economy. Global efforts to reduce emissions of greenhouse gases are leading to increased focus on policies that can reduce energy use or promote low emissions generation.

Australia's economy-wide target under the United Nations Framework Convention on Climate Change is to reduce emissions by 26-28 per cent on 2005 levels by 2030. By the second half of the century, achieving net zero emissions is likely to be necessary to meet international climate commitments.

The cost of producing electricity from renewable resources has declined significantly over recent years and remains on a rapid downward trajectory.

The International Energy Agency suggests energy efficiency is the single largest action in the optimal pathway to a decarbonised energy system¹.

These trends are leading to an increased interest in clean energy generation and energy efficiency opportunities in the Australian market.

A 2016 report by the Australian Sustainable Built Environment Council found that cost-effective energy efficiency opportunities could deliver almost \$20 billion in financial savings by 2030². It also found that ambitious energy efficiency, fuel switching and renewable energy technology have the potential to result in net zero emissions buildings by 2050.

Designing, constructing and refurbishing for efficient buildings today will avoid locking in emissions and energy intensive assets for many decades. Importantly, scaling up efforts to improve energy performance will build industry experience and grow supply chains, helping to reduce costs.

This being so, there is still a lack of information or awareness about best practice energy initiatives in the property sector. The Clean Energy Finance Corporation (CEFC) commissioned *Energy in Buildings: 50 Best Practice Initiatives* as a practical, user-friendly resource for property owners and managers. We hope that this will lead to greater awareness and implementation of initiatives across the property industry to reduce costs and emissions.

1. *Energy Efficiency Market Report, October 2016*

2. *Low Carbon, High Performance, May 2016*

Of the 50 initiatives described in this handbook, many can have relatively short-term paybacks. For the right market sector and climate zone, 16 of the initiatives could typically pay back inside 5 years, and 36 of them within 10 years. Many of those 36 initiatives are also relatively affordable: about one third, in a new-build scenario, would require an additional cost less than 0.1% of overall asset value. Most are also appropriate for existing buildings, depending on the scope of the retrofit.

ABOUT THIS HANDBOOK

PURPOSE AND TARGET AUDIENCE

Lack of information or awareness about particular opportunities is a major barrier to best practice energy initiatives in the property sector.

Energy in Buildings: 50 Best Practice Initiatives is intended to provide information and raise awareness about initiatives that can help property owners or managers reduce energy costs and cut emissions for their buildings.

This handbook aims to identify initiatives that you won't find in the current National Construction Code (NCC), helping to promote best practice energy performance in the property sector.

In the office sector, best practice projects are readily able to achieve a 5.5 star NABERS Energy rating. Three buildings have already achieved a 6 star NABERS Energy rating without any Green Power contribution.

It's also important to recognise that buildings designed now, for completion in two or three years, will enter a market where they will be competing with an increasing volume of higher performance building stock.

Some projects are even pursuing a target of 'Net Zero Energy' – whereby any energy drawn from the grid is offset in full by clean energy generated on site and exported to the grid over the course of a year.

The initiatives outlined in this handbook will encourage building owners to be more ambitious about the energy performance of their buildings, helping to reduce costs and position their assets for a low carbon future.

This handbook is also intended to help the market adapt to the rapid and continuous changes to technology and industry practice. For example, in the past five years LED lighting and EC (electronically commutated) fans have leapt from the fringe to standard practice in many buildings. Solar photovoltaic systems have also reached a tipping point, with the number of large scale installations planned increasing rapidly over the past 12 months.

The 50 initiatives in this handbook have been grouped in a way that acknowledges the specialised design professionals required to design and incorporate them in practice.

WHAT THIS HANDBOOK DOESN'T DO

This handbook is intended to guide the selection of possible initiatives at the earliest stages of design and planning only. It provides advice of a very general nature, and should not be used as a substitute for specialist project-specific advice from building industry professionals.

In particular, this handbook does not attempt to address:

- **Variability in energy pricing** – consumption charges vary with location, organisation size and level of consumption, and some customers are subject to peak electrical demand charges.
- **Variability in the upfront cost premium** – costs vary with location, and even between one contractor and the next.
- **Complex interactions between market sectors and climate zones** – occupied hours, internal heat loads and ventilation rates all interact with a building's climate zone, meaning that for some initiatives in certain climate zones some building typologies are a better fit than others.

THE CEFC'S ROLE

STUDY METHODOLOGY

The CEFC engaged engineering consultants Norman Disney & Young (NDY) to create this handbook.

NDY's first step involved its staff across its Australian and international offices identifying over 150 different energy efficiency and clean energy initiatives – which were then refined down to 50 initiatives via a series of workshops with the CEFC.

The initiatives that have made it into this handbook are typically those which:

- Have been demonstrated as technically viable at commercial scale;
- Are not prescriptive requirements of the National Construction Code;
- Are applicable at building scale (rather than precinct or fitout, for example); and
- Should ideally be integrated into the design from the earliest possible stages.

This list was then circulated amongst a number of peak industry bodies and leading private sector building owners for their input and further refinement.

These organisations' real-world experience, combined with that of NDY, has informed the guidance that this handbook provides regarding upfront cost premium, payback period, market sector feasibility and climate zone suitability.

For each initiative, a real-world example has been provided to demonstrate a project on which it has been applied.

The CEFC's mission is to accelerate Australia's transformation towards a more competitive economy in a carbon constrained world, by acting as a catalyst to increase investment in emissions reduction.

The CEFC invests, applying commercial rigour, to increase the flow of finance into the clean energy sector. We do this through an investment strategy focused on:

- Cleaner power solutions, including large and small-scale solar, wind and bioenergy;
- A better built environment, with investments to drive more energy efficient property, vehicles, infrastructure and industry; and
- Investing with co-financiers to develop new sources of capital for the clean energy sector, including climate bonds, equity funds, aggregation facilities and other financial solutions.

As a specialist property financier, the CEFC works across the property sector to drive best practice in energy efficiency, clean energy and low emissions building and technology standards.

The CEFC can provide both debt and equity finance solutions for property upgrades, entire new builds and across property investment portfolios. We also support innovative, clean energy technologies which can benefit the property sector by providing capital funding for early stage businesses.

Since inception in 2012, the CEFC has committed over \$612.50 million in the property sector (as at 30 March 2017).

**THE CEFC'S MISSION
IS TO ACCELERATE
AUSTRALIA'S
TRANSFORMATION
TOWARDS A MORE
COMPETITIVE ECONOMY
IN A CARBON
CONSTRAINED WORLD,
BY ACTING AS A CATALYST TO
INCREASE INVESTMENT
IN EMISSIONS REDUCTION.**

HOW TO USE THIS DOCUMENT

The 50 best practice initiatives in this handbook are presented on the following pages in a 'dashboard' format.

Each initiative includes a brief outline of the possible improvement, accompanied by a longer detailed description. Symbols – explained on these two pages – are used to indicate climate zone suitability, upfront cost premium, payback period, and market sector feasibility.

