Abstract

The continuing degradation of the environment is a cause for considerable concern. In response, environmental rating systems have been developed and a number are in use or in development in Australia and elsewhere. The general trend has been towards the development of rating systems as design tools. However, there appears to be a gap between predicted environmental performance and actual performance – particularly in the case of energy consumption, an easy to quantify metric. NABERS (the National Australian Building Environmental Rating System) was developed for Environment Australia in 2001 to serve as a reporting tool. It was designed for use by non-specialist assessors in order that a large number of buildings in Australia could be rated. As a consequence, some of the metrics adopted shared the failings of design-oriented rating systems – they are qualitative and therefore not necessarily indicative that desired environmental outcomes were achieved.

Consequently, NABERS is now being reconfigured to provide, to the greatest extent practicable, quantitative measures that do demonstrate good environmental outcomes. This paper outlines the approach taken, in relation to commercial buildings, for two built environment indicators of environmental impact: biodiversity and indoor air quality.

Keywords: Building environmental rating, biodiversity, indoor air quality, Australia.

1. Introduction

Building environmental rating systems have been developed to assist in the procurement of low environmental impact buildings. Given the continued deterioration of the air, water and soil quality and the depletion of resources this is becoming an increasingly pressing need. However, most rating systems are intended for use at the design stage and therefore are based on assumed best practice in relation to energy, water, site use, materials and sometimes design and construction processes.

An alternative approach was adopted by Environment Australia in the development of the National Australian Building Environmental Rating System (version 1, 2001) [1]. This was intended to be a reporting system in which existing buildings would be rated using, as much as possible, actual performance data. It was designed to allow non-specialist assessors to rate buildings with the intention that a large number of occupiers of residential and commercial buildings would be able to rate their own buildings. The disadvantage of such a system is that non-specialists are not able to undertake complex measurements or analyses that will deliver a rigorous, scientifically

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defensible result. Environment Australia decided to further develop NABERS into a more rigorous system [2]. The issues to be measured include energy use and greenhouse emissions, refrigerant use (greenhouse warming potential and ozone depletion potential), water use, stormwater runoff, stormwater pollution, sewage outfall volume, landscape diversity, toxic materials, indoor air quality, transport, waste and occupant satisfaction. Through a discussion of two of the issues, landscape diversity and indoor air quality, the development of quantitative measures is explained.

2. Landscape diversity

While the intention of a building environmental rating system may be to maintain or promote biodiversity it is usually landscape diversity that is addressed by focussing on flora rather than fauna. Therefore, while the discussion commences with biodiversity, it is landscape diversity that will be measured. “Biodiversity can be most simply defined as the variability of life, from the minute genetic level through to the large scale of an ecosystem. The existence of the human race is dependent on the interactions of all forms of life, and by extension, on diversity.” [3]

Australia is a megadiverse country. It has the world’s second highest number of reptile species, the fifth in flowering plants and many species of birds, mammals, reptiles and flowers are found only in Australia [4]. It is estimated that there are 290,000 species of flora and 200,000 species of fauna in Australia [5]. However, colonial settlement of Australia over the past 200 years has resulted in biodiversity decline and this must be reversed if the risk of environmental, social and economic [6] decline is to be reduced.

The 2001 State of the Environment Report notes that: “Studies of the urban environment and biodiversity in urban settings are important if these components of biodiversity are to be sustained...Because most Australians live in urban environments, increasing awareness of biodiversity and the role of individuals is essential” [7]. However, scientists work mostly on non-urban agendas and “…the notion that cities themselves are inherently linked to the natural systems that govern life on earth” has not been perceived until recently as part of the environmental agenda.

Greenbie suggests that applying an ecological definition of sustainability to urban communities might be viewed as an oxymoron. He notes that urbanisation destroys natural phenomena and processes and has ecological impacts far beyond the urban fringe [8]. This is embedded in the notion of the ‘ecological footprint’ [9]. Therefore, biodiversity is very relevant to the built environment since it displaces natural habitat, alters water flows and in its construction and operation pollutes water, land and air. There are opportunities to improve biodiversity, even in relatively dense cities. An alternative view is that increasing urban density while reducing opportunities for local biodiversity may protect land of medium to high ecological value from development.

