ASSESSING SUSTAINABLE ADAPTATION OF EXISTING BUILDINGS TO CLIMATE CHANGE

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ABSTRACT

Adaptation to climate change is emerging as one of the main requirements for existing buildings in satisfying the environmental performance criteria of sustainability. Impacts from climate change will require buildings to perform satisfactorily in varying environments but this is a dynamic process that demands an ability to adapt performance in response to constantly varying conditions. Much of the existing commercial building stock in Western Australia has the ability to adapt to varying conditions such as climate change, which provides some potential for reusability and thus sustainability. However, there are many issues involved including what impacts climate change will create and how to balance occupant needs with considerations of adaptive reuse. As a first step in identifying opportunities for adaptation of existing buildings, the link between adaptation to meet the demands posed by climate change and adaptation that addresses other factors of change is discussed. Current sustainability assessment systems tend to be relevant for new construction only and focus on economic and environmental aspects of sustainability to the exclusion of social criteria. National Australian Built Environment Rating System has taken a step towards addressing this gap by considering the influence of occupant behaviour on performance. The paper forms part of a work in progress to extend the current body of knowledge into sustainable adaptive reuse of the existing building stock.

Keywords: sustainability, existing buildings, adaptability, climate change, NABERS.

INTRODUCTION

European researchers agree with CSIRO and the Australian Bureau of Meteorology that the number of very hot summer days in some Australian cities could double by 2030 and summer heat waves will be common in Europe by the end of this century. Australia has already warmed by about 0.8°C since 1950 and the Bureau of Meteorology recently announced that 2003 was Australia's 6th warmest year since 1910, with the global average temperature being the 3rd warmest since 1861. The hottest year, both globally and in Australia, was 1998 (Hennessy 2004). The global climate is changing significantly (IPCC 2001, Fry 2004) and producing widespread impacts. Australia is particularly vulnerable to climate change because it is already a generally dry continent which experiences high natural climate variability (Australian Greenhouse Office 2003). There is a general view that some form of adaptation may be able to reduce climate change impacts on the built environment (Camilleri et al 2001, Hertin et al 2003, Larsson 2003, Liso et al 2003, Steemers 2003, Lowe 2004

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and Rousseau 2004). Adaptation is also considered to be an effective strategy to improve the sustainability of existing buildings (Brand 1994, Pickard 1996, Ball 1999, Kohler 1999, Latham 2000, Cooper 2001, Kohler and Hassler 2002, Douglas 2002, Gregory 2004). This strategy is firmly supported by Rovers (2004) with the justification that the existing building stock has the greatest potential to lower the environmental load significantly within the next 20 or thirty years. However impacts from climate change will also require changes to construction of new buildings (Sanders and Phillipson 2003) but this would be less challenging than retrofit of existing buildings. In fact adaptation of existing buildings is seen to represent a major challenge particularly in assessing a structures vulnerability to climate change (UKCIP 2001).

This paper reviews the predicted changes in climate that are significant to buildings in Western Australia and how adaptation may help to combat them. The Australian assessment system NABERS is described and the initial findings of a user survey carried out by the Australian Department of Environment and Heritage are presented. The detailed survey results will be released for publication at a later date than COBRA 2004, therefore at this stage, permission has been granted to reproduce only a brief summary of comments from users. The aim of this paper is to establish how effective NABERS is in assessing the environmental performance of existing buildings and particularly impacts related to climate change.