The 50 initiatives have been grouped onto pages according to the specialist design professionals likely to be consulted (architects or electrical engineers, for example) and the particular consideration (heating or cooling, for example). This grouping is indicated by the light blue tab on the edge of each page. On each page, initiatives are then ordered according to how quickly they can typically pay back.

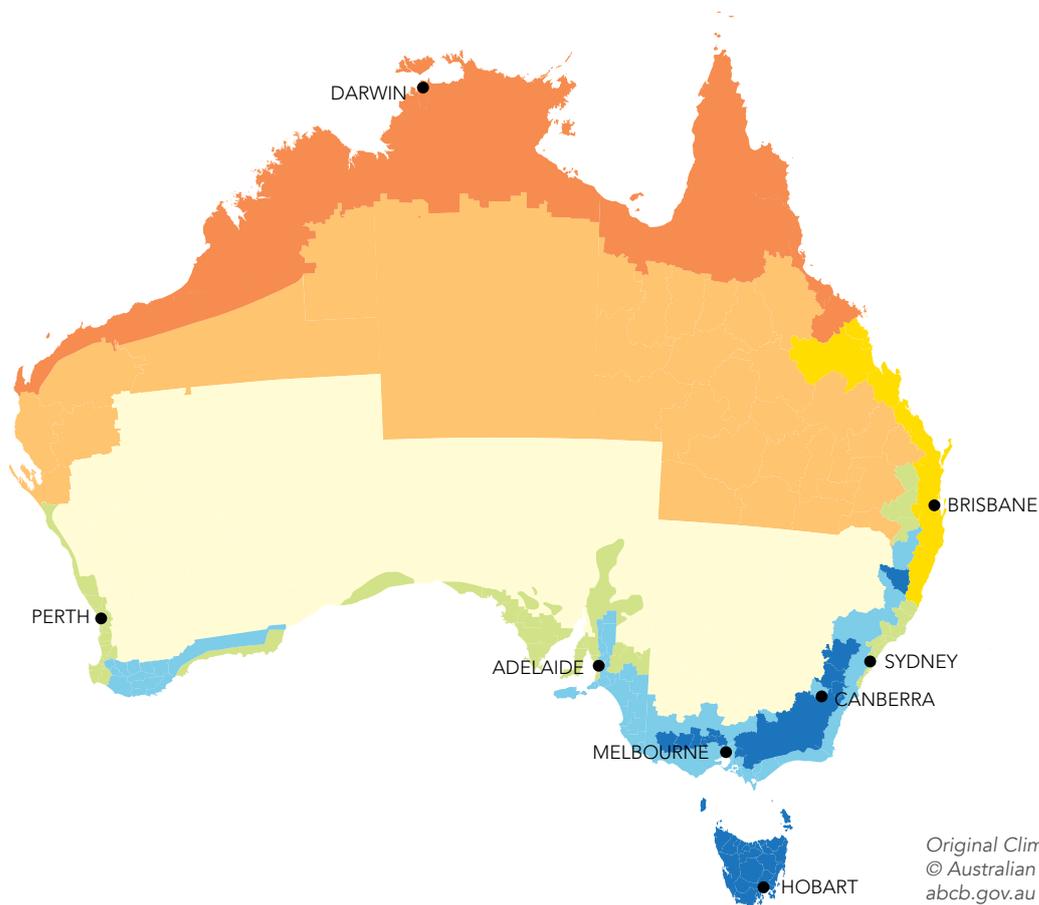
CLIMATE ZONE (Indicated by colour)

- 1 - High humidity summer, warm winter (Darwin)
- 2 - Warm humid summer, mild winter (Brisbane)
- 3 - Hot dry summer, warm winter
- 4 - Hot dry summer, cool winter
- 5 - Warm temperate (Adelaide, Sydney, Perth)
- 6 - Mild temperate (Melbourne)
- 7 - Cool temperate (Canberra, Hobart)
- 8 - Alpine

CLIMATE ZONE SUITABILITY (Indicated by style)

- 1 Ideally suited
- 1 Moderately well suited
- Unlikely to be suited

The various initiatives are more or less worthwhile in different climate zones. An initiative will realise the maximum energy efficiency benefit in a climate zone that it is ideally suited to.



Original Climate Zone Map
© Australian Codes Board
abcb.gov.au

UPFRONT COST PREMIUM

\$	<0.1% of Asset Value
\$\$	<0.3%
\$\$\$	<0.5%
\$\$\$\$	0.5%+

Indications of upfront cost premium have been assigned based on typical current costs of implementation for new buildings in metro areas.

This amount is the typical uplift that might be expected over the cost of a standard practice solution, in a market sector that the initiative is ideally suited to.

PAYBACK PERIODS (YEARS)

<5	Short term
<10	Medium term
<20	Long term
20+	May never pay back

Indications of payback period have been assigned based on a new building in a climate zone and market sector that are ideally suited to the initiative. Typical metro area energy prices and maintenance costs have been taken into consideration.

Only simple economic payback has been considered – different internal rates of return and consequent net present values have not.

MARKET SECTOR FEASIBILITY

	Office
	Retail
	Hotel
	Industrial (Warehouses, Manufacturing and Logistics)
	Healthcare (Hospitals, Laboratories and High-Dependency Aged Care)
	Residential (Homes, Apartments and Independent-Living Aged Care)
	Common Living (Student Accommodation and Low-Dependency Aged Care)
	Education

A large number of variables influence cost, payback period, suitability and feasibility on any given project, and this indication should not be used as a substitute for project-specific professional advice.

Keep in mind that not all of the initiatives described are compatible with one another – it would not be possible to implement all 50 in the same building.

To reiterate - this handbook is only intended to provide very general advice and guide the selection of initiatives in the earliest stages of design - it should not be used as a substitute for project-specific professional advice.

ARCHITECTURAL BUILT FORM

1 2 3 4 5 6 7 8 \$ <5

REDUCES HEATING, COOLING, LIGHTING AND VENTILATION ENERGY USE
 'Passive design' aims to exclude direct sun during hot weather, admit direct sun during cold weather, optimise natural daylight, control glare - and in naturally ventilated buildings, maximise access to breezes. A rectangular building footprint stretched from east to west helps minimise direct sun from angles where it is difficult to control. Optimising the size of external windows is important - for curtain walls a raised sill is helpful. A narrow floor plate is desirable, atria can be included, and often a central core is preferable. Incorporating prominent stairs can also help by reducing lift energy use.

AMDC, Swinburne University of Technology, VIC



COLOUR & REFLECTIVITY OF EXTERNAL MATERIALS

1 2 3 4 5 6 \$ <5

REDUCES COOLING ENERGY USE
 When high reflectance (high 'albedo') materials are used on the exterior of a building - in particular the roof - it decreases the amount of heat that is absorbed from direct sun, reducing air conditioning energy. It also helps keep the local air temperature around the building cooler, which can reduce air conditioning energy. Materials that are very light in colour are ideal, but colour is not the only factor - the chemistry of coatings can be altered too. Specialised paints can be used to increase the reflectance of existing buildings. Low-rise buildings with large roof areas are ideal candidates.

