ENVIRONMENT DESIGN GUIDE

REVISITING ENERGY EFFICIENCY IN COMMERCIAL BUILDINGS

Deo Prasad, Shailja Chandra and Matt Fisher

SUMMARY OF

ACTIONS TOWARDS SUSTAINABLE OUTCOMES

Environmental Issues/Principal Impacts

- Minimisation of energy consumption and related greenhouse gas emissions
- Importance of energy efficiency in context of productivity and health of occupants
- Improvement in indoor thermal and visual comfort
- Improvement in the efficiency of the energy systems.

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:

- Have an integrated design approach to establish and fulfil energy performance goals. The integrated design process should ensure consistency in vision and outcomes
- Carry out early design charetts and decision-making workshops to select appropriate strategies and energy systems; this should also lead to a well-integrated management and maintenance system
- Have an understanding of user needs, apathies and endurance levels regarding the indoor conditions to correctly assess the deliverables
- Technologies and strategies should be deployed with an in-depth understanding of the tailored needs of a particular project.

Cutting EDGe Strategies

- Consider ground coupled heating and cooling
- Consider enhancement of natural ventilation through strategies such as hybrid ventilation and Task Ambient Conditioning
- Consider envelope designs that integrate the best of facade designs (advanced windows, light redirecting envelope system, dynamic envelope) and lighting engineering, plus control systems such as sensors
- Consider use of solar energy technologies such as building integrated photovoltaics and purchasing 'green' energy
- Consider co-generation, using the heat from building appliances or in-house emergency generators
- Consider integrated design approach to best combine these technologies and strategies.

Synergies and References

- Energy efficiency goals are best realised with an integrated design approach, requiring a shift in conventional architectural practices to integrate new rules of thumbs for design, new skill-supports such as energy analysts, and revised guidelines and manuals to put the energy-efficiency vision in practice.
- An efficient management and maintenance system is imperative to realise the goals and performance objectives
- Good understanding of user needs and behaviour trends will help in correct assessment of system capacities and efficiencies
- *BDP Environment Design Guide*: GEN 14, GEN 33, GEN 38, GEN 42, DES 6, DES 28, DES 12, DES 37, DES 39, TEC 2, TEC 3, TEC 6, TEC 7, TEC 9, TEC 10, PRO 2, PRO 3, PRO 19, CAS 1, CAS 2, CAS 8, CAS 10, CAS 20.

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*The previous version of this DES 2 (*Energy Efficiency in Commercial Buildings *by Deo Prasad May 1995) emphasised the need for including fundamental concepts of energy efficiency such as climatically suitable designs and forms, benefits of tailored building facades and envelopes for day lighting and sun control, inclusion of thermal mass, an efficient management and operational plan and significance of alternative energy sources.*

This Note revisits the scope for energy efficiency in commercial buildings and discusses some emerging technologies and trends in thinking.

1.0 BACKGROUND

Energy efficiency in commercial buildings is now much better understood than only a few years ago. A number of *BDP Environment Design Guide* publications have discussed energy efficient design strategies, e.g. Natural Lighting of Buildings (DES 6), Natural Ventilation in Passive Design (TEC 2), Energy Systems, Appliances and Equipment (DES 37), Architectural Applications of Photovoltaics (DES 28), Perceived Comfort (DES 12), An Overview of Operational Energy Minimisation (TEC 7) and Post Occupancy Evaluation and Sustainable Design (GEN 42).

Section 2 presents a range of current technological solutions for the improvement of energy efficiency in commercial buildings. Whilst the role of passive design principles is indisputable, this Note takes a leap towards active and innovative strategies that technology offers today, without replicating the passive design discussions, which have already been covered in the previous version of this note.

Section 3 introduces a discussion of some important user and behaviour related issues. Central to the success of any energy efficient strategy or technique is the role and requirements of building inhabitants. Recent investigations have found that energy efficiency solutions can significantly influence worker productivity, both positively and negatively, through the resulting indoor air quality, comfort and lighting environments. It is also now realised that occupant behaviour can also directly influence the success of a building's actual overall energy efficiency. The importance of issues regarding user perception and awareness levels, involvement or apathies, and use and operations of the energy systems are discussed.

Section 4 highlights the need for an integrated design process (IDP) to be adopted by architects to ensure that initial energy efficiency decisions are carried right through the stages of consultant involvement, documentation, construction, commissioning, as well as building management, maintenance and occupation. It is discussed that an integrated approach ensures that energy-related design intentions are in fact successfully realised, managed and operated.

Please note that whilst many of these techniques are intended for the design of new buildings, they are also of relevance when retrofitting existing commercial developments.

2.0 TECHNOLOGICAL SOLUTIONS FOR ENERGY EFFICIENCY IN COMMERCIAL BUILDINGS

The emerging demand for 'green' buildings provides an ideal opportunity for the incorporation of energy efficient design measures and technological initiatives in commercial buildings. This section discusses developments in technological possibilities in various energy-consuming or energy-producing components in commercial buildings.

Whilst a great deal of literature has described more traditional 'passive' approaches to energy efficiency in commercial buildings, the intent of this note is to highlight the suitability and benefits of some of the recent active technological approaches. It must be noted that passive approaches are considered the fundamental underpinning of any energy efficient approach.

The strategies presented in this note include:

- Ground source heat pumps
- Enhanced ventilation
- Integrated envelope and lighting systems
- Building integrated photovoltaics (BIPV)
- Appliance efficiency
- Cogeneration.

