ENVIRONMENT DESIGN GUIDE

DESIGNING, MANAGING AND RETROFITTING NON-RESIDENTIAL BUILDINGS TO REDUCE GREENHOUSE GAS EMISSIONS

Stephen Pupilli

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SUMMARY OF

ACTIONS TOWARDS SUSTAINABLE OUTCOMES

Environmental Issues/Principal Impacts

- Annual energy use resulting from the activities of the non-residential sector increased by 44 per cent to 218 PJ (Petajoules = 1015 Joules) per annum, between 1990 and 2000; and is expected to rise to 289 PJ by 2010 under a business as usual scenario. This sector of energy use remains one of the highest growth sectors in Australia.
- The wholesale and retail sector and the government and community services sector remain the largest consumers, and are responsible for an estimated 72 per cent share of the total consumption. Electricity represents nearly 70 per cent of total energy use and the principal applications of energy in non-residential buildings remain as HVAC (Heating, Ventilation and Air Conditioning) at an average across the sector of approximately 34 per cent, lighting (26 per cent), appliances, including cooking (25 per cent) and hot water (13 per cent).
- The recent addition of energy provisions for non-residential buildings within the Building Code of Australia (BCA) (Classes 2 to 4 buildings in 2005 and the remainder in 2006) and the expansion of the MEPS (Minimum Energy Performance Standards) scheme for many appliances used in non-residential buildings is expected to contribute significantly to raising the base level efficiency of new building designs.
- Despite the above, significant opportunities still exist for improving the energy efficiency of new designs beyond the minimums specified in the BCA and little progress has been made in capturing the cost-effective energy saving potential available in the existing building stock.

Basic Strategies

In many design situations, boundaries and constraints limit the application of cutting EDGe actions. In these circumstances, designers should at least consider the following:

- Incorporate an energy management specialist in the design team from the initial stages of design to model and analyse building and services design options and to assist in the development of a fully integrated energy efficient design.
- Monitor existing buildings and their sub-components of energy use against applicable targets developed during detailed efficiency reviews (energy audits) of the sites.
- Undertake regular energy efficiency reviews (energy audits) of existing buildings (maximum five yearly or when a significant discrepancy is found during the above monitoring initiative). Establish an investment program to implement the cost-effective initiatives identified.
- Select greenhouse friendly fuel alternatives and systems. These may conflict with energy efficiency ideals and need to be suitably analysed to achieve the optimum improvement for each case.

Cutting EDGe Strategies

- Incorporate the increased levels of information available on the energy performance characteristics of glazing, materials and equipment to derive the optimum design for each specific building and application.
- Improve the accounting practices for energy efficiency investment so that the investors benefit directly from the actions. In the case of tenants, the benefits need to be transferable so that the incentive of efficiency is traded as tenants move in and out of buildings. Implement annual disclosure of energy efficiency to tenants, owners and other stake-holders and at time of sale.
- Implement dynamic monitoring and performance assessment of building energy use.

Synergies and References

- EMET, 2004, *Energy Efficiency Improvement in the Commercial Sub-sectors*, for the Sustainable Energy Authority of Victoria and Australian Greenhouse Office
- BDP *Environment Design Guide*: GEN 33, DES 2, DES 11, DES 17, DES 21, DES 35, DES 36, DES 37, CAS 10, NOT 10

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Energy consumption related to Australia's non-residential buildings is expected to double between 1990 and 2010, unless a comprehensive program of energy efficiency improvement is implemented in this sector of the building industry. Recent studies have shown that significant potential for efficiency improvements exists for non-residential buildings. This paper highlights a number of key areas where improvements can be made during the initial design of a new building, and outlines how the performance of existing buildings can be improved through refurbishments in management and maintenance techniques. The paper also identifies some of the financial disbenefits and gaps in education and awareness within the sector, which need to be addressed if a significant level of improvement is to be achieved and sustained.

1.0 INTRODUCTION

The non-residential buildings sector consumed approximately 151.1 PJ of energy in 1990, resulting in greenhouse gas emissions of 32.2 Mt CO_2-e (EMET & SOLARCH). Excluding the direct purchase of green-energy, renewable energy sources comprise a negligible component of the total energy use by this sector, with electricity being the dominant source of energy.