Plumpton Marketplace, NSW



EXTERNAL SHADING

1 2 3 4 5 6 7 8 \$\$ <10

REDUCES COOLING ENERGY USE
 External shading is used to exclude direct sun before it reaches a building's windows and control glare. Horizontal 'fins' are the best type of 'fixed' (non-movable) shading for facades facing North (and South, for northern locations); vertical fins are best for East and West. 'Operable' (movable) shading can be used to admit direct sun when it's needed, exclude it when it's not, and improve natural daylight - but also takes longer to pay back. Shading structures must incorporate a 'thermal break' to avoid decreased insulative performance. Vegetation can be used as shading, with deciduous plants being very effective in temperate climates.

Power and Water Corporation, Darwin, NT



ENHANCED DAYLIGHTING

1 2 3 4 5 6 7 8 \$\$ <10

REDUCES LIGHTING ENERGY USE
 Beyond the built form, a number of other factors influence natural daylight (and therefore lighting energy). 'Soft-coat low-E' glass coatings on clear glass provide the best possible daylight transmission (measured as 'VLT' or 'T_v', where higher is better) while achieving good solar control. 'Light shelves' are like external horizontal shading, but they also extend inside of the building. They are light in colour, and bounce daylight deeper into the building. Products are also available that can be fixed inside the window to achieve the same effect without the shelf. 'Sawtooth roofs' and 'clerestory windows' can be useful in some built forms.

Main Assembly Building, Tonsley, SA



GREEN ROOFS & GREEN WALLS

1 2 3 4 5 6 7 \$\$\$ 20+

REDUCES COOLING ENERGY USE
 Green roofs and walls provide enhanced thermal mass and insulative performance, and help keep the local air temperature around the building cooler - reducing air conditioning energy. They also provide acoustic and stormwater quality benefits. 'Intensive' green roofs have deeper soil, larger plants and can be used as rooftop gardens - but are also very heavy. 'Extensive' green roofs have shallow soil, ground-covering plants, and are lighter. A wire trellis with creepers can provide excellent shade, but a true 'green wall' has a dense population of plants growing out of a vertical medium with an automatic watering system.

Burnley Campus, University of Melbourne, VIC



INSULATED ROLLER DOORS

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ \$ <5   

REDUCES HEATING AND COOLING ENERGY USE

Where roller doors are required for access to a heated or cooled space they can be a significant point of heat transfer, resulting in higher energy use. In these applications a product should be chosen that has insulated panels or slats and is well sealed around the edges. Ideally these roller doors should also operate automatically to limit the length of time they remain open. In less temperate climates it is also worthwhile considering industrial 'air curtains' (set to only operate in very hot or cold weather) which will limit air movement into and out of the space while the doors are open.

Supermarket, Epping, VIC



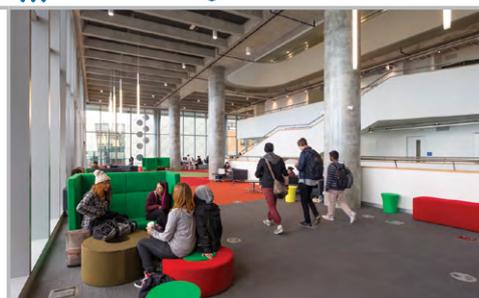
INTERNALISED THERMAL MASS

③ ④ ⑤ ⑥ ⑦ ⑧ \$\$\$ <10       

REDUCES HEATING AND COOLING ENERGY USE

Thermal mass - provided by high density materials like concrete, brick and 'phase change' materials - helps to smooth out changes in indoor temperature without using energy. In winter, it can absorb heat from direct sun which is released back overnight. In summer, heat which accumulates in the thermal mass can be cooled down using 'night purge' ventilation. Thermal mass is most effective when it's located inside of insulation, and when it's not covered up by internal finishes - examples include 'reverse brick veneer', insulation under polished concrete floors, and insulating around the edge of each floor slab.

AMDC, Swinburne University of Technology, VIC



AIR TIGHTNESS

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ \$\$\$ <10       

REDUCES HEATING AND COOLING ENERGY USE

When the wind (or a ventilation system) causes a pressure difference between inside and outside, air tries to move from one to the other - increasing heating and air conditioning energy. 'Blower door testing' is used to measure how air tight a building is, and can be a useful diagnostic tool. Revolving doors perform much better than sliding doors - and where secondary swing doors are required they should be on push-button release to discourage their use. Taped 'weather-tightness membranes' can be used instead of conventional building wrap - and very high performance buildings can also use internal 'air-tightness membranes'.

30 Research Way, Monash University, VIC



ENHANCED INSULATION & THERMAL BREAKS

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ \$\$\$ <20       

REDUCES HEATING AND COOLING ENERGY USE

The thermal resistance of insulation (measured as 'R-value', where higher is better) and its continuity as it wraps around a building help to minimise heat transfer - as does the avoidance of 'thermal bridges' (localised points in steel or concrete structures where heat transfers more easily). Exceeding the minimums in the National Construction Code is often worthwhile. Rigid insulation can be installed outside of the structure - for example 'insulated sandwich panel' for roofs, or 'insulated sheathing' for walls. Structural 'thermal break' products can help where a structural element penetrates through the line of insulation.

Right Homes - The Siding, Lathlain, WA



MIXED MODE VENTILATION

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ \$\$\$ <20        

REDUCES VENTILATION ENERGY USE

Mixed mode ventilation systems combine mechanical ventilation (which uses fan energy) and natural ventilation (which doesn't) - most alternate between the two based on the weather. Some buildings have windows that open automatically, others turn-off their mechanical ventilation when someone opens a window. Transient spaces - for example building foyers - are often ideal candidates. 'Solar chimneys' and 'wind catchers' can be used to enhance some designs. Buildings designed for natural ventilation can also incorporate a 'night-purge cycle' easily, which flushes out hot air from the building overnight.

Inggarni Wardli, University of Adelaide, SA



GLAZED FACADES - SOLAR CONTROL

1 2 3 4 5 6 \$\$\$ <10       

REDUCES COOLING ENERGY USE
 The solar control performance of windows (measured as 'SHGC') affects how much heat from direct sun enters the building, which affects heating and air conditioning energy. Tinted glass and 'ceramic frits' are common ways of achieving better solar control, but both also come with proportional reductions in natural daylight. 'Soft-coat low-E' coatings provide the best possible solar control for only a slight reduction in daylight. 'Interlayers' (inside laminated glass) and films can also be used. 'Interstitial shading' - wood or metal inside a double-glazed unit - is another option, but this reduces insulative performance.

Peter Doherty Institute, University of Melbourne, VIC



GLAZED FACADES - INSULATION

1 2 3 4 5 6 7 8 \$\$\$ <10       

REDUCES HEATING AND COOLING ENERGY USE
 The insulative performance of windows (measured as 'U-value', where lower is better) affects how much heat transfer occurs between inside and outside. Double-glazed units ('DGUs') perform better than single-glazing, and filling the cavity with argon gas improves their effectiveness. 'Low-E' coatings can improve both single and double glazing, with liquid-applied coatings available for pre-existing windows. The window framing system also has a major influence - one large pane performs better than many small panes. Timber performs better than metal, but metal window frames and curtain wall systems can be 'thermally improved'.