2.1 Ground source heat pumps

Ground source heat pumps are mechanical systems that assist space heating and cooling by releasing or absorbing heat to and from the earth, which remains at a stabilised temperature throughout the year. In Australia the temperature of the earth is a constant 17-19°C, at a depth of 2 metres *(Australian Energy News, 1999).*

The system consists of loops of piping buried underground, which are connected to the internal spaces of the building via heat exchangers (Refer to Figure 1). In winter, circulating water transports relative warmth from the earth through the building. In summer, the system transfers heat from the building, exchanging it with the relative coolth of the earth (see also TEC 6).

The Australian Geological Survey Organisation (AGSO) building in Canberra demonstrates the success of this system. The ground source heat pump system eliminated the need for cooling towers, lowering the capital costs, reducing annual energy consumption and resulting in lower greenhouse emissions.

A predicted running cost saving $A936,000 over 25 years reinforces the savings in capital costs, energy costs and maintenance costs (Prasad, 2000).

Chris Arkins presents further benefits of the system: (Arkins 1999)

- Simultaneous heating and cooling can be achieved for different parts of the building
- Plant room sizes are reduced by 20-50%,
- Mechanical equipment requirements are significantly reduced
- Durability is high as the system is protected from the weather (underground)
- Ground source heat pumps are relatively low maintenance systems
- The risk of legionnaires disease is eliminated, since there are no cooling towers.

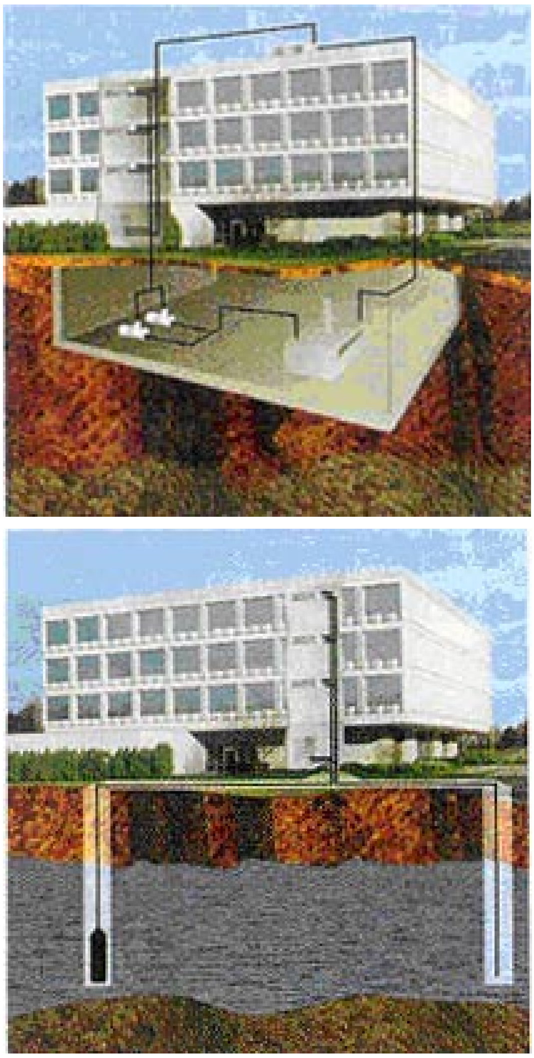

Figure 1. Horizontal loop system and pond loop system (source: *Australian Energy News*, March 1999, p55)

2.2 Ventilation

Whilst ventilation is regarded as a natural phenomenon in buildings, many scientific processes can actively enhance the rate of natural ventilation.

a) **Hybrid ventilation (mixed mode)**

Hybrid ventilation offers energy efficiency opportunities by combining the best of both worlds - natural and mechanical ventilation. Using intelligent control systems, switching between natural and mechanical modes can be controlled as required, relating to time of day and if possible the different seasons of the year (CSIRO, 2001).

While this technology is still in its infancy its use is increasing. A four-year International Energy Agency (IEA) research project on hybrid ventilation (Annex 35 HYBVENT) is working to develop control and measurement strategies for diagnostic purposes of the hybrid systems methods, to predict system performance and to promote cost-effective systems. Australia (through CSIRO Building Construction Engineering (BCE) and the University of Sydney) is one of 15 countries participating in this venture (CSIRO, 2001).

For the success of every hybrid system deployed in buildings, there is a requirement to have an appropriate control and management system and if possible a performance monitoring to fine-tune the system.

b) **Task ambient conditioning**

The task ambient conditioning (TAC) strategy uses occupant operable windows linked with sensors for automatic shut-off of mechanical HVAC when the windows are opened. This leads to savings in wasted energy, as well as involving the phenomenon of '*endurance*' whereby occupants are willing to tolerate a wider range of thermal comfort conditions when provided with the capacity to control their comfort environment (Shipworth, 1999).

This phenomenon is discussed further in Section 3, and suggests that if the tolerance levels of users can be increased, passive design strategies in particular stand a better chance of being used more widely in commercial buildings.

2.3 Integrated envelope and lighting system

Offsetting electrical lighting with natural daylight is a fundamental principle of energy efficient design. However sometimes it is difficult to realise its full potential and implementation simply with passive strategies. The benefits of integrated envelope and lighting systems are discussed with this in mind.

The concept of an integrated envelope and lighting system takes a cross-disciplinary approach and incorporates the best technological, aesthetic, comfort and energy-efficiency considerations in presenting a building envelope tailored for an optimum performance.

A research project at Lawrence Berkeley National Laboratory (LBNL) by Eleanor S Lee and Stephen E Selkowitz explores the concept of dynamic envelope/lighting systems that respond in real-time to temporal changes in sun and sky conditions in order to control daylight intensity and solar heat gains, and provide a more uniform, comfortable interior work environment (Lee et al, LBNL).

Another concept that was studied at LBNL was light-redirecting envelope systems that assist in uniform and deeper distribution of daylight flux in the space interiors (Lee, E, et al, LBNL).