The major sources of greenhouse gas emissions resulting from the operation of non-residential sector buildings are related to the provision of lighting, heating, cooling, ventilation and domestic hot water services. The specific contribution of these services varies for each building type and other factors, such as climatic location and activity levels.

The most effective and cost-efficient opportunities to reduce the greenhouse impact of non-residential buildings occur during the new construction design phase. Buildings undergoing refurbishment present the second most cost-effective opportunity. Retrofitting buildings with energy efficient technologies is the least cost-effective option. However, in the short to medium term, it will be necessary to concentrate on this third option due to the large number of poorly performing existing buildings which comprise the bulk of this sector, and which will not have any significant refurbishment in the medium term.

EMET (1999) foreshadowed that a potential reduction in greenhouse gas emissions of up to 19.8 Mt CO_2-e is possible from the non-residential sector by 2010, through the implementation of a number of initiatives for existing buildings and new building designs. For this improvement to be achieved, a range of disincentives will need to be addressed and improvements in the design, management and retrofitting of buildings will need to be instituted. The latter will need to be underpinned by a program of awareness and education to achieve the required shift in attitudes and practices within the industry and building occupants.

The proportion of embodied energy to operating energy in the non-residential building sector varies widely with building type and intensity of operations affecting the desirability of carrying out the refurbishment of a component or a system, or its replacement.

This paper focuses on the issues related to the removal of disincentives to energy efficient developments, and on the opportunities available in both new and existing non-residential buildings.

2.0 COST INCENTIVES TO IMPROVE ENERGY USE EFFICIENCY

Energy management opportunities with excellent financial returns (less than 3 year payback) exist in many commercial buildings, but often little effort is made to capture those savings. The most common reasons for such lost opportunities relate to lack of incentives and lack of knowledge/awareness on the part of the building owner, developer, manager or occupant.

From the developer's perspective, there is no financial incentive to achieve a design which produces a higher level of energy efficiency, as this adds little to the building's market value at present. A system of building design rating, which clearly evaluates the operating costs of a future building and provides a clearer picture of cost-effectiveness and financial returns to the future owner, is required to inspire the building developer to make the extra effort to achieve higher efficiency. This evaluation process needs to follow the building through the construction and commissioning stage to ensure that the building is finally constructed in accordance with the original design intent, and that the projected performance is achieved by the final product.

The Australian Building Energy Council's (ABEC) voluntary code of practice will assist in the development of a framework of incentives for this process, however a method of transferring the additional cost burden of producing an energy efficient building to the future beneficiaries of the actions (i.e. the future occupants of the building) is needed. This would provide a self-sustaining source of funds which would be directly offset by ongoing operational cost savings achieved by the building during its lifetime.

Design tools such as energy computer simulation packages (e.g. ESP-II, DOE2, Bunyip, etc) are available to assist designers in quantifying and verifying the future performance of their buildings, however a reliable form of target development is required to ensure that a realistic but optimum performance is achieved for each design.

From the perspective of the owner of an existing building, the incentive to undertake energy efficiency initiatives is vastly eroded by the loss of those savings to the tenants/occupants. Under typical retail lease conditions, the building owner is able to retain as little as 25% of any financial savings achieved by energy management actions. The remainder is transferred over to the tenants under operating cost transfer requirements. However, the transfer of the capital cost related to such improvements to the tenants/occupants is strictly controlled, resulting in the owner retaining the entire burden. This process effectively reduces the cost incentive to the owner by 75%.

A review of the corporate accounting requirements for capital and operating cost allocations and eligibility for energy efficiency projects could improve the capture rate within the existing commercial building sector by a factor of 3.

The above issue relates to the energy used by the 'house services' (common areas and services) of a commercial building. Energy used by the tenant/occupant can account for approximately half of the total energy used by the building, however due to the relatively short term occupation of these spaces by individual tenants, there are limited incentives for undertaking any efficiency improvement initiatives within this area of energy use. An equitable method of writing off the additional cost of an efficient design or building retrofit against the savings achieved is required to improve the capture rate in this area of energy use. Such arrangements would allow savings realised by the works to be transferred to a capital management arrangement which funded the process in the first instance, and transferring any remaining savings to both the owner and the occupant of the space for the life of the improvements undertaken. This process would not only remove the current level of disincentives for energy efficiency, but positively reinforce the incentives.