171 Collins Street, Melbourne, VIC



GLAZED FACADES - SUPER INSULATION

1 2 3 4 5 6 7 8 \$\$\$\$ <20       

REDUCES HEATING AND COOLING ENERGY USE
 The best insulative performance that can be achieved for windows with the approaches above is generally around a system U-value of 2.5 W/m².K. Triple-glazing offers further improvements, and filling the two cavities with krypton gas improves their effectiveness. Metal window frames and curtain wall systems can also be properly 'thermally broken', whereby plastic connections are incorporated in between the two sides of the framing to interrupt and slow the transfer of heat from one to the other. These approaches can deliver significantly better performance, with system U-values of around 1.0 W/m².K.

Melton Library and Learning Hub, VIC



THERMOCHROMIC & ELECTROCHROMIC GLASS

1 2 3 4 5 6 \$\$\$\$ <20      

REDUCES COOLING AND LIGHTING ENERGY USE
 Thermo-chromic glass becomes darker when it's heated up by direct sun, and clearer again when it cools down. This improves natural daylight when the glass is not in direct sun, and limits solar heat gains (reducing air conditioning energy) and glare when it is. Electrochromic glass also changes from clear to dark, but that change is instead triggered by an applied electric voltage (typically controlled by a local switch or a building management system), which provides choice over whether to allow or exclude solar heat gains. Electrochromic glass is sometimes used for privacy control.

Glassworks Headquarters, Dandenong South, VIC

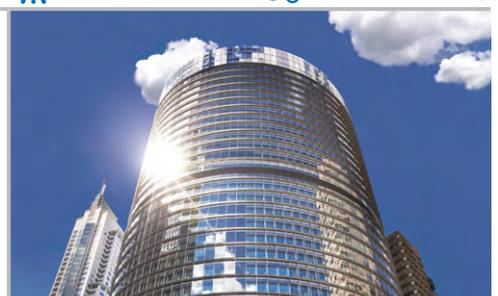


DOUBLE SKIN FACADES

1 2 3 4 5 6 7 8 \$\$\$\$\$ <20   

REDUCES HEATING, COOLING, LIGHTING AND VENTILATION ENERGY USE
 Double skin facades involve a secondary line of glass outside of the main glass facade. They allow the introduction of movable external shading on high rise buildings, which enables very clear glass to be used (improving natural daylight) and enhanced solar control (reducing air conditioning energy). Double skin facades generally have a better overall insulative performance, and can be designed to deliver effective natural ventilation in high rise buildings. They can be ventilated or sealed, and the distance between the glass can be wide or narrow. When narrow and sealed they're called Closed Cavity Facades (CCF).

1 Bligh Street, Sydney, NSW



INTERNAL BLINDS

1	2	3	4	5	6					\$	<5							
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REDUCES COOLING AND HEATING ENERGY USE
 Well-designed internal blinds can significantly improve the energy performance of windows. To provide the most benefit, they should have a light coloured backing and automatic control based on when the glass is in direct sun or the space is unoccupied. To reduce the amount of heat transfer, thicker blind fabrics or 'Low-E' fabrics can be selected, as can fabrics with a reflective metallised backing. In mechanically ventilated buildings, slots can also be designed into the blind 'pelmet' to suck out the hot air that accumulates between the glass and the blind fabric before it reaches the occupied space (which may reduce air conditioning energy).

Raine Square, Perth, WA



SOLAR PHOTOVOLTAIC PANELS

1	2	3	4	5	6	7	8			\$\$\$	<10								
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GENERATES ELECTRICITY ON-SITE
 Solar photovoltaic ('PV') systems use 'strings' of panels to convert sunlight into DC voltage that 'inverters' then convert to useful AC electricity. If strings face different directions a 'multi-string' inverter can be used, or every panel can have its own 'micro-inverter'. Ideally panels face north, with a tilt roughly equal to the location's latitude - but if space is limited then other options are worth considering. System efficiencies vary; typically the more efficient the more expensive. 'Embedded networks' enable local sharing of excess solar electricity, which can improve the business case.

Lifestyle Working Collins Street, Docklands, VIC



BUILDING INTEGRATED PHOTOVOLTAICS (BIPV)

1	2	3	4	5	6	7	8			\$\$\$\$	<20						
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GENERATES ELECTRICITY ON-SITE
 Building integrated photovoltaic ('BIPV') materials generate electricity from sunlight and also replace the function of a conventional building material - for example glass or roof tiles. BIPV can use higher efficiency 'crystalline' silicon technology, but often uses 'amorphous thin-film' technology, which is better suited to dim and diffuse light and curved surfaces. There are coloured options, opaque options, and options with different transparencies. BIPV is particularly attractive for high-rise buildings where the roof space is relatively small - spandrel glass and shading structures are potential options.

Alan Gilbert Building, University of Melbourne, VIC



ELECTRICAL ENERGY STORAGE

1	2	3	4	5	6	7	8			\$\$\$\$	<20								
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REDUCES PEAK DEMAND AND ENABLES ON-SITE GENERATION
 Storage of electricity does not reduce overall energy consumption, but it can provide other benefits. Some systems store and re-use excess clean energy instead of feeding it to the grid - offering some cost benefit, but also improving the NABERS Energy rating for some buildings. Other systems store off-peak grid electricity for re-use in the peak-period, to reduce the maximum demand on the grid. Lithium ion batteries are the smallest and lightest option, but are expensive. Flow batteries (zinc bromide for example) can be completely drained without impacting performance, but are larger and heavier.

Alkimos Beach, WA



COGENERATION & TRIGENERATION

				5	6	7	8			\$\$\$	20+							
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ON-SITE GENERATION WITH REDUCED HEATING AND COOLING ENERGY USE
 Cogeneration (also called 'CHP') systems generate electricity from combustion (typically of natural gas, but biogas is also possible), and use the waste heat to provide hot water. 'Trigeneration' refers to the same process but waste heat is also used by an 'absorption chiller' to create chilled water. The electricity produced by these systems is cleaner than grid electricity in most locations, but when natural gas prices rise faster than electricity prices they become less financially viable. Maintenance requirements also need to be considered. Larger buildings or groups of buildings with a constant high demand for hot water are ideal candidates.

567 Collins Street, Melbourne, VIC



CLEAN ENERGY

LED LIGHTING

1 2 3 4 5 6 7 8 \$ <5

REDUCES LIGHTING ENERGY USE

Light Emitting Diode (LED) lighting provides more light for the same amount of electricity when compared to fluorescents, metal halides and halogens. Less waste heat also means less air conditioning energy. LEDs reach full brightness instantly and can be turned off and on again quickly, allowing controls such as occupancy detection to be used. In the majority of applications it is important to choose LEDs with a high Colour Rendering Index ('CRI', measured out of 100), which affects how accurately the human eye perceives colour. They also tend to have exceptionally long lifespans, meaning less maintenance.