The role of control measures such as 'light sensors with regulators' can be very crucial in extracting best performance out of a specially tailored lighting system. Effective use of control sensors can help maintain a lighting system as intended. Bob Veir in TEC 3 describes some of these control systems.

- Passive Infrared- these react only to energy sources such as the human body.
- Ultrasonic-react to volumetric motion change such as body or equipment movements
- Dual-combines ultrasonic and passive infrared in one unit allows the sensor to take advantage of the best features of both technologies while eliminating flaws (Bob Veir, Feb 1997).

The role of advanced windows in energy use reduction has been discussed in DES 17 (Thomas, 1997) and PRO 19 (Thomas et al, 1998). By simply switching to improved performance glazing in commercial buildings it is possible to achieve relative reductions in peak cooling load demand in the order of 20–50% as shown in Figure 2 below (for two Australian locations).

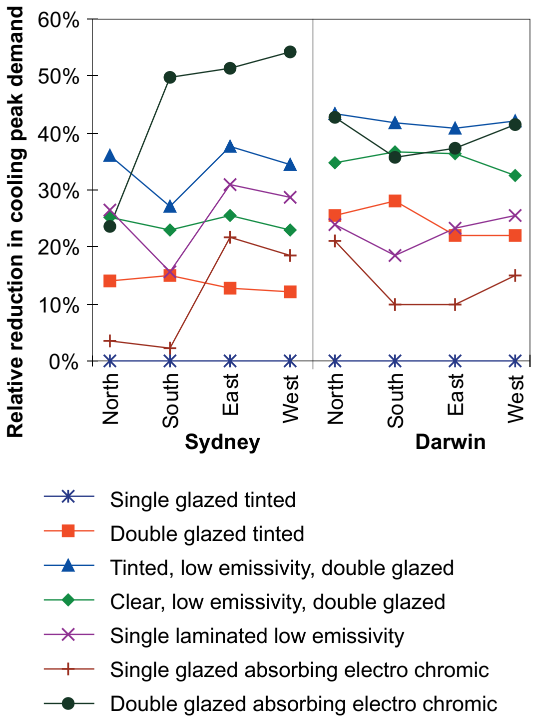

Figure 2. Effect of glazing types on cooling and peak demand

The key contributor to facade glazing related heat gain is solar gain. Figure 3 shows an increase in cooling and heating energy requirements for different locations as a function of solar aperture (a proxy for the size of openings combined with the solar heat gain coefficient). Figure 4 on the other hand, shows the relative insensitivity of U-vales to the cooling and heating energy needs. These are relative indications and based on typical square plan office buildings.

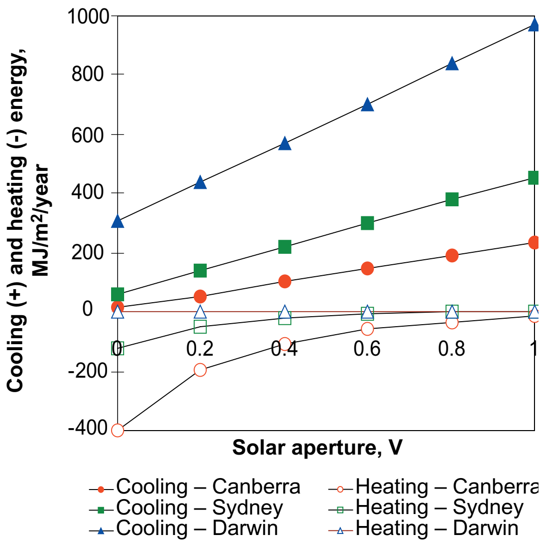

Figure 3. Effect of solar aperture on cooling and heating energy

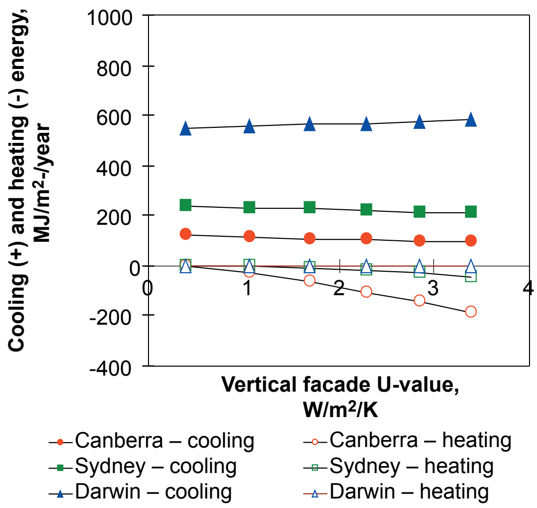

Figure 4. Effect of U-values on cooling and heating energy

However, to assess the suitability and sequencing of gadgets and strategies, it is necessary to have a better understanding of the tailored and specific requirements and factors for efficient daylighting designs in buildings in Australia.

Some of the starting points are bringing lights into space from two opposite sides, dimming/switching off lights during the daytime, appropriate shading devices for glare protection and appropriate surface reflectance. More complex systems involve laser cut panels and redirecting systems for deeper and uniform light penetrations.

According to the study done at Lawrence Berkeley National Laboratory, daylighting is unique in that it requires designers to solve not only complex technical issues on a case-by-case basis, but also qualitative issues as well (e.g. glare, brightness contrasts, view and design aesthetics) (Lee, E, et al, LBNL). This requires a synergy between architectural design, lighting design, and mechanical systems together with the management user issues. Hence there is a need for an integrated approach that can take account of all these disciplines and thus provide an optimal solution. Section 3 discusses IDP in detail.

2.4 BIPV in buildings

Building integrated photovoltaics (BIPV) offers a tremendous opportunity for architectural enhancement, as well as energy and economic savings. Opportunities to integrate photovoltaics are many, and are marking their realm through smaller integrated elements such as roof shingles and tiles as well as larger integrated systems.