Improvements in the level of awareness of energy efficiency among the owners and investors of smaller buildings is required. Typically, this segment of the commercial sector makes little use of design and energy management consultants, and owners and investors are often unaware of opportunities which may be available to improve energy efficiency. Assistance in obtaining the relevant expertise will result in substantial reductions in emissions from this previously untapped segment of the commercial sector.

Finally, an improved level of ongoing building energy performance assessment is required, to ensure that projected savings are achieved and maintained for the life of the building. The process requires a method of developing appropriate target performance levels for all combinations of building type, operation and climatic conditions, and the development of a metering and monitoring strategy which provides instant assessment of operating performance against specific targets and provides an early warning of errant operation. The process should be independent of the size of the building and should allow all parties (tenant, owner, etc) to benefit.

3.0 MANAGEMENT OF ENERGY IN EXISTING BUILDINGS

The most neglected aspect of energy management is the role of the building/energy manager in achieving and maintaining the level of performance required for each of the building's systems and services. This process will typically result in the deterioration of performance of building systems by up to 30%. Among the activities of effective building energy management are:

- ensuring that effective commissioning and fine-tuning of each building system occurs at the original handover stage of the building and following any other improvements carried out during its life
- monitoring and verifying energy performance of the total building and each component
- managing the process of identifying and developing proposals for additional improvements through energy audits or feasibility studies
- setting up monitoring systems to identify efficiency problems, and malfunctions which cause increased energy use
- managing maintenance and operational staff and processes to ensure continued achievement of targeted energy efficiency levels for each building system and service
- regular reporting of performance to building owners and investors
- implementing and maintaining an energy management plan for the building
- providing adequate information, instruction and means of communication.

4.0 THERMAL PERFORMANCE OF THE BUILDING ENVELOPE

The opportunities for improving thermal performance of non-residential buildings vary widely between building types and operations. The concepts used in residential buildings for siting and designing buildings for low energy consumption are often inapplicable to non-residential buildings and this requires an understanding on behalf of the designer of the building structure, and a good level of communication between the mechanical and architectural design consultants.

Buildings with high levels of internal heat gain and relatively small surface areas (e.g. office buildings, computer/communications centres, etc) have a continuous need to expel excess heat from the building. In this case, envelope designs which capture solar heat and light can produce negative effects on energy use efficiency. On the other hand, heating and cooling requirements for building types with high surface areas and low internal heat loads, such as shopping centres, schools, hospitals, etc are more sensitive to climatic conditions and provide a positive response to improvements to the thermal performance of the building envelope.

The 'thermal sensitivity' of a building can vary from almost no increase in energy use per degree of rise in temperature, to 5% or more increase per degree. However, irrespective of the building type, improvement in the performance of the envelope provides an immediate reduction in the infrastructure required to provide the cooling and/or heating demands of the building. This reduces the total system capacities, instantaneous energy demands and ongoing energy requirements. The cost of implementing effective measures for envelope performance improvements can therefore be immediately written off against reductions in heating/cooling system requirements. This process becomes more cost-effective as the sensitivity of the building type increases. Such measures include: higher levels of insulation; better window thermal performance; wiser choices of internal and external colours and finishes; management of infiltration, etc.

Despite the level of sensitivity for any specific building type, imbalances in heat gain across the building, caused by inappropriate envelope design, can be a major source of conflict and inefficiency within air conditioning systems, and requires a higher level of sophistication in system design and operation. For example, an office on the north-west corner of a building with a poor envelope may need cooling on winter afternoons, while the rest of the building needs heating. For this reason, it is a better option to limit heat flows through the building envelope to a low and relatively uniform level of heat gain or loss, rather than attempt to capture heat through north facing glazing with the intention of distributing it to other parts of the building.