Oakdale Industrial Estate, NSW



OCCUPANCY DETECTION

1 2 3 4 5 6 7 8 \$ <5

REDUCES LIGHTING, VENTILATION, HEATING AND COOLING ENERGY USE

Occupancy detection uses sensors to identify when people are no longer using a space and switches-off (or turns-down) building systems, saving energy. This is common for interior lighting, but it's also effective for heating, ventilation, air conditioning and exterior lighting. There are a variety of different sensor types, suitable for a range of different distances. Some are designed to detect movement; others detect 'presence' (when someone is present but not moving). Systems are even available that have one occupancy sensor per light, providing a high level of responsiveness and energy efficiency.

Corso North Lakes, QLD



DAYLIGHT DIMMING

1 2 3 4 5 6 7 8 \$ <5

REDUCES LIGHTING ENERGY USE

Daylight dimming (sometimes called 'daylight harvesting') uses sensors to identify when there is a good amount of natural daylight available and turns down lighting, saving energy. The sensors used are called 'PE cells' (photoelectric cells) - for external lighting it's normally just called 'PE cell control'. A sensor can either be built-in to every light or shared between a group of lights - but it's important to keep groups of lights small (because, for example, blinds might be adjusted). Internally, it provides the most benefit near the facade, skylights and atria.

Oakdale Industrial Estate, NSW



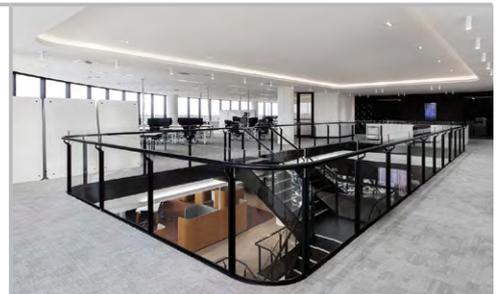
FLEXIBLE LIGHTING ZONES & USER CONTROL

1 2 3 4 5 6 7 8 \$\$ <5

REDUCES LIGHTING ENERGY USE

Addressable lighting control systems, such as 'DALI' (Digital Addressable Lighting Interface), provide the ability to link any individual light to any particular switch or sensor, all without altering any physical connections. This allows the grouping of lights to be easily reconfigured - for example when desks are rearranged in an office. It also enables separate lighting 'scenes' to be setup where a space is used for a number of different purposes. Some control systems allow people to change the brightness of an individual light using their smartphone. Using only the lights needed results in less energy use.

Chadstone Tower One, VIC



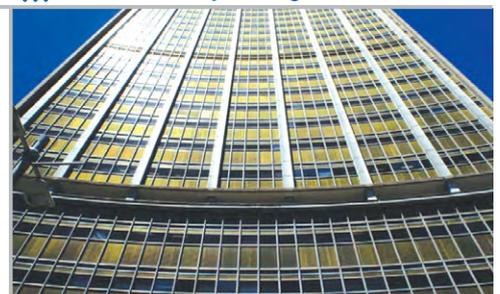
POWER FACTOR CORRECTION

1 2 3 4 5 6 7 8 \$\$ <10

REDUCES PEAK DEMAND ON THE GRID

Large buildings are often charged not just for how much electricity they use, but also for their 'peak demand' (the peak power drawn from the grid at any time). In many locations this is based on 'apparent power' (measured as 'kVA', where lower is better). For buildings that have a poor 'power factor' during peak periods, 'power factor correction' equipment can be installed which reduces the apparent power drawn from the grid, thereby saving money. The main causes of poor power factor tend to be 'AC' motors (including pumps, fans and appliances) and some 'switched-mode' power supplies for computer equipment.

33 Alfred St, Sydney, NSW



SUB-METERING SYSTEMS

1 2 3 4 5 6 7 8 \$\$ <10

PROVIDES INFORMATION TO MANAGE ENERGY USE
 Sub-metering systems use a number of carefully placed energy meters 'downstream' of the main utility meter to pinpoint how different parts of the building are using energy. This allows energy wastage to be identified, and helps in managing improvement. Connecting sub-meters to a Building Management System ('BMS') or other energy management platform will automatically record all the data in one place, with software that can shape it into useful graphs, and provide alerts when unusual consumption is detected. It can also be linked to display screens inside the building to show live energy use information to people.

Coles Energy Centre, Mulgrave, VIC



BUILDING MANAGEMENT SYSTEMS (BMS)

1 2 3 4 5 6 7 8 \$\$ <10

REDUCES HEATING, COOLING AND VENTILATION ENERGY USE
 A Building Management System ('BMS') is a dedicated computer and network that controls all the equipment (such as pumps, fans, 'dampers', chillers and boilers) that are part of a building's heating, ventilation and air conditioning system. They can provide very sophisticated control, but their influence on energy efficiency depends on how they are designed. Control philosophies differ - and shifting the emphasis from precise temperature control to energy efficiency can realise substantial savings. Installing more sensors can also enable more sophisticated approaches and help to verify that the system is behaving as expected.

1 National Circuit, Canberra, ACT

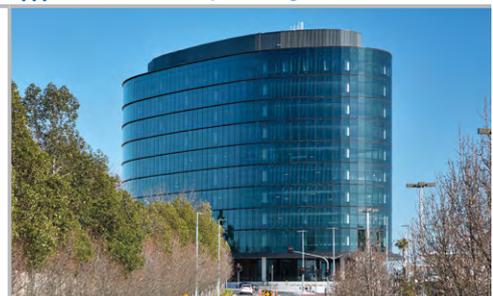


BMS ANALYTICS

1 2 3 4 5 6 7 8 \$\$ <20/<5

REDUCES HEATING, COOLING AND VENTILATION ENERGY USE
 Analytics platforms work with a BMS to analyse all the data that it collects and generates. The software can search for patterns which indicate equipment may not be operating as efficiently as it could (as well as when equipment may be close to failure), and generate a list of actions. They can also 'learn' over time and optimise controls based on inputs like weather forecasts. Their effectiveness depends on the information available to the BMS and how proactively the actions are implemented. Existing buildings often experience faster payback periods (<5 years instead of <20 years) because there are more significant inefficiencies waiting to be identified.

Chadstone Tower One, VIC



SOLAR HOT WATER

1 2 3 4 5 6 7 8 \$ <10

REDUCES HOT WATER ENERGY USE
 Solar hot water systems collect heat from direct sun, usually for domestic hot water purposes - reducing the requirement for gas or electricity. In 'flat plate' systems, water flows through a dark-coloured panel. In 'evacuated tube' systems, a liquid flows through dark-coloured double-walled glass cylinders, then transfers the heat to water in a storage tank. Evacuated tube type systems are more thermally efficient, particularly in cold weather. Usually solar hot water systems are fitted with a gas or electric heating element to 'boost' the hot water temperature when the solar contribution alone isn't sufficient.