ADAPTATION

Adaptation refers to any adjustment that can respond to anticipated or actual consequences associated with climate change. Significant challenges exist in developing adaptation strategies, due to uncertainties in climate change science (Lowe 2001, Sanders and Phillipson 2003, Fry 2004) and difficulties in ascertaining necessary timeframes for adaptation, and institutional barriers to adaptation (Australian Greenhouse Office 1999, Fry 2004). According to (O'Donnell 2004) for example, owners of older buildings often see no benefit in adapting buildings to green standards and in fact green buildings are often considered a luxury (Sanders and Phillipson 2003). A view not shared by (Brand 1994, Pickard 1996, Ball 1999 Latham 2000, Douglas 2002 and Gregory 2004) who see how, in environmental terms, many older buildings have characteristics that make them more adaptable and resilient. Despite this there are problems in developing strategies for older buildings that revolve around producing assessment systems that can identify the necessary changes. Over the next decade the commercial building sector will need to recognise and address particular greenhouse concerns. This expanding sector with fast-growing emissions can significantly contribute to meeting Australia's greenhouse gas reduction target and simultaneously improve the comfort and health of all Australians in their built environments. The Australian Greenhouse Office believes that all members of the building industry will play an active role in meeting the challenge to slow global warming (Australian Greenhouse Office 1999). The growth of commercial buildings has also created an increase in the amount of vacant commercial buildings in the Perth CBD. As this trend appears to show little sign of changing it may force building owners to contemplate adaptation of their buildings for alternative uses (Property Council of Australia 2004).

According to Ashworth (1996) almost half the output of the construction industry around the world is work associated with existing buildings. This is a result of a switch from new buildings to adaptation and rehabilitation of existing structures. Latham (2000) views adaptation as a process that reaps the benefit of the embodied energy and quality of the original building in a dynamic and sustainable manner. It is in fact viewed as a much more complex process involving economic, social and environmental change effects such as climate change and requires continuous adjustments as a result (Larrson 2003).

Kohler (1999) maintains that in industrial countries we should stop constructing additional new buildings, limiting ourselves to improve the existing stock. Older buildings certainly comprise materials that possess lifecycles potentially much greater than those actually realized during their initial occupancy. On this basis it could be argued that they are therefore durable particularly as the structural elements are often capable of delivering their design performance for several lifetimes. The importance of this trend is that adaptation effectively extends the useful life of existing buildings by making them more durable (Douglas 2002, Lowe 2004, Larrson 2004). In making buildings more durable, adaptation enables them to perform over time and react to varying conditions created by internal and external agencies including climate change. In principle adaptation achieves this by applying minor or major works to a building to enable it to suit new conditions including new requirements brought about by climate change, a view suggested by (Steemers 2003, Larrson 2004). An integrated approach to extending the useful life of existing buildings should use adaptation strategies that combine durability and climate change initiatives. Integrating innovative measures with the requirements of climate change adaptation is seen as an immediate task for built environment research (Steemers 2003, Lowe 2004).

Adaptation has long been championed by forward thinking environmentalists because buildings represent not only the materials that enclose and decorate the space but also substantial embodied energy. Designing buildings for adaptive reuse factors time into the equation of sustainability but existing and most new buildings were only built to deal with the climate current at the time of building (Fry 2004). For a building to be truly sustaining it needs to endure and adapt to climate change incrementally over time (Steemers 2003). A pressure state response model of the impacts of climate change on existing buildings and a range of likely responses to combat them are shown in Table 1**.** It is apparent that many of the responses to combat climate change serve mitigation as well as adaptation requirements as described by Lowe (2001), Camilleri et al (2001) and Mills (2003). It also becomes clear that strategies for adaptation in response to climate change are also strategies that would be used to adapt buildings for a change of use or refurbishment (Larsson 2003). However measures taken at the design and build stage are cheaper and easier to incorporate than during subsequent adaptation schemes. The long lifespan of the existing building stock means the majority of it will still be in use between 50 and 100 years time. It is crucial therefore to develop policy and strategies that encourage early adaptation of existing buildings (Camilleri et al 2001). This view is supported by Steemers (2003) who indicates that unless the rate of building replacement or sustainable refurbishment is implemented building design and construction will have little role to play in tackling global warming.

Literature confirms that there is a big difference between what is built and what the user wanted or intended (Zimmerman and Martin 2001, Cohen et al 2001). The gap between theory and application relating to the specific questions of occupancy ideal and that which is built and operated needs to be identified. The gap is partly created by lack of feedback where in-use performance is evaluated in terms of performance