2.1 Biodiversity in existing rating systems

The National Australian Building Environmental Rating System 1 (NABERS I) [10] was developed for Environment Australia in 2001. Building on brownfield sites was rewarded while building in areas of high value flora and fauna was not. Reducing the footprint of the building on the site, usually by increasing density, was rewarded as
was planting native flora – the greater the percentage of the site area, the greater the point score. Finally, providing permeable surfaces was rewarded so as to charge ground water aquifers and to support flora and fauna on the site – the smaller the percentage of impermeable paving, the higher the point score.

The US system LEED EB Version 2.0 (Leadership in Energy and Environmental Design – Existing Buildings) addresses biodiversity by rewarding reduced site disturbance and green site and building exterior management. The UK system, BREEAM (Building Research Establishment Environmental Assessment Method), has been developed for a number of building types including industrial units, houses, eco-homes and offices. Land Use and Ecology are given credit points by addressing three issues: the ecological value of the land, the change of ecological value of the site and the effective use of the building footprint.

NABERS 1, LEED and BREEAM take a similar approach to the rating of design strategies aimed at maintaining or improving biodiversity. They do not provide a measure of biodiversity but instead rewards practices that increase the likelihood of maintaining or improving biodiversity locally or remotely.

2.2 Landscape diversity in the proposed rating system (NABERS II)

There are few agreed means of measuring biodiversity, and no scientifically validated systems were identified at the scale of the individual building site. Neither is it practical or possible to produce a complete biodiversity inventory for a particular site – particularly for a commercially viable biodiversity rating system intended for the property sector. Instead, surrogate measures for biodiversity are used by scientists, recognising that what is measured and how it is measured “reveals something about what you most value” [11].

On the basis of a literature review, landscape diversity is assessed on the basis of:

- the extent of local native cover, and
- the degree of spatial complexity of flora on the site.

Other important but less easily quantified issues will be addressed by means of NABERS Advisory Notes. They include environmental weeds, bird dispersed exotics, the provision of habitat in urban areas and built structures and building design attributes resulting in bird deaths and injuries. Other relevant issues are addressed elsewhere in NABERS. They include the use of pesticides and herbicides, pollution and human-induced climate change.

For most cities in Australia the original condition was forest or woodland having up to 3 layers of vegetation – ground cover, shrubs and trees, though in their climax state Australian forests comprise mostly layer 3, trees. However, for both urban and suburban sites it would not be feasible or even desirable to recreate the original forest conditions. Australian native forest trees are inappropriate for most urban and suburban gardens. They tend to be too large, many drop limbs and recent fires in urban areas of Australia have highlighted the danger of substantial native cover in urban areas.

Gardens, comprising native or exotic plants, or both, are highly managed systems maintained to varying degrees in a semi-mature state by pruning, irrigating, aerating, tilling, clearing and controlling using a variety of chemicals. Moreover, urban
settlements modify microclimate and water, soil and air quality. Urban landscapes, therefore, are cultural landscapes and cannot recreate pre-settlement conditions [12].

2.3 Measuring and rating landscape diversity in NABERS II
Two measures of landscape diversity were identified: the extent of local native cover and the spatial complexity of flora on the site [13].

2.3.1 Extent of indigenous native cover (B1)
This provides an assessment of the local native cover as a percentage of total site area. Indigenous native planting on the ground level, mid-levels, vertical surfaces and rooftop gardens will be included. Indigenous native cover will be calculated for ground cover, shrubs and trees.

2.3.2 Degree of spatial complexity in the landscape (B2)
Spatial complexity is the second surrogate measure for landscape diversity. Plant cover on rooftop gardens will be included. Vegetation will be assessed in three layers [14]:

- Layer 1  Lawn, ground cover or small shrubs<0.5 m in height
- Layer 2  Shrubs 0.5 – 5 m
- Layer 3  Trees >5 m

The theoretical “optimum” special complexity is based on the following distribution of layers:
1. 30% (approximately) of the area comprises single layers of flora (layers 1, 2 or 3),
2. 30% (approximately) comprises two layers (any combination of 1+2, 1+3 and 2+3), and
3. 30% (approximately) comprises three layers (1+2+3).