Global Change Institute, University of Queensland, QLD



TRANSCRITICAL CO₂ HEAT PUMPS & CHILLERS

1 2 3 4 5 6 7 8 \$\$\$ <10

REDUCES HEATING, COOLING AND REFRIGERATION ENERGY USE
 Carbon dioxide (CO₂) can be used as an alternative to more common 'HFC' refrigerants. Its different physical properties mean the refrigeration cycle operates differently - rather than heat transfer always occurring with the evaporation or condensation of the refrigerant, a transcritical CO₂ system operates partially in the supercritical fluid region, with heat transfer occurring with only a change in temperature. This provides energy efficiency benefits that are particularly well demonstrated in cold stores, refrigerated display cabinets and vending machines, as well as domestic hot water heat pumps.

Coles Supermarket, Coburg North, VIC



CONDENSING BOILERS

1 2 3 4 5 6 7 8 \$ <5

REDUCES HEATING ENERGY USE

Condensing boilers (sometimes called 'condensing water heaters') use water vapour in the exhaust gases (a natural result of combustion) to pre-heat the incoming water and save energy in comparison to conventional boilers. They are usually 90% to 98% efficient, compared with the National Construction Code minimum requirement of 80% or 83%. They are best suited to domestic hot water systems and low-temperature heating hot water systems (such as under-floor systems) because water vapour is most effectively 'condensed' from the exhaust gases when the incoming water is cooler than about 55°C.

AMDC, Swinburne University of Technology, VIC



LOW LOAD BOILERS & CHILLERS

1 2 3 4 5 6 7 8 \$\$ <5

REDUCES HEATING AND COOLING ENERGY USE

Chillers and boilers only have the ability to operate stably in a particular range. If they are turned-down below about 20% of their capacity - as happens in some buildings during particular seasons and low-occupancy times of day - they start operating in inefficient modes ('cycling', for example, or 'hot-gas bypassing') and the water temperatures they provide can be unstable. Smaller 'low-load' chillers and boilers can be installed to operate at these times instead. As well as operating more energy efficiently, the need for maintenance can also be reduced. Typically larger buildings are better suited.

567 Collins Street, Melbourne, VIC



CENTRALISED HEATING & COOLING PLANT

1 2 3 4 5 6 7 8 \$\$ <10

REDUCES HEATING AND COOLING ENERGY USE

Large buildings can benefit from using common central heating and air conditioning plant rather than distributed stand-alone systems. Larger plant items can be more efficient, and best practice energy initiatives become possible that wouldn't be otherwise. 'Diversity' in the demand for heating and air conditioning means total plant capacity can often be lower - and 'staging' can help maximise how often individual plant items operate near their optimum capacity (improving energy efficiency). Limiting when condenser water, chilled water and heating hot water flow to each area is important to reduce pumping energy and distribution losses.

Bathurst Shopping Centre (William Street), NSW



GROUND SOURCE HEAT PUMPS & CHILLERS

1 2 3 4 5 6 7 8 \$\$ <10

REDUCES HEATING AND COOLING ENERGY USE

Ground source heat pumps (sometimes called 'geothermal') use the relatively stable temperature of the earth to make heating and cooling systems more efficient. This involves running a liquid through pipes buried in the ground - sometimes horizontally a few metres deep, other times vertically in bores up to 100m deep. Installation should be by a specialist contractor. Local ground conditions need to be taken into account, and low-rise buildings are normally better suited. Large bodies of water can be used in a similar way, but potential impacts on aquatic plants and animals need to be assessed.

Fairwater, Blacktown, NSW



VARIABLE AIR VOLUME FUME CUPBOARDS

1 2 3 4 5 6 7 8 \$\$\$ <10

REDUCES HEATING, COOLING AND VENTILATION ENERGY USE

Unlike older 'constant volume' models, 'VAV' (Variable Air Volume) fume cupboards vary the amount of air exhausted as the 'sash' is opened and closed. If the amount of air being exhausted can be linked to the amount of outside air being drawn into the laboratory, it results in heating, air conditioning and fan energy savings. Fume cupboards can also be provided with automatic sashes that close when no one is using them. 'Manifolding' multiple fume cupboards together and incorporating heat recovery can provide energy savings in locations with very hot or cold weather - but in other locations it can increase fan energy.

Green Chemical Futures, Monash University, VIC



ECONOMY CYCLES FOR SMALL SERVER ROOMS

1 2 3 4 5 6 7 8 \$\$ <5        

REDUCES COOLING ENERGY USE

Spaces such as server rooms in buildings generate a lot of heat internally and require year-round air conditioning, but only to keep them below about 26°C. At times when it is colder outside (the absolute majority of the year in many locations) an 'economy cycle' can be used to draw outside air through the space while the air conditioner is switched off, saving energy. Ideally this means locating such rooms near the facade of the building. Hot or cold aisle arrangements - where air conditioning is supplied to one side of IT racks and hot air discharged to the other - should be used wherever possible.

Bendigo Hospital, VIC



UNDER-FLOOR AIR DISTRIBUTION

1 2 3 4 5 6 7 8 \$\$\$ <10   

REDUCES COOLING ENERGY USE

Under-floor air distribution ('UFAD', sometimes called 'displacement') systems deliver air through the floor and remove it at ceiling level. Rather than mixing the air in a space and diluting pollutants, air rises up gradually, carrying pollutants and heat away from people. Cool air delivered via UFAD is typically around 18°C (to avoid cold draughts) - not as cold as in conventional systems, which allows chillers to operate more efficiently, and increases how often they can be switched off as part of an 'economy cycle'. Control of humidity without the excessive use of 'reheat' is an important consideration; the use of 'split cooling coils' is one approach.

720 Bourke Street, Docklands, VIC



IN-SLAB HEATING & COOLING

1 2 3 4 5 6 7 8 \$\$ <10        

REDUCES HEATING, COOLING AND VENTILATION ENERGY USE

In-slab heating and cooling systems pump hot or chilled water through pipes to affect the temperature of the surrounding concrete and provide localised heating or air conditioning (or influence the temperature of the thermal mass). Pipes are either cast into the concrete slab, or laid on top and covered with a screed. Tall spaces are ideal candidates - the temperature above people's heads can be allowed to fluctuate, which reduces heating and air conditioning energy. 'Zoning' of the system into a number of smaller areas should be considered to help compensate for relatively slow warm-up and cool-down times.

Melbourne Convention & Exhibition Centre, South Wharf, VIC



CEILING FANS & DESTRATIFICATION DEVICES

1 2 3 4 5 6 7 8 \$\$ <10    

REDUCES HEATING AND COOLING ENERGY USE

Faster air movement results in people feeling cooler without any change to the air temperature. Because of this, ceiling fans can be used to keep people cool while providing less air conditioning (or no air conditioning) - saving a significant amount of energy. In tall spaces that have heating, 'destratification' fans can be used to push warm air down to floor level (which would normally rise up due to its natural buoyancy) - meaning less heating energy is required. Products are also available that achieve the same effect without the spinning fan blades. Fans with a low input power (measured as 'W') should be selected.