4.1 Improvement opportunities for building envelope

A good starting point for this area of opportunity, is to construct a computer model of the building's design and operations, including all internal heat loads and the structure and design of the air conditioning systems used to cope with the load. It is not sufficient to analyse only the envelope, as this ignores the influence of the internal activities on the building's energy requirements and the ability to allow for the air conditioning system to efficiently cope with the variations in requirements within the building and across the seasons. Energy simulation packages such as ESP-II, DOE2, Bunyip and others of this type, are suitable for this purpose.

Using this method, passive design aspects of the envelope can be integrated with active systems and internal heat sources to produce an integrated design for optimum energy efficiency.

Aspects of the building envelope which could be evaluated using this process include:

- heat load reduction strategies such as shading, colour selection, insulation, heat reflection, landscaping, etc
- solar heat capture through a combination of orientation, window performance, thermal mass, insulation levels, etc
- daylight capture through light wells, skylights, windows, etc and selecting performance that allows light penetration with reduction in heat transfer to the space
- reduction in losses through thermal barriers, weather-stripping, air locks, treatment of construction joints, etc.

Methods applied for the reduction of internal heat loads include (refer to DES 37 and elsewhere in this note for additional information):

- selecting efficient equipment such as low energy office equipment and efficient lighting systems
- direct extraction of heat from plant and equipment
- isolation of plant and areas which require different temperature levels or operating hours.

Methods for dispelling internal heat loads include:

- ventilation – natural or forced; daytime and/or night flushing
- application of dedicated plant and services
- direct extraction of heat
- other applicable methods (coordinate with the mechanical consultants and equipment suppliers).

5.0 ENERGY SOURCES – ENERGY SYSTEMS AND GREENHOUSE GAS EMISSIONS

Different energy sources vary substantially in the quantity of greenhouse gas emissions they produce for the same amount of delivered energy. Table 1 is an excerpt from the *Greenhouse Challenge Workbook* produced by the Australian Greenhouse Office. It shows the variation in average greenhouse gas factors for electricity and natural gas among the Australian states.

Electricity shows large variations, depending on its method of generation and source fuels (e.g. Tasmania has the lowest factor due to the large component of hydroelectric power). Natural gas, on average, produces only a quarter of the emissions produced by electricity, for the equivalent amount of useful energy delivered. However, end-use efficiencies can differ, reducing or even negating the difference. For example, a heat pump with a Coefficient-Of-Performance (COP) of 3 has similar greenhouse gas emissions to a gas heater with an efficiency of 75%, in much of Australia.

The selection of the 'cleanest' energy source for building services such as heating, cooling and hot water is the primary method of reducing the overall greenhouse gas emissions related to a building's operations. The use of combined and/or hybrid systems (systems which use a combination of energy sources and/or processes in an integrated operation) is a possibility where operating patterns and heat balances provide suitable opportunities. Such systems may include combined heat and power systems, which increase the efficiency of power generation from a typical of 30% to up to 85%; or other forms of cogeneration. Each of these applications require careful planning and engineering to ensure successful design and operation.

Location	Electricity kg $C0_2$/GJ	Natural gas kg CO_2/GJ
NSW/ACT	255	63.2
Vic	372	58.9
Qld	283	56.7
SA	264	57.6
WA	305	62.3
Tas	0.4	-
NT	192	54.6
Average	277	59.4

Table 1. Greenhouse Gas Emissions per unit of delivered electricity and gas, by state, 1994

Source: Australian Greenhouse Office

The use of active renewable energy systems (apart from the 'passive' design principles discussed previously), in commercial buildings, varies with the building type and operation. The most common applications include solar hot water systems, solar space heating (sometimes incorporating heat storage), geothermal cooling, solar boosting of heat pumps, etc.

6.0 IMPROVING THE ENERGY EFFICIENCY OF NON-RESIDENTIAL BUILDINGS' SERVICES

Energy improvements of over 50% have been achieved through the application of conventional technologies and management/operational techniques within the operation of specific building services.

