

Building Environmental Performance Assessment: Methods and Tools

Paul Downton



Figure 1: 30 The Bond, the first Green Star 5-star rated building in Australia (Image: DEXUS Property Group)

ABSTRACT

This note deals with the methods and tools for assessing the environmental performance of a building design in the early design phase of a building project. It describes building environmental performance assessment (EPA), explains how it is used in design, and points to a number of EPA modelling and rating tools that are commercially available in Australia, including energy performance tools, and life cycle analysis (LCA) tools.

This note, originally titled DES 33, was first published in May 2000. Its author was Peter Graham. It was extensively revised and updated by Paul Downton in November 2011.

Introduction

At the turn of the 21st century, Australia's mainstream building industry, in line with rising concerns about the increasing cost of energy and the impact of carbon emissions, began a belated move towards sustainability. Clients, regulatory and rating agencies began setting increasingly stringent environmental performance goals, and expected designers to possess the knowledge and tools to meet them.

Today designers must be able to identify a building's potential environmental impacts and determine whether the measures taken to deal with them will meet the expectations of their client and society. An environmental performance assessment (EPA) can empower designers to do this.

Environmental performance assessments provide a measure of the extent to which buildings might influence their environment, so that their design or operation can be altered to minimise harm and improve amenity. All EPAs are based on systematic procedures and verifiable data.

An EPA can be holistic, considering all aspects of a building through life cycle analysis (LCA), or partial, looking only at particular components or measures. It can be applied virtually, through the use of computer software models, or actually, through measurement of existing buildings in use.

EPAs tend to focus on energy related impacts but increasingly they include other environmental issues, such as water and biological system impacts.

Using EPA

Fundamentally, EPA is about assessing how a building works in relation to its environmental impacts. In using EPA, designers will be able to answer fundamental questions such as:

- What was the basis for environmental design decisions?
- What was the method of assessment?
- Have the environmental impacts of the consumption of materials, energy, water and other resources been considered?
- Will the energy embodied in the building be offset by savings in operational energy over the building's lifetime?
- What quantity of greenhouse gas emissions will be generated?

- Will the indoor environment facilitate comfort, health and productivity?
- Are environmental outcomes being achieved cost-effectively?

To get full benefit from EPA, the design decision-making process must be structured to enable inclusion of environmental information. The process of design is iterative and dynamic and limited by time constraints. EPA may increase the time and cost of design and require the inclusion of consultants prior to the design development phase, and allowance must be made for this.

Bear in mind, though, that an EPA process can deliver offsetting benefits, such as more integrated solutions

EPA challenges the traditional design approach of many sub-systems, and calls instead for an integrated team approach.

and better feedback to designers. For example, feedback to the architect on heating and cooling loads could lead to a redesign that cuts HVAC capital and operating costs. EPA challenges the traditional design approach of many sub-systems, and calls instead for an integrated team approach.

"A successful project...typically requires advocacy by the owner, and the leader of the design team, along with a 'buy-in' at minimum from other key project participants." (Bobenhausen and Witner 1998)

POSITIVE DEVELOPMENT – DESIGNED GENEROSITY

In response to the observation that humanity has exceeded the Earth's carrying capacity and that our "ecological overdraft" needs to be redressed, positive development has extended the horizons of assessment to propose that buildings can measurably increase the ecological base.

Instead of simply avoiding damage to nature, positive development seeks to add to the total of ecosystem goods and services and build in such a way as to repair and enhance ecosystems. It proposes that "the built environment can create the infrastructure, conditions and space for nature to continue its life-support services and self-maintenance functions" (Birkeland 2008). The most credible contender for an assessment tool that might encourage positive development is provided by the [Living Building Challenge](#).

See EDG note [GEN 4, "Positive Development: Designing for Net Positive Impacts"](#).

Owen (2000) calls for a systematic approach to design that incorporates consideration of environmental performance using life cycle design thinking. She proposes a process that helps the design team understand the consequences of different decisions and interpret the environmental impacts of their design solutions early on. Rather than simply identifying last minute solutions to design problems, she recommends using “design for life” thinking to assist in developing more suitable designs at the inception stage.

DESIGN FOR LIFE

A design philosophy and approach which incorporates consideration of the full life cycle of the product so that its “current-use” life can be maximised and it can be readily returned to further use (via adaption, disassembly, recycling, reuse or remanufacture) at the end of its current use.