Gilligan's Backpackers, Cairns, QLD



CHILLED BEAMS

2 3 4 5 6 7 8 \$\$\$ <20    

REDUCES COOLING ENERGY USE

Chilled beams are coils at ceiling level with chilled water circulated through them. The chilled water need not be as cold as that in other types of air conditioning system, and as a result chillers operate more efficiently. A 'passive' chilled beam has a fully exposed coil and air flow driven by natural convection, with a partially radiant cooling effect. An 'active' chilled beam has a fan that forces air across the coil. The dedicated outside air system required with either type needs to be carefully designed to avoid condensation problems. Typically larger buildings are better suited.

Corso North Lakes, QLD



WATER-SIDE FREE COOLING

1	2	3	4	5	6	7	8	\$	<5						
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REDUCES COOLING ENERGY USE
 During cool weather, water-side 'free cooling' uses a heat exchanger to reject heat from the chilled water loop directly across to the condenser water loop, allowing chillers to be switched off. In free cooling mode, the heat rejection equipment (for example cooling towers) is run at, or near, full capacity to minimise the condenser water temperature, but this additional energy is more than offset by the chiller energy savings. Free cooling is most effective in systems that don't require chilled water to be as cold - for example chilled beam systems and data centres.

700 Bourke Street, Docklands, VIC



DIRECT EVAPORATIVE COOLING

		3	4	5	6	7	8	\$	<5					
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REDUCES COOLING ENERGY USE
 'Direct' evaporative cooling systems add moisture directly to the outside air being drawn into the building, and as the water evaporates it reduces the air temperature. Moisture is either added using misting sprays or by trickling water over pads. This uses much less energy than refrigerative air conditioning, but it also makes the air more humid. Larger amounts of air typically need to be drawn through the building than other system types. They are most effective in dry weather conditions - evaporation is less effective in humid weather, and there is a limit to how much moisture can be added to the air.

TAFE SA Noarlunga Campus, SA



INDIRECT EVAPORATIVE COOLING

		3	4	5	6	7	8	\$\$	<20								
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REDUCES COOLING ENERGY USE
 'Indirect' evaporative cooling is different - air drawn in from outside is cooled without coming into contact with water. It provides air conditioning that's almost as energy efficient as 'direct' evaporative systems, but without the disadvantage of high humidity. Two separate streams of air are ducted through an 'indirect' unit - the first is cooled by adding moisture, then discharged to atmosphere - the second takes in outside air and pushes it into the building. The two cross-over through a heat exchanger, reducing the temperature of the second air stream without adding any humidity. They are still less effective in humid weather.

Engineering Pavilion, Curtin University, WA



WATER-COOLED CHILLERS

1	2	3	4	5	6	7	8	\$\$	<20						
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REDUCES COOLING ENERGY USE
 Water-cooled chillers reject heat to a condenser water system, in contrast to air-cooled chillers which reject heat directly to the atmosphere. Condenser water systems connected to cooling towers or 'hybrid wet-dry coolers' (sometimes called 'adiabatic') result in chillers running more efficiently in the majority of weather conditions. Where there is a substantial alternative water source (for example stormwater harvesting or a municipal 'purple pipe' system) this can be utilised. Design and operation needs to manage microbial risk, and typically larger buildings are better suited.

567 Collins Street, Melbourne, VIC



CHILLED WATER STORAGE

1	2	3	4	5	6	7	8	\$\$	<20				
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REDUCES COOLING ENERGY USE
 Chilled water storage allows chillers to operate at times of day that differ from when air conditioning is needed. Chilled water is typically created overnight (chillers operate more efficiently in cooler weather), stored in very large tanks (designed to allow the coldest water to sink and warmer water to rise), and drawn upon as needed. In locations with a strong 'diurnal swing', the additional energy for pumping is more than offset by the lower chiller energy. Some systems use 'phase change material' ('PCM') to allow smaller tanks, but this can be less energy efficient where colder chilled water is needed to freeze the PCM.

Colleges of Science, Australian National University, ACT



DEMAND CONTROLLED VENTILATION

1 2 3 4 5 6 7 8 \$\$ <5    

REDUCES HEATING, COOLING AND VENTILATION ENERGY USE
 Outside air is pushed into buildings by ventilation systems to dilute the carbon dioxide, odours and other chemicals produced by the people and materials inside. In conventional systems the amount of outside air does not vary. Demand controlled ventilation uses sensors to identify when the air in a space is fresh enough and turns-down ventilation systems, saving energy. Carbon dioxide ('CO₂') sensors are common, but volatile organic compound ('VOC') sensors can be used instead. Sensor placement needs to be carefully considered during design - and re-calibration of the sensors is important during operation.

720 Bourke Street, Docklands, VIC



ELECTRONICALLY COMMUTATED FANS

1 2 3 4 5 6 7 8 \$\$ <5        

REDUCES VENTILATION ENERGY USE
 Electronically commutated ('EC') fans use brushless motors with permanent magnets and DC voltage controlled by a microprocessor - like the fans found in desktop computers. These motors are more energy efficient than conventional AC motors because they don't have the same copper wire windings. The speed of EC fans can be controlled without the need for an external 'variable speed drive' ('VSD'). This means that fans in a wider range of places throughout a building (for example in fan coil units) can have their speed adjusted, which also saves energy.

Riverside Centre, Brisbane, QLD

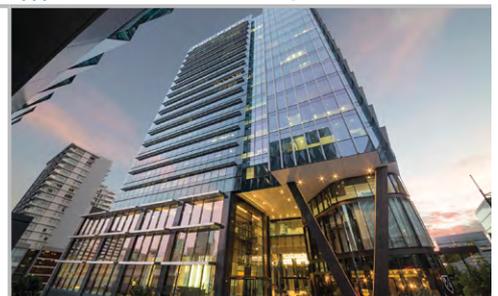


LOW-PRESSURE LOW-TEMPERATURE VAV

1 2 3 4 5 6 7 8 \$ <10    

REDUCES VENTILATION ENERGY USE
 Low-temperature 'VAV' (Variable Air Volume) air conditioning systems supply colder air (about 11°C) than was typical of older systems (about 14°C), enabled by the development of 'swirl diffusers'. As a result less air needs to be pushed through the system to provide the same amount of air conditioning, reducing fan energy. 'Low-pressure' ventilation systems are designed for air to be pushed through without applying as much pressure (measured as 'Pa', where lower is better), also saving fan energy. Typical designs target a 'pressure drop' of about 0.8 Pa per metre of duct and aim to minimise the air speed across coils and filters.

Tower One, Collins Square, Melbourne, VIC



SINGLE-ROOM HEAT RECOVERY VENTILATORS

3 4 5 6 7 8 \$\$ <10   

REDUCES HEATING, COOLING AND VENTILATION ENERGY USE
 Single-room heat recovery ventilators are small devices which supply outside air through an external wall using very efficient EC fans. Heat recovery between the incoming and outgoing air streams also saves energy. One type incorporates a small counter-flow plate heat exchanger. The other type uses an internal ceramic structure to accumulate heat when the fan runs in one direction, and then releases it again when it reverses direction (which happens automatically about every minute). Typically they are only large enough to serve individual rooms, and are automatically controlled using internal humidity or carbon dioxide sensors.