Generally, appropriate approaches to achieving a financial improvement in building services involve the following, in order of cost-effectiveness:

- *Improve the operation/management of the system* – i.e. is it operating only as required; is the right component selected for operation; is the correct system being used to ensure operation at optimum capacity; should the system be used at all or is there a better alternative for providing the required end result.
- *Improve the efficiency of operation* – The questions which apply here include: is the system correctly controlled; is the plant correctly sized for the load; what conflicts can occur in the operation, and have they been removed or prevented; are alternative systems/sources of energy being used (e.g. economy cycles in air conditioning).
- *Improve the efficiency of plant and systems* – This is the most cost-intensive strategy and it involves retrofitting and/or replacing existing plant with more efficient controls, components and/or systems.

The selection and application of each of the above options requires a current knowledge of technologies and techniques, in addition to an understanding of the intent, design and operation of each of the systems. The most effective method of identifying these types of initiatives is by undertaking a comprehensive energy audit and feasibility study. Sustaining the savings and continuing the improvement into the future requires a continuing process of monitoring, performance assessment and review, as described previously in this paper, and should include regular external re-evaluation through energy audit updates.

The following paragraphs provide a simple summary of key energy management initiatives available within the most common building services and systems applicable to non-residential buildings.

6.1 Lighting systems

The most effective energy management initiatives applicable to lighting systems include (in order of typical cost effectiveness):

- Staff awareness – i.e. enlisting the support of building occupants and staff to control lighting more effectively to reduce unnecessary operation.
- The use of daylighting – i.e. turning off selected lighting systems when sufficient daylight is available to the space.
- Improved maintenance program – e.g. bulk replacement of tubes coupled with regular cleaning of surfaces, fittings and tubes and reduction of excessive light levels (see below).
- Reduction of excessive light levels through de-lamping, dimming, autotransformers, re-design and replacement, etc.
- Simple restructuring of systems to better utilise the available light – e.g. relocating or disconnecting fittings which are not providing any useful purpose (e.g. lighting the top of a cupboard); replacing blanket lighting with background lighting plus task lighting; rewiring the systems to better serve the requirements of occupants and operations; changing interior colours and finishes to improve light reflection.
- Improved control to minimise use to times of requirement (photo electric cells; movement detectors; global timers; central control systems; time delay switching, etc).
- Replacement and/or retrofit of systems with more efficient options, e.g. higher efficacy lamp types; high performance reflectors, diffusers and ballasts and other components; higher efficiency fittings.
- Complete redesign and replacement with a dedicated design for current operations, including components of each of the above efficiency/ performance options.

Energy consumption reductions of over 50% have been achieved consistently within lighting systems, through the application of the above types of initiatives.

6.2 HVAC systems

This component of energy application is the most sensitive to effective operating and control strategies to achieve low emission operations. It is also one of the most difficult with regards to any major design or structural change as a retrofit project, due to the cost and impracticality of undertaking significant structural changes to the systems once they are installed at the site.

The most cost-effective strategies in improving energy use efficiency related to HVAC systems, include the following:

- Implementing a thorough and effective maintenance program to ensure that all control components of the system operate under optimum conditions and operate in the required mode. Undertake regular efficiency reviews of all primary plants.
- Adding cost-effective energy efficient control strategies such as outside air economy cycles, overnight flushing, air quality sensor control of outside air, optimum stop/start, etc.
- Adjusting and coordinating thermostat settings to minimise unnecessary and/or conflicting operation of heating and/or cooling plant and to provide a comfort level more consistent with the climatic conditions of the location/season.
- Improving the control of small to medium size systems by minimising operation when spaces are not occupied – e.g. the use of manual start with automatic 'off' control using time delay switches, movement detectors, time clocks, thermostatic cut-offs, etc, as applicable to the situation.
- Gaining effective control and operation of the plant by reviewing its design constraints and its requirements for operation, and adapting the control and operation of the plant to best meet these loads.
- Reducing conflicting operations by eliminating systems which use such techniques for temperature control, or where this is not cost-effective, by overriding the conflicting systems using global commands when this is possible, during the specific load conditions.
- The addition of improved controls and/or technologies to increase the efficiency of plant operation, such as Variable Speed Controllers on fans and pumps, electronic thermal expansion valves, etc.
- The replacement of major components with more efficient alternatives, such as higher efficiency chillers, more appropriate systems (e.g. radiant heaters instead of space heaters in locations with high air movements), geothermal cooling/heating, etc.
- Improvement to the thermal performance of a building's structure by adding insulation, changing external colours, adding protection to windows (e.g. shading, high performance glazing etc), reducing losses through open doors and windows, sealing cracks and construction joints, weather-stripping, etc.