Climate Change	**Impact on Built Environment**	**Adaptation/Mitigation**
Pressure	**State**	**Response**
Reduction in air quality	More frequent use of mechanical filtration and ventilation Increased energy demand Increased emissions Sick building syndrome	Cleaner production Low embodied energy materials High efficiency natural filtration Reduce operating emissions of buildings Legislation
Increased temperatures	Greater use of air conditioning Increased energy use Increased emissions Power blackouts	Natural ventilation Insulation/Reflective materials High efficiency air-conditioners Ground coupling tubes
Increased solar radiation	Faster weathering of materials Higher expansion/contraction Quicker fading of colours Comfort levels affected High temperature build-up	Window tinting Reduced glazing area Reflective colours UV resistant materials Solar screening/shading
Increased heat island effect	Higher urban temperatures Increased water consumption Associated health problems Increase of smog levels	Increase landscape planting Reduce hard paved areas Install ponds and lakes Rooftop planting
Increased storms	Frequent damage to buildings Damage to transmission lines Dust storms Insurance claims	Higher wind loading codes Convert to underground power Better envelope/joint detailing
Increased rainfall	Flooding Stress on stormwater drains Stress on sewage treatment plants Penetration in to buildings Soil erosion Corrosion	Relocation of buildings Elevated sand pads Onsite rainwater storage Better detailing Reduce hard paved areas Larger gutters & drains
Increase of termites & woodborers	Reduced material life cycles More frequent infestation treatment Insurance claims/higher premiums	Reduced use of timber Physical barriers in lieu of chemicals More effective treatments
Reduced rainfall	Desertification Foundation problems Reduced water supplies Water restrictions Reduced water quality	Greywater/blackwater recycling Water efficient appliances Rainwater storage tanks Drinking water filtration Waterless urinals/toilets Excess water tariffs
Lower minimum temperatures	Increase in heating demand Increased emissions Increased energy use Condensation/mould	Wall/loft insulation Double glazing Solar powered heating Improved envelope detailing

Table 1 Climate change impact and adaptation PSR model. Derived from Australian Greenhouse Office (1999), Du Plessis et al (2003), Mills (2003), Camilleri et al (2001), Hertin et al (2003), Steemers (2003).

objectives (Steemers 2003). A key objective therefore is to address the building occupant both directly through user needs surveys and indirectly through the assumptions made about their current and future needs. Most existing rating systems in Australia are intended for use at the design and development phase. Whilst design is clearly of crucial importance, it is no guarantee of sound environmental performance during operation. It makes sense therefore to develop a rating system that is specifically designed for existing buildings that measures impacts including those of the occupiers during the operational phase.

AUSTRALIAN CLIMATE CHANGE IMPACTS

In Western Australia the strongest influences on climate are believed to be in the Indian and Southern Oceans. The dynamics of the Southern Ocean are unique and although not well understood are recognized internationally as a key driver in the global climate system (Kemp 2003). A model of how climate systems interact across Australia and its surrounding oceans would be a powerful predictive tool for long-term weather forecasting with implications beyond Western Australia. Potentially it will lead to better climate prediction across Australia and possibly the whole Southern Hemisphere (Bates 2003, Kemp 2003). The WA state government Indian Ocean Climate Initiative (IOCI) is aiming for greater understanding of WA's climate across seasons, years and decades. Improved national climate and drought predictability will also come from growing knowledge of major Southern Hemisphere weather patterns (Bates 2003).

Heating, ventilation and air-conditioning and lighting are seen as the three major impacts from climate change on existing and new buildings in Western Australia. They account for 84% of commercial building greenhouse emissions which is made up of cooling 28%, air handling 22%, lighting 21% and heating 13%. Building shell performance has a large impact on the heating, cooling and lighting efficiency of commercial buildings. Therefore improvements in the thermal, daylighting and natural ventilation performance will reduce emissions, lower energy consumption and lower cooling requirements (Australian Greenhouse Office 1999). Lighting was seen as the area with the most potential for emission reduction with up to 70% of the total being reduced. An important conclusion was the lack of significant difference in reduction potential between new and existing buildings with an average of 50% for each sector. This contradicts the view that demolish and rebuild strategies offer a greater opportunity to produce new more environmentally efficient buildings than adaptation. The opposite may well be the case and a program of extended use of existing buildings as a major component of a mitigation strategy is supported by Du Plessis et al (2003).