However, according to Richard Perez (Perez, 1998) there is more to it. There are certain factors about BIPV on which commercial building owners are uniquely positioned to capitalise, namely:

- PV's electrical output matches well with patterns of energy use in commercial buildings, promoting effective management of electricity demand.
- PV applications are now being integrated directly into building roofs, envelopes, and surrounding spaces and these technologies are evolving rapidly.
- Business-owned PV systems convey tax advantages, such as accelerated depreciation.

(Perez, R, 1998)

Another opportunity offered by BIPV technology and commercial buildings is the fact that the inverter included in the solar system can also be configured to double as an uninterruptible power supply (UPS). This synergy has been used in the commercial high-rise complex developed by Forrester Kurts in the Brisbane CBD. The building incorporates an 80 kW building integrated PV system. The PV's DC power output is converted to AC power ready for use by the building's tenants through the use of an 'off-the-shelf' uninterruptible power supply system. Power supplied by this system eliminates the need for a diesel-based emergency power generator system. The UPS output will be on-sold to building tenants to provide a 'secure' supply for sensitive computer equipment. The UPS is provided on a commercial basis by the developer and allows the conversion to AC power at zero cost to the project (Barram, 2000).

Figure 5. Kogarah city centre development
(Architects: Allen Jack and Cottier)

Figure 6. ECN Building Atrium, Netherlands
(Architect: Tjerk Reijenga)

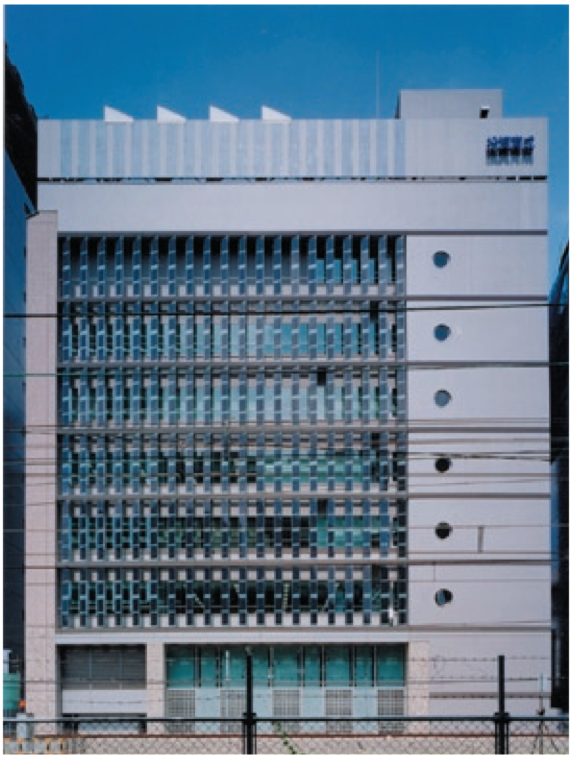

Figure 7. SBIC Building, Tokyo, Japan – facade shading

2.5 Appliance efficiency

A report prepared for the National Appliance and Equipment Energy Efficiency Program *(NAEEEP)* estimates that measures to improve energy efficiency of appliances and equipment can cut more than 7 Metric ton of CO_2 equivalent per year out of the national inventory during the period 2008-2012 *(Australian Energy News, March 2000, p38*).

A tremendous potential for energy efficiency can be unleashed by simply targeting appliances such as computers, printers, photocopiers and refrigeration used in a building. By switching over to smart appliances fitted with automatic and intelligent systems it is possible to maximise savings while minimising inconvenience. This means that less power will be consumed when equipment is operating and/or it switches to a lower energy consumer mode *(Electricity Supply Magazine, Feb 1995).*

Innovative initiatives in appliance design are providing energy efficient opportunities. News articles such as 'Lighting Futures' (Editor – Kathleen Daly) provide details of many such energy saving and high performance appliance and lighting fixtures.

Standby power of electrical appliances and equipment is also becoming an important issue. Standby power is the fractional amount of electricity which is used when appliances are not performing any function or even when switched off. With the increasing efficiency of these appliances, this fraction becomes very significant and actions are needed to reduce this.

As the standby losses are mostly associated with the appliance selection, most of the harm is done at the commissioning stage. Hence it is crucial that the contractors are advised to investigate standby losses associated with each appliance or piece of equipment before installing on site. There is also a need for awareness amongst consumers so that they can seek information on standby energy consumptions before ordering or buying appliances for the office.

2.6 Co-generation

Cogeneration is the recovery of heat energy from various plants and machines for reuse elsewhere. The cogeneration method can provide a very efficient way of eliminating all the related heat and efficiency losses.

According to David Shipworth (Shipworth, 1999), co-generation can take place at either the building level or at urban district level. At the building level, co-generation produces energy using the waste heat from air-conditioning generators, refrigeration condensers or incineration facilities, but can be applied to any process which generates waste heat that would otherwise need to be vented.

At district level, industrial processes such as power generation can produce simultaneous electricity and heat, the heat captured can be used for industrial or domestic purposes.

Figure 8 shows the incremental difference in thermal efficiency between the use of thermal brown coal and cogeneration and their inverse relationship to carbon dioxide emissions.

In the case of commercial buildings, in-house emergency power generators can be designed for cogeneration and the heat can be used for ancillary heating functions such as hot water, space heating, swimming pool heating or wherever low-quality energy is required.