Savings in HVAC energy use of between 30% and 50% are not uncommon for typical existing buildings, using a combination of the above initiatives.

6.3 Domestic hot water systems

(e.g. hot water used in toilets, kitchens and other building amenities)

Energy consumption for domestic hot water varies widely across the non-residential building sector. Building types involving accommodation (hotels, motels, hospitals, etc) have relatively high components of domestic hot water use. As do buildings incorporating food related activities, such as restaurants and various types of retail outlets. Energy use for hot water delivery in office buildings and similar building types can be dominated by system losses rather than usage, therefore the design and retrofitting considerations in these situations are completely different to the more intensive buildings.

Water conservation issues are also a prime consideration in domestic hot water consumption. Initiatives related to domestic hot water systems include:

- Reduction of waste and losses by fixing water leaks from pipes and fittings, insulating lines and system components, and reducing the size of reticulation systems and hours of activation.
- Reducing the temperature of the water stored and reticulated on the site. Use local booster heaters where necessary to provide higher temperature water at required local points (e.g. dishwashing in kitchens).
- Reducing standing losses by disconnecting/ isolating systems or components of surplus capacity or temporarily surplus to requirements (e.g. during vacation breaks or even on weekends or overnight).
- Improving utilisation efficiency by installing water efficient fittings and services, installing flow control devices and pressure reducers, etc.
- Replacing systems with more greenhouse friendly options – e.g. solar hot water (gas boosted over electric boosted); solar boosted systems; gas systems; heat pumps; dedicated local units, instead of larger reticulated systems, etc.
- The addition of heat and/or water reclaim systems to major users of hot water – e.g. laundry operations; capturing heat rejected from cooling/ refrigeration systems and process plants.

Savings of up to 100% of water heating energy consumption can be achieved by the above means.

6.4 Building management systems

A finely tuned Building Management System (BMS) can optimise the efficiency of a building's plant and operations by constantly evaluating the requirements of the building and the plant, and operating the appropriate equipment to best meet the current needs.

However, BMS's are traditionally a poorly utilised and poorly managed resource in buildings, and can often be a major cause of poor energy efficiency through improper management and operation of systems and through interference by operators not familiar with the intrinsic operation of air conditioning systems.

Principle energy management tasks provided through BMS systems in commercial buildings include:

- Metering, monitoring and trending the performance of the building and individual critical components of the plant and comparison against specific targets to ensure that any degradation in performance is immediately identified and reported.
- Coordinating/managing the operation of the central plant (heating, cooling and ventilation systems) to eliminate unnecessary and/or conflicting operations.
- The management and control of electricity and gas consumption (load management functions) to reduce the cost of energy to the site and to reduce internal overloads of energy infrastructure – e.g. preventing all plant from running up to full load, simultaneously causing an overload of power systems and excessive electricity demand charges.
- Selecting the most appropriate size and type of plant to best meet the immediate requirements of the plant and systems – e.g. selecting the low-load chiller, when the building demands drop to a specific level.
- Providing the majority of the energy management functions itemised above under lighting, HVAC and hot water systems.

Due to the uniqueness of the design of each building, its HVAC services and its operations, the energy management strategies incorporated within each BMS need to be developed and commissioned specifically for each case. This will require the services of a BMS specialist in the specific system required, in consultation with an energy manager and services engineer familiar with requirements of the building.

Ad hoc changes to operating parameters within the system, usually resulting from complaints about comfort levels, are the main reason for severe loss of effectiveness and efficiency of systems controlled by the BMS. This practice should be eliminated, with all changes being coordinated through the strategy designer and properly documented for ongoing maintenance and management purposes.