(EDG note 70 NP, “[Glossary of Environmentally Sustainable Design](#)”)

Goal Setting

The first step in any environmental design process is to establish the project’s environmental performance scope and goals, preferably in association with the client and appropriately skilled consultants.

Designers need to be able to compare the potential performance of design alternatives prior to finalising design solutions. To do this effectively, there needs to be a clear statement of the environmental goals of the project and prior commitment to allowing time for environmental assessment during the design process.

The first step in any environmental design process is to establish the project’s environmental performance scope and goals.

Project goals can be set by reference to environmental guidelines. Professional institutions such as the Australian Institute of Architects publish design guidelines for the environmental performance of buildings (see [Sustainable Design Strategies for Architects](#)). These are also used as the foundation for industry best-practice awards.

Best-practice design should respond to specific site and surrounding contextual conditions. Goals can be relative, absolute or a combination of both. For compliance to be determined, goals must be measurable. For instance, a project might aim for a reduction in operational energy consumption of 10 per cent (relative to a “standard” building of the same type in the same climate) and at the same time set an absolute target of generating 10 per cent of its energy from renewables.

Weighting

Once the impacts of a design have been identified, the issues need to be weighted with regard to the project’s environmental goals, in order to provide an indication of the importance of each. Weightings are crucial. Even if all the scores in a rating system are the same (one point for ticking every box), application of different weights of importance for each point can change the overall score. Thus, if one product addresses energy saving, water efficiency and habitat loss and a competing product doesn’t address habitat loss, and if you give low weighting to protecting habitat, the product that doesn’t address the issue can be seen to be very competitive with one that does – and vice versa.

Weighting is used to a certain degree within rating schemes (e.g. Green Star) in order to convert environmental performance attributes of building designs into points or stars. In some cases, characteristics of buildings, rather than different environmental impacts, are weighted by their potential to enhance the performance characteristic that the rating scheme is designed to promote.

EPA Tools

The major environmental impacts of a building are determined at concept design, particularly when deciding on plan shape, form and envelope characteristics. Decisions made during conceptual design can have the greatest influence on project performance with the least associated cost. It is important, therefore, that environmental design tools be applied at design stage in order that the environmental implications of different iterations of design may be monitored progressively.

Arguably, unless environmental assessment becomes an integral part of conceptual design, practitioners will only ever make marginal use of EPA tools (Soebarto and Williamson 1999). Peshos and Hall (2000) argue that a successful environmental design process is different from a traditional process as it must provide for the input of consulting engineers and environmental consultants during conceptual design to gain maximum benefit from EPA tools and to avoid time or financial penalties.

It has been well established that the environmental performance of building projects is improved if environmental performance is embedded as a key philosophy of the project.

TOOL PREDICTIONS VS. REALITY

For a review of the major North American and Australian sustainability rating tools and energy simulation software packages, with discussion of the literature surrounding predicted vs. actual energy performance in green buildings, and an argument for a more performance-orientated ratings regime, see EDG note [66 BP "Mind the Gap: Predicted vs. Actual Performance of Green Buildings"](#).

In any case, it has been well established that the environmental performance of building projects is improved if environmental performance is embedded as a key philosophy of the project, rather than something to be considered after the cost and quality aspects of the project have been established.

Tool developers have recognised the need to make their programs fit early in the design process, and environmental design tools catering for conceptual design, such as Ecotect (see Energy Modeling Tools, below), are readily available. These tools address environmental issues arising from the site and surrounding context and provide an opportunity for the designer to weight environmental issues.

Tools provide an interface for the input of project data, access to calculations and environmental information databases, calculation of assessment and suitable representation of outputs. To be useful to designers through the design process, therefore, they must provide a user-friendly interface.

EPA tools can help inform sustainable design by introducing systematic assessment of design options, with a documented process demonstrating compliance to tender conditions or to environmental performance goals set by clients, regulatory or rating agencies.

A good assessment tool will embed environmental performance assessment in the design process and improve the effectiveness of the design team.

A tool cannot make integrated decisions about whether the impacts identified by a design decision will diminish the capacity of ecosystems to continually meet the needs of human beings. In other words, it cannot assess a building's contribution to ecological sustainability.

Tools range from highly complex and specialised programs to simple checklists, and provide various levels of environmental performance assessment. The decision must be whether to use a tool that provides a large amount of detail about the environmental impacts associated with design decisions, or to use a simple tool or checklist, that provides general guidance only.