A formula embedded in a spreadsheet simplifies the calculation for the assessor. All vegetation, native, indigenous native and exotic, is to be measured. The areas of vegetation and the layer combinations are the attributes measured on site and form the data input for the calculation. A simplified measurement protocol not requiring detailed site measurements has been developed.

2.3.3 Rating landscape diversity
An integrated landscape diversity index combines the native cover and spatial complexity indices and normalises them to account for beneficial effects of urban density to produce a single index of landscape diversity. The result is a star rating between 0 and 5 stars where 0 stars represents unacceptable practice (little or no biodiversity associated with the development) and 5 stars best practice.
3. Indoor air quality

Poor indoor air quality affects occupant health as well as their productivity. More generally it influences feelings of well-being. Studies in the US, Australia and Finland, for example, demonstrate that reductions in worker productivity due to degraded indoor environments have a significant economic cost [15]. Certain groups are more vulnerable to pollutants than others: the very young, the elderly, those with pre-existing respiratory or cardiovascular disease or those who are sensitised to a substance. Studies have indicated that at any one time in commercial buildings, 15-20% of occupants report health problems attributable to the building (headaches, drowsiness and so on). ‘Sick building syndrome’ may be indicated when the figure is in the order of 40% or more [16].

A number of substances have been identified as contributors to poor indoor air quality [17]. The substances causing indoor air quality problems for humans are gases or particulates and they are either pollutants or allergens. Their health effects include, inter alia, headaches, tiredness, aggravation of asthma and allergic responses, cancer, organ damage and in some cases, death.

Pollutants and allergens may come from building materials, building operation and maintenance and the external environment. Their impact on human health is not only a function of their toxicity but also their concentration in the air. Thus dilution by means of adequate ventilation can reduce their impact on human health. However, increased ventilation rates may result in increased heating, cooling and ventilation energy requirements – resulting in increased greenhouse gas emissions. Safe concentrations of many pollutants have been estimated (i.e. by the Australian National Health & Medical Research Council) [18] and while they form a useful guide, it is clear from the literature that more research is required. The effect of many Volatile Organic Compounds (VOCs) remains uncertain, as is the ‘cocktail effect’ of the many indoor air pollutants.

3.1 Indoor air quality in existing rating systems

Indoor air quality in NABERS I was not measured quantitatively since it was expected that non-experts should be able to undertake the building rating. Consequently, NABERS I ratings [19] were based on deemed-to-satisfy provisions such as materials selection for flooring, finishes and fit-out, ventilation, environmental tobacco smoke (reward for not smoking) and cleaning (reward for use of central or high efficiency filter vacuum cleaning).

LEED addresses ventilation rates and effectiveness for both naturally and mechanically ventilated spaces, exposure to environmental tobacco smoke, CO₂ monitoring (with links to Building Automation System advised), construction management plans for construction and pre-occupancy phases, low-emitting materials (adhesives and sealants, paints and coatings, carpet and composite wood) and indoor chemical and pollutant source control. References are made to ASHRAE standards (for ventilation and CO₂ levels, for example), industry standards and so on. The architect or responsible person is required to sign a LEED Letter Template stating that the compliance standards have been met.

BREEAM gives credits for the use of natural materials such as solid timber, materials not containing lead or asbestos, for providing adequate ventilation and for
using particleboard and medium density fibreboard meeting British Standards. Airborne particulates and organisms including moulds and dust mites are not assessed. Existing systems are based on a mix of deemed-to-satisfy provisions and standards to be met though not on measurement of indoor air quality for a range of potentially harmful substances.