ASSESSING CLIMATE CHANGE IMPACTS

Effective adaptation to climate change depends on our ability to assess the potential opportunities and impacts.Current assessment methods tend to focus on factors of sustainability that exclude important criteria such as user needs and impacts from climate change which does not present a complete picture. Arguably, a single assessment system cannot be developed across all situations requiring sustainability assessment. It may therefore be necessary to use a combination of systems or devise a new mechanism to provide integrated social, economic and environmental information for decision makers (Steemers 2003, Rousseau 2004 and Lowe 2004). There are very few examples of where truly integrative sustainability assessments have been undertaken. The National Greenhouse Strategy is being developed in Australia to provide an integrated assessment of climate change impacts and sectoral adaptation strategies. As part of this initiative a national framework will develop strategies and actions to support adaptation to climate change (NGS 1998).

Of the many existing methods that can be adapted for sustainability-based assessment, no single preferred model has emerged from worldwide studies. The origins and intents of systems around the world differ from tools intended for use at the design stage to post occupancy evaluation tools. The National Australian Built Environment Rating System (currently being commercialised) is a performance-based rating system that measures the overall environmental performance of existing commercial office

Show instructions

Show technical background

NABERS Whole Building

Occupant satisfaction

This table shows the sum of the results of the occupant satisfaction survey

view /add survey results

	average of survey results
THERMAL COMFORT	
Overall temperature satisfaction	
How cold it gets	
How hot it gets	
Temperature shifts	
thermal comfort score	
VENTILATION COMFORT	
Overall ventilation satisfaction	
Air freshness	
Air movement	
Draughts	
ventilation comfort score	
NOISE	
Overall noise satisfaction	
Office noise (voices and office equipment)	
Noise from air-conditioning and lighting systems	
Noise from outside the building	
noise score	
VISUAL COMFORT	
Overall lighting satisfaction	
Level of light at your desk	
Glare from lights	
Glare from windows	
visual comfort score	
HEALTH	
Sore eyes	
Headaches	
Runny nose	
Dry throat	
Dry or irritated skin	
Lethargy	
Dizziness	
Nausea	
health score	
TOTAL SCORE	

Table 2 NABERS Occupant Survey. Source Department of Environment and Heritage (2004).

buildings and residential homes during operation. NABERS is built up from a series of separate environmental indicators. Each of these has its inputs on an individual worksheet within an Excel workbook as shown in Table 2. NABERS rates a building on the basis of its measured operational impacts including energy, refrigerants (greenhouse and ozone depletion potential), transport, water use, stormwater runoff and pollution, sewage outfall, landscape diversity, waste and toxic materials, indoor air quality and occupant satisfaction. To start the process data is filled in into each of the individual worksheets. Once completed the scores for all of the worksheets are summarised in the summary sheet and the overall score is calculated. Each worksheet has instructions describing how to gather and enter data for that worksheet. Background as to why the environmental issue dealt with in the worksheet has been included and the rationale of the scoring system are also included. Help in relation to individual data inputs is obtained from drop down text boxes in each cell of the spreadsheet. The environmental impact performances are based on a scale of 1 - 5, where 2.5 is the benchmark average. This average in based on, where possible, measured Australian averages.Individual scores from these environmental impact categories are amalgamated ultimately into a single score out of ten - where a low score represents the worse end of current practice, a score of five represents current average practice and a score of 10 represents world-beating performance. Almost all office buildings can rate on this scale, providing immediate recognition of poor performers and good performers in the current market, while also providing targets for national and international best practice.

DISCUSSION FROM USER SURVEYS

In requiring the collation of data relating to the operational aspects of an office building, not the design or construction aspects, NABERS is relevant to existing buildings. Incorporation of the Australian Building Greenhouse Rating System in the energy and greenhouse emission assessment categories is supported by most users and considered appropriate. It was felt that because assessment is based on actual performance it contributes to rigour and reliability of the rating tool. Occupant satisfaction provides a method of evaluating the social impact of a building which most other assessment methods do not consider. The assessment method is most useful for building owners and facility managers responsible for sustaining existing buildings. By being performance based the system fills a significant gap in the decision support tools available for asssessing environmental impacts of buildings.