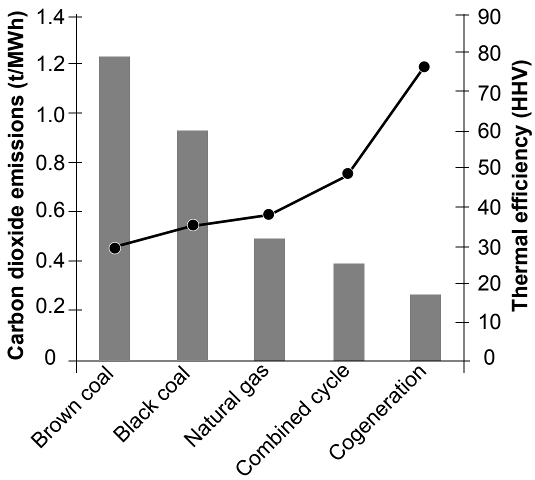

Figure 8. Electricity generation efficiencies
Source: Australian Cogeneration Association (ACA) (Roarty, 1999)

Recent research on heat co-generation as a potential source of energy from the photovoltaic cells is fast gaining attention and is likely to give a boost to the use of photovoltaics in buildings.

3.0 COMMERCIAL BUILDINGS AND USERS

Central to the success of any energy efficient strategy or technique is the requirements and role of building inhabitants. Users are at the forefront of the energy efficiency discussion, both in terms of the impact that energy efficient approaches can have on occupants and their productivity levels, and conversely how user attitudes and awareness of occupants have an important influence on the functioning of energy efficiency systems in buildings.

There is therefore a need to understand the behavioural dimension to assess user needs, demands, awareness levels and apathies regarding use and operations of the energy systems around them.

Three main themes will be discussed:

- Energy efficiency, indoor air quality and its effect on worker productivity
- Comfort bands and endurance
- Modifying user behaviour through involvement and awareness

3.1 Energy efficiency, indoor air quality and its effect on worker productivity

Energy efficiency has often focused on developing architectural solutions that provide both environmental and economic benefits. However it is becoming apparent that the design of buildings (or redesign in the case of retrofitting) can significantly impact on the success of comfort and lighting environments, with significant implications for the resulting worker productivity levels (both positively and negatively).

Through the careful design of specific solutions a designer (often working with specific consultants) not only has the ability to improve energy efficiency performance but also respond to occupant requirements and influence worker productivity.

A report released by the Rocky Mountain Institute (Friend, 1994) documents several cases in which efficient lighting, heating and cooling have measurably increased worker productivity, decreased absenteeism, and/or improved the quality of work performed. A couple of US examples include:

- Pennsylvania Power and Light cut lighting energy use by two-thirds with a lighting retrofit in their drafting department. This resulted in a 24% return on investment. Productivity also improved 13.2% with the improved lighting
- Lockheed Missile and Space Company cut the projected energy use of a new office building in half; the efficiency improvements added four percent to the cost of the building, which the energy savings would repay in four years. The results were a 15% decrease in absenteeism and a 15% increase in productivity – and those benefits "paid 100% of the extra cost of the building in the first year." (Friend, 1994)

More important is the issue of indoor air quality (IAQ). Research has indicated that the development of office spaces which are sealed from external air movements and internally conditioned can lead to a reduction in IAQ (Sick Building Syndrome). Inadequate design and/or maintenance of the heating, ventilation and HVAC systems, a shortage of fresh air, and a lack of humidity control gives the same result (Armstrong Laboratory, 1992). This again has implications for workers' health and productivity.

A 1997 joint study between the US Department of Energy and LBNL found that the health status of the workforce has an immediate and direct impact on the national economy. They estimated total costs to the US economy as high as $168 billion/year, attributing $6-19 billion to increased respiratory disease, $1-4 billion to increased allergies and asthma, $5-10 billion to sick building syndrome, and a potentially huge amount, $12-125 billion, to reduced productivity (Solberg, et al, 2002).

Exacerbated by the use of modern building materials, furnishings and fabrics, and cleaning products, which emit Volatile Organic Compounds (VOCs), productivity implications of bad air quality on building inhabitants have increased.

This brings us to an interesting discussion on how the two requirements of providing a healthy indoor environment and achieving energy efficiency, can be used to complement each other.

A study by Rey et al (2000) attempts to take this approach and derives an optimum ventilation rate, which achieves high environmental indoor air quality while at the same time offering compatibility with high energy savings.

It was found that in commercial buildings energy savings are sometimes made through reduced ventilation rates, however this can also lead to a deterioration of the indoor air quality and may trigger a productivity loss. This suggests that ensuring high ventilation flows may be a smarter investment to obtain a desired quality of indoor air (and productivity). However it is also possible that ventilation rates are over-estimated and consume unnecessary energy. According to Rey et al, ventilation rates suggested by American ASHRAE standards didn't guarantee the dilution or elimination of pollutants; on the other hand, flows based on the European norms Pr ENV 1752 were excessive. The optimum ventilation rate suggested by this study is an intermediate value conducive to both a better indoor air quality and low energy consumption.

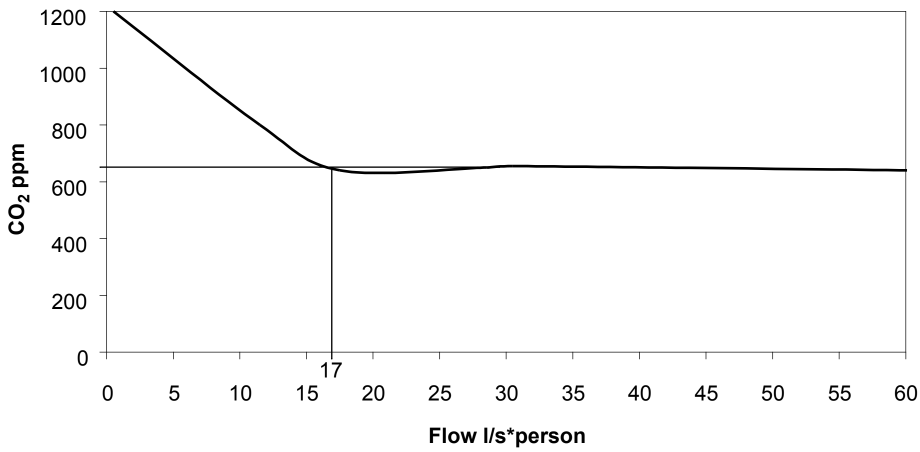

Figure 9. CO_2 Concentration in terms of flow/person
* (Assumptions: 7 people/100 sqm is used as the occupation factor, VOCs=5.5ppm, CO_2=645ppm)