3.2 Indoor air quality in the proposed rating system (NABERS)
Based on the literature, a number of indoor air quality substances have been identified (these substances are named consistently in most reports [20]). These are:

Chemical

- Passive smoke, in tobacco smoking (generates fine particles, aerosols and VOCs)
- Respirable fibres such as asbestos, fibreglass and rockwool
- Combustion products such as nitrogen dioxide (NO₂) from gas combustion and carbon monoxide (CO) from car exhausts, cigarette smoke and combustion of some fuels
- Volatile Organic Compounds (VOCs), in new building products, consumer products, office equipment, cleaning products
- Formaldehyde, found in pressed wood products such as medium density fibreboard and some consumer products (formaldehyde is a VOC but is commonly treated separately in the literature)
- Lead, once used in paint and flashings in older buildings
- Ozone, from photocopy machines and ozone generators used in odour control
- Radon

Biological

- House dust mite allergens, in bedding, soft furnishings and carpet
- Fungi and moulds, from persistent indoor condensation, water entry to interior from leaks in building fabric, stagnant water
- Bacteria, such as Legionella, from cooling towers, spas, fountains and large reticulated hot water systems
- Pollen

Following industry and research sector consultations, a standard group of tests was determined. Some of the IAQ issues identified above were not relevant to commercial buildings or were addressed by existing regulations and so were excluded. Smoking within commercial buildings in Australia is no longer permitted for example. The tests, to be undertaken with the building occupied to typical levels, comprise:

1. Carbon dioxide (CO₂)
2. Carbon monoxide (CO)
3. Ozone (O₃) (measure in indoor air if concentrations in exhausts from office equipment)
4. Formaldehyde (HCHO)
5. Volatile Organic Compounds (TVOC & VOCs)
6. Respirable dust (where no filtration systems are present)
7. Airborne bacteria
8. Airborne viable fungi & mould

For each ranges from unaccepteable (0 stars) to best practice (5 stars) and average practice (2.5 stars) were established from Australian and international standards.

The tests are to be undertaken by environmental consultants. They are located in most capital cities in Australia and are capable of carrying out the air sampling and measuring. Where direct reading instruments are not used the samples will be sent to laboratories for analysis.

Buildings will score 5 stars if all criteria standards are met or exceeded. They will score 0 stars if any ONE or more of the 1 star criteria standards are not met. For all other cases, points will be awarded to each of the 8 measurement criteria according the category to which they belong. If CO₂ is measured within the range of 651-740 ppm, for example, the building will be awarded 4 points. This should be done for all 8 criteria and then the total score divided by 8 to get the final star rating.

4. Conclusion

Building environmental rating systems have been developed to assist architects and engineers at the design stage procure buildings having reduced environmental impacts relative to conventional buildings. Case studies of such buildings abound in the literature though very rarely is supporting data advanced. Often, lists of design strategies and equipment utilised but no performance data are the basis on which the claims are made.

Moreover, the rating systems utilise, with good intentions, best practice guidelines, national or international standards or arbitrary targets to which the designers are to adhere if the building is to achieve a good rating. However, evidence emerging indicates that buildings achieving good ratings at the design stage may perform below expectation. The aim of NABERS II, therefore, is to provide a rating system that can verify the performance of buildings in use and thereby provide a feedback loop to the building sector generally as well as national, state and local governments in Australia.

NABERS II uses performance measurables such as energy and water consumption. Electricity use is metered and factors are available to convert energy use into greenhouse gas emissions. However, for landscape diversity such measures do not exist. On the basis of scientific evidence available, surrogates were developed to rate the landscape diversity of buildings and their sites. Indoor air quality, on the other hand, can be measured and much is known about the substances that harm human health. Nevertheless, the cocktail effect of the interaction of many substances such as VOCs and the safe limits for them is not known conclusively. Therefore, as for landscape diversity, there is a significant element of expert judgement involved in devising rating measures and protocols. Despite the uncertainties, it is hoped that NABERS II will provide an accepted and reliable system for reporting on the environmental impact of Australian residential and commercial buildings.
References


[6] “The CSIRO estimates that the total annual value of ecosystem services within Australia is $1327 billion.” In Biodiversity Australia State of the Environment Report, p.5.


[12] Personal communication, Dr Andras Kelly, Landscape Architect, 15/05/03.


[15] The CSIRO estimates that the cost of poor indoor air quality in Australia may be as high as $12 billion per year. Refer also to Seppänen, Olli, (undated) *Criteria for Healthy Buildings*, Helsinki University of Technology, Finnish Society of Indoor Air Quality and Climate, downloaded 25/01/03, www.sureuro.com/helsinki/presentations/03_Seppanen_2pres.pdf.

[16] *Personal communication*, Dr Steven Brown, CSIRO, Melbourne, May 2003.


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