The system does not cover all environmental impacts but the present choice of indicators is supported as there has to be balance between the number chosen and the usability of the rating system. NABERS significantly contributes to assessing the gap between what is designed and actual environmental performance. Users felt there was a need for a review process to ensure ongoing improvement in benchmarking as more data on actual performance is collected. There was overall support for the fact that a poor score in any one area cannot be compensated by a very high score in another category. One criticism was that important links between categories such as water recycling and sewer discharge reduction meaning the system does not recognise the synergies of more integrated approaches. However the Australian Department of Environment and Heritage, developed the system in consultation with industry and other stakeholders, considers that such links are indeed recognised. For example, a building that recycles water will obtain credit in its score for water use as well as sewage outfall volume.A second criticism was that assessment against current averages does not correspond to the initial aim to set aspirational levels of environmental performance. In response, DEH feel that NABERS is directed at the existing building market which is by defintion average. It therefore adopts the philosophy that there are greater environmental gains to be had if all buildings, which are below average, become average rather than improving buildings that are already good performers.There was general support that NABERS avoids trade-offs between different envrionmental impacts by using a cumulative methodology with credits for separate categories. Energy and greenhouse scores seem to be more highly weighted than the others but DEH state this was done to reflect agreed headline environmental priorities in Australia. Global warming, energy consumption and ozone depletion are covered but what about other environnmental impacts? The range of impacts was intentionally limited by DEH and based on perceived priorities and was also drawn around what could be assessed on site. Concerns were expressed about including occupant surveys as a way of measuring performance because of the influence of personal issues on the way people respond. It was felt that some occupants may be unhappy with their current situation or even take a dislike to answering survey questions. Both would skew any realisitic assessment of environmental performance. These problems have been recognised but occupants are considered to be an essential component of the stakeholder framework. The DEH response was that the use of surveys is well understood and accepted in the field of building science. An essential element underpinning the NABERS philosophy is that buildings are not merely engineering problems; they are fundamentally human systems.Building users are one of the key target audiences for a tool like NABERS and none of ther surveys affect the base building rating.

The system is adaptable to most Australian regions and spreadsheets were generally considered to be user friendly. NABERS should eventually provide feedback leading to better building management and design principles. The basis of scoring for indicators does not appear to be consistent as it is linear for some components and non-linear for others.The weighting factors used to aggregate indicators to a single value which were not clear or explained in the original version of NABERS have been updated for better understanding. The numbers of existing buildings are significant, it would therefore be useful if a tool such as NABERS was available in a simpler form to allow a first cut assessment of the building asset portfolio. This would enable large portofio holders to highlight areas of poor peformance at a glance and identify key problem areas before using a more detailed version. This was recognised by DEH and there is potential for NABERS to be used in a modular way to limit the key impacts being considered and focus on areas that are considered most important.

CONCLUSION

The paper has identified that the built environment in Western Australia is experiencing significant impacts from climate change and that the commercial building sector is a significant contributor to the change. It has also shown that despite the variability, climate change and the degree to which it will affect the sustainability of existing buildings can be predicted with a reasonable level of confidence. Strategies such as adaptation can enable buildings to be more sustainable because they help to meet changing conditions over an extended lifecycle. The research supports the argument that these same strategies should be linked to adaptation processes that help buildings to perform under the new conditions imposed by climate change. However, assessing the performance of existing buildings presents problems in itself. Current assessment systems do not provide a full profile of sustainability because they tend to exclude input from building occupants. The NABERS assessment system includes occupant surveys as part of the assessment process and therefore addresses this problem. A periodic review of the environmental indicators will be essential to keep the system up to date with current research. If commercialised by another party the government and other relevant agencies should continue involvement in ongoing develoment of the system. To ensure long term viability the management of the system should include realistic performance targets for market uptake of a voluntary program. The voluntary nature of NABERS means it may only appeal to those already commited to environmental practices therefore its use should be encouraged using an incentives program.The organisation carrying out commercialisation of the system should ensure they have a process in place for this. The literature review in conjunction with the survey has highlighted several broad questions concerning the NABERS assessment method and adaptation to climate change. These will be addressed in greater detail once the analysis of the user surveys carried out by the Department of Environment and Heritage is available.

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