To prevent the gradual degradation of the effectiveness of the BMS system, a periodic review of its operating strategies should be undertaken by a suitably experienced energy manager. This task should not be confused with normal maintenance of the system and its software, which should be carried out routinely to ensure that the BMS operates within its normal parameters.

6.5 Other energy usage systems

Other energy consuming systems which are relevant to various building types may include: compressed air systems; steam systems; OH&S ventilation systems (e.g. car parks); swimming pool pumping and heating; cooking; laundry equipment, etc.

Each of these systems requires individual analysis by an energy manager to determine the best combination of initiatives applicable to their operation. Some generic initiatives which may be applicable to many of these systems include:

- the use of high efficiency electric motors
- replacing oversized motors with more appropriate sizes
- identifying and eliminating losses
- using variable speed drives to eliminate throttling of pumped and ventilated systems, which are currently operating over capacity, or those which have variable operating load requirements
- eliminating unnecessary operations by installing appropriate control strategies and systems
- applying an effective and regular maintenance and review program to ensure that systems operate at optimum conditions and load levels.

7. CONCLUSION

The rate of greenhouse gas emissions produced by Australia's non-residential buildings could be reduced by around 20 Mt of CO_2-e per annum by the year 2010, using the cost-effective application of available technologies and techniques. In order to achieve emission abatement levels anywhere near the potential available, a comprehensive program of energy management would have to be implemented encompassing all key areas of energy use and influence.

Improving the investment incentives for developers, owners and occupants of buildings to achieve improvements in energy efficiency is critical to ensure that a significant proportion of the opportunities available to the sector are actually implemented. This will require a re-structuring of a number of existing accounting and legal issues, to redirect benefits from improved energy efficiency, to the parties who are burdened with the financing of such improvements.

A building's energy use is determined during the initial design stage. Strategies for achieving energy efficiencies must be implemented at that stage, and through the development of an integrated design involving a thermally efficient building envelope, effective planning of the building use, and the design of appropriate and efficient building services and controls. The next most effective time to achieve significant improvements in operating efficiency is during significant refurbishment of an existing building, when major changes to the building's structure and plant become financially feasible. Improving the knowledge and awareness of building and services designers, and by making available appropriate tools for the determination and verification of improvements, is a key strategy in achieving this change.

Retrofitting existing buildings to achieve improved operating efficiency is the least cost-effective approach available, however due to the high proportion of poorly performing existing buildings, which will not undergo significant retrofits during the next 20 years, this approach remains the one with the largest potential for improvement.

Irrespective of the effectiveness of a building's design in achieving energy efficiency, it is the manner in which the building is operated, maintained and improved over its lifetime that will determine its level of emissions. Many instances have been recorded where buildings of identical design and operation have shown vastly different levels of energy efficiency, due to differences in the management practices applied to those buildings. Also, irrespective of the performance achieved at the initial commissioning of a new building, the development of new energy efficiency technologies and techniques, means that the building will soon be out of date when compared with subsequent new buildings. Improving the level of awareness and knowledge within the building management and maintenance industry, is therefore a primary task in achieving a sustainable improvement within non-residential buildings.

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Australian Greenhouse Office (1996) *Greenhouse Challenge Workbook.*

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BIOGRAPHY

Stephen Pupilli is the Managing Director and co-founder of EMET Consultants Pty Limited, which is a professional engineering and energy management company specialising in optimising the operating efficiency of all types of building services and industrial processes. Steve has been involved in the energy management and the engineering industry for over 20 years, and has been responsible for the development of many of the systems and techniques currently in operation within the industry.

Programs developed and managed by Steve Pupilli and the EMET team have operated in all parts of Australia and every climatic region, and to date have resulted in energy savings worth in excess of $300 million, reductions in greenhouse gas emissions of over 2 million tonnes, and have been recognised by being awarded three National Energy Management Awards.

Steve has represented the Australian Government on building efficiency matters at various international conferences and for many years he has been involved in the development of energy efficiency standards, codes and guidelines as representatives for Industry Associations, Government bodies and the Institution of Engineers alike.

Steve is a Mechanical Engineer and a Senior Member of the Institution of Engineers Australia.