The study suggests that there is a ventilation flow rate after which no matter how much more the flow is increased, the CO_2 ppm (part per million) concentration practically no longer decreases, (Figure 9). It therefore suggests a ventilation rate of 17litres/second per person in office buildings for a 0% smoker space is optimal.

Figure 10 illustrates possible savings by using the optimum ventilation rates.

An additional issue, which must be considered when trying to maximise worker health and productivity in relation to indoor air quality, is the issue of commissioning. It has been found that the majority of off-gassing (releasing high levels of VOC's) occurs in the very short period upon completion of building, fit out, and furnishing.

However, occupants are, in fact, much more tolerant than first realised. It has been found that users will accept a wider range of comfort parameters where passive strategies are involved that allow for individual control. A break from this traditional definition may provide 'endurance' for a broader comfort range, and the potential development of greater passive space conditioning.

3.3 Modifying user behaviour through involvement and awareness

One final way that users' needs and attitudes can influence energy efficiency is in their levels of consumption and patterns of behaviour. There is a surprising range of energy conservation measures that individuals can undertake using the same building and/or equipment.

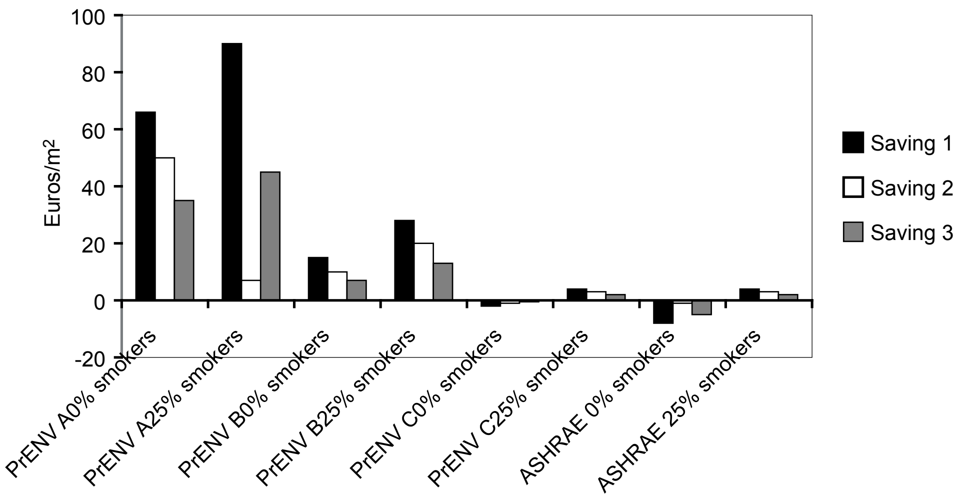

Figure 10. Possible Energy Saving in ventilation (Euros/m^2)

The VOC concentrations decrease over a period of time and therefore it is advisable that a safe time-gap between commissioning and occupancy should be allowed and an effective clean-up method should be carried out, particularly in buildings with a controlled and sealed environment.

The normal practice of a 24-hour clean-up by automatic-ventilation system in the buildings is not effective enough to reach the acceptable levels of VOCs. During the early stages of occupancy or before occupancy, it is highly advisable that a high rate of ventilation is maintained, assisted with high indoor temperatures (around 30°C) to release and flush out the VOCs from the building.

3.2 Comfort bands and endurance

A major barrier in the adoption of passive design strategies has been a misconception of occupant 'comfort'. For many years comfort in commercial spaces has been defined by the use of quite narrow range temperature and humidity set points, primarily related to mechanically conditioned indoor environments.

One way to influence behaviour is through the user's involvement in the early design and planning stage. It has been found that occupants are more likely to maintain a commitment towards energy efficiency, or any other green goals throughout the life of the building if they are involved and informed about the strategies that are integrated into a development. Workshops can involve users into the design process and integrate some of their preferences, requirements and ideas.

James Scott Brew reports Northland College involved students and faculty members early in the design process of their building. This strategy proved to be successful in developing a strong follow-through in their commitment to a 'green' building (Brew, 2002).

Another important aspect to successful user inclusion of energy efficiency strategies is that of *awareness, accessibility* and *operability.* It is important to consider the users needs and awareness levels in the design of any system. It has been found that some energy efficient strategies have been defeated by the end user through a lack of information on their use, leading to the occupants drastically reducing their effectiveness.

Some of the issues that create gaps between energy conservation strategies and actualised energy efficiency are as follows:

- Misuse and casual use of energy efficient devices
- Improper use of passive initiatives
- Hard to comprehend and hard to use ‘smart’ devices
- Inability to control, monitor and manage systems
- Inability to disseminate the building use protocols amongst the users

The above issues can lead to users overriding automatic or smart control systems, or the incorrect operation of passive control elements (such as the opening of windows at the wrong time).

This indicates the need for effective building commissioning and management as well as the effective induction and instructing of end users. Whilst traditionally these roles fell outside the responsibility of the architect, it is becoming apparent that for the success of such energy efficient strategies, a more integrated approach is required (see Section 4 about the importance and scope of this integrated approach).