Wade Institute, Ormond College, Melbourne, VIC



HEAT RECOVERY VENTILATION SYSTEMS

1 3 4 5 6 7 8 \$\$\$ <20       

REDUCES HEATING AND COOLING ENERGY USE
 Heat recovery ventilation ('HRV') systems use the air-conditioned or heated air leaving a building to pre-cool or pre-heat the incoming outside air. 'Run around' pipe heat exchangers (which circulate a liquid between coils in two ducts) and most 'plate' heat exchangers transfer temperature only. 'Enthalpy wheels' and some plate heat exchangers transfer both temperature and humidity. Heat recovery is most beneficial during very hot and very cold weather - in milder weather the additional fan, pump and/or motor energy offsets the benefit - making bypass ductwork important in temperate climates.

Gold Coast University Hospital, QLD



VENTILATION AND HEAT RECOVERY

IMPLEMENTATION

MANDATORY MINIMUM REQUIREMENTS

Mandatory minimum energy efficiency for buildings is regulated in a number of ways.

All new buildings and significant renovations must comply with Section J of the National Construction Code ('NCC'). The Australian Building Codes Board is currently³ going through a process of consultation on its draft amendments to the 2019 version of the NCC, which includes proposed changes to Section J.

Most State and Federal Government leased offices are required to achieve some level of NABERS Energy rating (typically a Base Building rating) as part of a 'National Green Lease Policy'.

The Commercial Building Disclosure program requires⁴ disclosure of energy efficiency performance of commercial offices, including their NABERS Energy rating, and as of July 1 2017, the threshold for disclosure will be lowered from 2,000m² to 1,000m².

Some Local Government planning schemes also include minimum requirements.

The NCC can be a useful resource for best practice projects because, while an initiative might only be required in a certain application, it is likely to be cost effective and feasible in many other applications as well.

That said, it's also possible to go well beyond these mandatory minimums using the initiatives described in this handbook.

USE OF VOLUNTARY RATING SYSTEMS

Voluntary rating systems can be a useful way of briefing performance expectations to project teams and benchmarking performance – but they can also be a source of confusion because their applicability differs.

NABERS Energy rates the energy efficiency of offices, hotels, shopping centres and data centres on a 0 to 6 star scale using operational consumption data.

NatHERS rates the passive heating and cooling energy efficiency of homes and apartments on a 0 to 10 star scale based on the architectural design.

Green Star rates holistic sustainability (energy efficiency plus other aspects) on a 4 to 6 star scale for new construction, and a 0 to 6 star scale for operational performance.

The Energy Rating label rates the energy efficiency of equipment on a 0.5 to 10 star scale.

The ENERGY STAR® label is a mark of energy efficiency regulated in the United States, but also appears on some equipment and appliances sold in Australia.

Other organisations also have tools in various stages of development for use in other market sectors – for example the Victorian Residential Efficiency Scorecard and the NABERS Home Energy Explorer.

GUIDANCE FOR NEW BUILDINGS

During the design phase, building energy consumption can be estimated using computer simulation – a service offered by a number of specialist and building services engineering consultancies, and generally referred to as 'energy modelling'. Energy modelling is distinct from the heat load calculations undertaken for the purpose of sizing mechanical plant or demand calculations to size electrical infrastructure.

The appropriate scope and detail of energy modelling varies with project stage and the energy efficiency targets being pursued. At concept design, the primary purpose of energy modelling is to inform the architectural and facade design, and the comparative performance of various options is what's most important – which can usually be delivered at reasonably low cost. At the other end of the spectrum, truly 'predictive' energy modelling, focused on accurately estimating consumption in operation, can be significantly more costly. In the middle are a series of defined 'protocols' referenced by the NCC Section J ('JV3') and Green Star, for example, which are appropriate to most projects between schematic design and construction.

NABERS Energy and NatHERS are the easiest ways of briefing design teams on the operational energy performance that a building is required to achieve – but they don't apply to a number of market sectors. For those market sectors, operational energy performance is often briefed as either a particular number of points against the Green Star credit for Greenhouse Gas Emissions, or a particular percentage improvement over 'NCC JV3 compliance' (determined using energy modelling). It is also important to nominate whether a project team is expected to 'certify' against the rating system – or just to use it as an internal benchmarking exercise.

3. Section J Overhaul, March 2017

4. What is CBD?, June 2011

GUIDANCE FOR EXISTING BUILDINGS

NABERS Energy and Green Star Performance are the most common tools utilised to benchmark operational energy performance. For market sectors which they don't cover, benchmarking is not as straightforward – but various organisations do have other tools under development.

The most common place to start when trying to improve the performance of existing buildings is with an 'energy audit'. Some in-house facilities management personnel have the skills and experience to undertake an energy audit, but it is also a service offered by a number of specialist and building services engineering consultancies.

The Australian - New Zealand Standard AS/NZS 3598 defines three different levels of audit. A 'Type 1' audit provides an introductory assessment of how energy is used on site (known as an 'energy balance'), and identifies the broad-brush initiatives appropriate for implementation. At the other end of the spectrum, a 'Type 3' audit provides a highly detailed assessment, with detailed initiatives and accurate estimates of costs and savings – typically most appropriate where a Type 1 or 2 audit has already been undertaken. A number of organisations are now developing more specifically targeted 'NABERS Roadmaps' for their buildings, which lay out a structured program of works to achieve each additional 0.5 Star NABERS Energy rating increment.

The cornerstone of any Type 2 or 3 energy audit or NABERS Roadmap is good quality 'interval meter data' (energy use data in 15 minute, 30 minute or 1 hour increments) from on-site sub-meters. If this is not available or does not provide sufficient detail, then 'energy data loggers' can be temporarily fitted to electrical circuits.

It is important to note that not all initiatives to improve the performance of existing buildings actually involve physical works. There are normally substantial improvements to performance that can be achieved via improved energy management practices, controls optimisation and retro-commissioning.

DISCLAIMER

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ADDITIONAL READING

There is a wealth of other information available compiled by a variety of other organisations. The following is a small selection of resources that have come to light during consultation with peak industry bodies and leading private sector building owners. They may be of interest to those targeting best practice on their projects.

- AIRAH & OEH, Optimising Your Heating, Ventilation and Air Conditioning Systems, July 2015
- AIRAH & GBCA, Building Simulation Procurement Guidelines, April 2015
- ASBEC, Low Carbon, High Performance, May 2016
- CIBSE, TM39: Building Energy Metering, October 2009
- City of Sydney, Commercial Building Improvement Guide, August 2015
- Department of Environment and Climate Change NSW, Sustainable Property Guide, April 2009
- Department of the Environment and Energy, HVAC HESS Fact Sheets, 2012 – 2013 (Various)
- HIA, Building the GreenSmart Way, July 2010
- NSW Business Chamber, Sustainability Toolkit – Offices, March 2009
- OEH, Energy Efficiency & Renewables Finance Guide, November 2014
- PCA & Arup, Existing Building Survival Strategies, July 2008
- Rocky Mountain Institute, Guide to Building the Case for Deep Energy Retrofits, September 2012
- Sustainability Victoria, Energy Efficiency Best Practice Guidelines, 2009 – 2015 (Various)

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