The use of a building operations manual is often insufficient to promote correct behaviour practices. In many cases induction training, adequate signage and instruction, and the use of a building energy manager may be a better influence for staff education and behavioural change.

4.0 INTEGRATED EXERCISES AND BENEFITS

Involving an energy efficiency agenda into architectural projects does add an increased level of complexity to the overall design process. It is being recognised that a more ‘integrated’ process is required if initial energy efficiency goals are to be realised in the final built form. It is important that a more holistic approach be taken including the formal setting of energy efficient goals, identifying key technology options, accurately testing alternative strategies, seeking and integrating appropriate consultant advice, as well as ensuring a consistency of documentation, construction, and commissioning practices. In reality, influencing building management, maintenance, and occupation phases is also required.

The conventional design process involves an array of ‘oversimplified’ arrangements between clients, architects, engineers and other role players. However in relation to energy efficient projects it is reported “the conventional design process is not generally capable of delivering the high levels of broad-spectrum performance that is required in many contemporary projects.” (Larsson, 2002).

Therefore, any discussion about achieving energy efficiency in commercial buildings must include acknowledgement of the requirement for a synergy and management of these issues from the outset of the design. The Integrated Design Process is a new approach that holds particular significance, which has been developed to ensure high performances in ambitious projects pursuing ‘greenness’.

4.1 Key elements of an integrated design process

Most of the design decisions are made early in the process and their repercussions occur throughout the life of the building. These early design processes are therefore the most crucial in establishing a goal and forming a vision to carry out the goals (Figure 11). These form the basis of an IDP.

“Integrated Design Process is a collaborative process that focuses on the design, construction, operation and occupancy of a building over its complete life cycle. The Integrated Design Process is designed to allow the client and other stakeholders to develop and realise clearly defined and challenging functional, environmental and economic goals and objectives.” (Larsson, 2002)

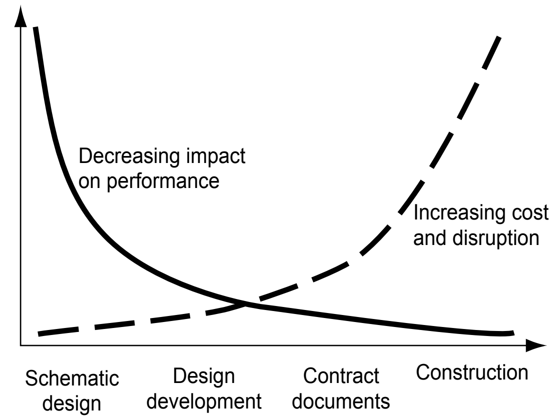

Figure 11. Significance of early design stage for final performance (Larsson, 2002)

As per Larsson (Larsson, 2002) the key elements of an IDP are identified as:

- Inter-disciplinary work between architects, engineers, costing specialists, operations people and other relevant actors right from the beginning of the design process;
- Discussion of the relative importance of various performance issues and the establishment of a consensus on this matter between client and designers;
- The addition of an energy specialist, to test out various design assumptions through the use of energy simulations throughout the process, to provide relatively objective information on a key aspect of performance;
- The addition of subject specialists (e.g. for daylighting, thermal storage) for short consultations with the design team;
- A clear articulation of performance targets and strategies, to be updated throughout the process by the design team; and
- In some cases, a design facilitator may be added to the team, to raise performance issues throughout the process and to bring specialised knowledge to the table;

“In the simplest of terms, IDP involves a synergy of skills throughout the process, involves modern simulation tools, and leads to a high level of synergy of systems” (Larsson, 2002).

4.2 Significance of IDP for energy efficiency goals

An integrated design exercise for energy efficient goals assists in identifying key variables for energy efficiency at the outset of the building design. However ideally this can be manifested only with the help of a tool that can translate the early design decisions into energy units and assist in decision-making.

4.2.1 Early design decisions

Early design 'charretts' and workshops can be excellent launching pads for energy efficiency goal establishment, by involving clients and users, mechanical and electrical engineers and other specialised consultants from the outset.

Energy goals can be translated into reality by involving modern simulation and other decision-making tools, a skilled engineer and an energy analyst. Often a cost analyst should also be involved to catalyse the decision-making. A coupled action of a cost analyst and the energy analyst may allow a live analysis, that enables immediate decision-making in light of the energy and cost savings of different options.

All this may result in an efficient design in terms of functionality, service intensity and comfort plus monetary gains in terms of unaffected capital costs, lower energy consumption costs and lower maintenance and management related costs.

Often the repercussions of decisions will be realised throughout the life of the building. This means that decisions that seem trivial amidst others should be integrated and prioritised early in the design to enjoy its benefits later in the life cycle of the building. IDP offers to do that.

The issue of end-use in the building is an example of this. Energy as a resource is of varying qualities and various fuel types differ in quality because of their end-use capabilities and/or the emission factors. As per Amory Lovins *(Lovins et al, 1999)*, "… people don't want megawatt hours of electricity, they want the services that energy ultimately provides."

By having an IDP, appliances and services can be matched with the right fuel type early in the design process and can have long-term effects on the energy efficiency statistics.

4.2.2 Role of energy analyst

What makes an IDP worthwhile from an energy efficiency point of view, is the role of the energy analyst and the energy performance workshops.

One of the jobs of the energy analyst is to dispel misconceptions about strategies that are thought to be significantly energy efficient but only yield small energy savings. On the other hand, other measures often ignored might prove to have significant, cost-effective savings (Henderson et al. 2001 as in Ehret, 2002).

Typically an energy analyst should establish certain parameters for the energy efficiency scheme. Some of them are suggested here:

- Energy efficiency goals: the client and design team should have a clear understanding of what the project is striving to achieve. Sample goals could be the reduction of energy costs and greenhouse gas emissions by 30% or that the building achieves a 5 Star Australian Building Greenhouse Rating (ABGR).
- The capital budget and required rate of return (or payback period) for energy efficient design options.
- Reporting and evaluation process: the design team should agree upon a reporting and evaluation process, whereby opportunities for energy efficiency are considered and compared to traditional design measures and technologies (known as 'business as usual') on a life-cycle basis.

4.2.3 Influence on post-construction stages

An integrated design approach can establish the right linkages between the designers, service engineers, occupiers and building managers. Ideally an IDP should result in a thorough documentation of the energy systems which reflects the decisions as the systems gradually develop. This documentation should also facilitate cohesion between the envisioned ideas of designers, client and engineers as to *how the system can reach its maximum efficiency*. This can then provide the basis for an efficient building management system.

Energy efficiency goal realisations are particularly sensitive to the post-construction commissioning and management practices. The following section therefore highlights the significance of post-construction stages for the design team, and discusses some key variables of a successful commissioning and building management.

4.3 Commissioning, management, monitoring and maintenance of energy systems

Central to the success of energy efficiency measures is correct commissioning, a good management control system with the appropriate monitoring systems and maintenance schedules.

Building commissioning is crucial to ensure that energy efficiency measures perform as intended. By performing various tests, commissioning assesses parameters such as air-tightness, indoor air quality and the working efficiencies and systems' compliance with environmental performance guidelines.

Similarly an effective building management system is necessary for continual performance delivery, evaluation, fine-tuning and performance improvement. Maintenance schedules and monitoring should also be incorporated in the management system. Generally a building management system should incorporate the following aspects:

- An automated system and control measures for various building services and systems
- Operational manual and protocol to inform and involve inhabitants
- A maintenance schedule and strict conformity with the schedule

- Short-term and long-term goals and benchmarks
- An energy audit system
- Annual certifications (such as ISO 14001) for energy/environmental standards.

At this juncture, the need to involve an energy manager is evident. The role of an energy manager is to ensure that all components of the management system are efficiently working as intended and to look for any opportunities that may enhance the system's efficiency. An energy manager is also the main force behind the development of training for efficient use of the systems. A monitoring program of peoples' behaviour and usage patterns led by the energy manager can assist in a better assessment of demand and trends.

Maintenance often emerges as the most crucial part of the overall performance of the system. This is because there are some components that may be detrimental for an energy efficiency vision if not maintained properly. Therefore often systems need nothing more than a well-designed maintenance scheme.

In systems such as heating, cooling, mechanical ventilation and hot water provision, maintenance is a significant factor for obtaining the 100% efficiency that the system is designed to provide. Owing to their size and extent these systems are similar to monsters in buildings, highlighting the need for maintenance, which increases the life of these irreplaceable systems.

In the case of lighting fixtures, the light output of most light sources falls off with use, called lumen maintenance or lumen depreciation. In such scenarios a lamp might consume the same amount of energy but its effectiveness might be halved *(Mclean, 1995).* Such installations may need frequent maintenance and cleaning in order to maintain the initial efficiency.

Use of controls to regulate maintenance schedules can be very effective. Melbourne-based Selby Biolab has taken on a range of infrared measuring equipment 'AVIO TVS 600' to detect potential problems with electrical equipment and mechanical heat loads such as faulty bearings valves of the cooling, heating and other equipment. This allows for timely maintenance due to notification of possible problems. Such control measures are a boon for building managers to detect the source of any problems.

Although the benefits of an IDP are indisputable, what may still be a barrier is the lack of in-house skills in many architectural practices. A Design Advisory Program (DAP) developed in Canada revealed that amongst many other needs, there was a prominent need from the architects to have access to services such as:

- modelling of energy usage and energy cost savings for design options;
- capital cost estimates resulting from design options;
- design improvements without major demands on in-house staff or budgets;
- training;
- new rules of thumb for design;
- guideline details and manuals; and
- mechanical/electrical performance specification for design/build projects.

(Bach et al, 2002)

5.0 SUMMARY

This Note explores some technological and user-related issues that influence the energy efficiency in commercial buildings. It must be stressed that the knowledge of technologies and awareness of user issues can only really be converted into realistic benefits with an associated holistic or integrated design process. This note describes the key elements and highlights the benefits of an IDP. The issues related to the management and maintenance of the building are discussed for inducing the desired level of awareness amongst design professionals so that an IDP can result in a synergy of design, construction and post-construction stages and can aid a common vision.

The following section captures some of the essence of the Note.

IDP emerges as the key to the establishment and accomplishment of energy efficiency goals. It is this process that offers fragmentation and integration of many green decisions and actions. IDP should also, from the outset, identify and prioritise green and effective actions.

Selection of the most appropriate technological strategy should be based on the correct assessment of occupants' issues and demands. The target should be to deploy technological solutions only to cater for the desired level of service and nothing more than what is demanded.

Users' behavioural studies and trends should provide occupants with the opportunity to manage their own surroundings in terms of control strategies for temperature and lighting.

Commissioning and management should be given due responsibility for the realisation of the goals. An integrated design exercise should, as a by-product, deliver an efficient management system.

A general awareness program for staff and occupants should also be integrated in the management system, to make them aware of the energy saved from simply turning off power supplies where they are not needed.

Control systems, maintenance and monitoring should be an integral part of the building management system. Effective controls contribute a great deal in optimising energy usage. Small measures such as placing the temperature sensors at a general temperature area rather than near the sunny window or heated area to get a more accurate measure of the current temperature is only possible through a tight management system.

Technology will advance rapidly in coming years and so will the user's needs, however what is central to a continual energy efficiency vision is an integrated approach that will bring together the various strands of technologies, user aspects and management issues.

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