Simple tools and checklists provide quick references to guide the generation of design solutions but they may not have the flexibility to be adapted for project specific issues or conditions.

BUILDING ENERGY SIMULATION SOFTWARE

Software used by building professionals to predict the energy performance of buildings; used to inform design and to help size air-conditioning and other building plant. Predicts how a building will perform when it has been built; provides insights into which aspects of the building design, materials and features contribute to or undermine energy efficiency and comfort, so that improvements can be made.

(EDG note [70 NP, "Glossary of Environmentally Sustainable Design"](#))

Complex tools provide a greater ability to assess context-sensitive environmental impact issues, and give more detailed information about the predicted outcome of a design choice. Simple tools and checklists provide quick references to guide the generation of design solutions but they may not have the flexibility to be adapted for project specific issues or conditions, and are dependent on the designer's interpretation.

The choice between tools will depend on available time, expertise, funding, client expectations, and the desired level of transparency and accountability of the design process.

Modelling Tools

There is such a vast number of EPA modelling tools in use around the world that it is almost impossible to keep track of them (the US Department of Energy lists over 400 on its [site](#)). Australia has been behind the US and Europe in respect of tool development and use, but it is catching up.

Most current Australian tools – notably AccuRate – concentrate on energy related impacts. These provide general guidance on reducing the energy consumption and greenhouse emissions of buildings in operation.

Although energy rating tools may have a limited scope, they can crucially affect and inform design decisions.

The EPA tools available for designers in Australia can be categorised as:

- energy performance modelling tools
- hybrid tools that integrate modelling of energy performance with the prediction of other influences on building environmental performance such as initial embodied energy, acoustics and indoor air quality
- LCA tools that identify the life cycle environmental impacts of building materials and products
- LCEA tools that predict the energy-related environmental performance of entire buildings, components or systems during operation

All of the environmental design tools available in Australia provide environmental performance indicators for various impacts. Most of them provide indicators of the relative embodied energy and CO₂ emissions associated with a design decision. The data are provided in relative scores, that is, the environmental impact of a building is presented relative to a “standard” or “reference” building of the same type. The greater the score relative to the benchmark building, the better the design decision is for the environment.

Energy Performance Tools

In Australia, tools commonly focus on energy related impacts. Although energy rating tools may have a limited scope, they can crucially affect and inform design decisions.

A great number of tools have been developed over the years but not all of them have gone on to win wide acceptance or commercial success. Examples include ENER-RATE, which was developed from the American ENER-WIN software but has very few users in Australia, and Ecotect, which has evolved and developed to gain widespread use in architectural practice.

Ecotect

Originally developed by Square One Research for use during conceptual design, Ecotect was focused on environmental impacts related to a building’s overall shape and the materials used. It is now part of a suite of software which Autodesk describe as “a comprehensive concept-to-detail sustainable building design tool” and which can be integrated into BIM (building information modelling).

AccuRate and NatHERS

AccuRate was developed by the CSIRO to provide quick assessment of house designs in an easy to use format. It models thermal flows through the building envelope and is the reference-rating tool for the Nationwide House Energy Rating Scheme (NatHERS).

A detailed description of AccuRate is provided in EDG note [DES 23, “AccuRate: 2nd Generation Nationwide House Energy Rating Software”](#). For more information about NatHERS, see the website: www.nathers.gov.au.

LCA and LCEA Tools

LCA is seen as one of the best methods for evaluating and comparing options (such as timber vs. aluminium windows) based on their environmental performance from material extraction through use and disposal.

Client expectations, particularly in the commercial arena, have been growing to include concern for everything from energy performance to impacts on regional biodiversity, but although work has begun at the time of writing there was a lack of rigorous Australian LCA data. Establishing a consistent and verifiable database of this kind is essential to the future development of EPA in this country. Currently [ecospecifier](#), a freely available product database using LCA methodology, is the best source for LCA data in Australia.

Australia’s Building Products Innovation Council (BPIC) has commissioned a project to establish a “[Life Cycle Inventory](#)” (LCI) for a wide range of Australian products and services. The base data will inform various existing LCA and ratings tools. It is hoped that this will lead to the establishment of consistent comparative measures for environmental impacts, not only for ecolabelling of building materials, but also for building rating systems.

LCAid

Carrying out an LCA of an entire building can be a time consuming and costly process. LCAid, an Australian tool for building designers, tries to simplify the process. It is intended to enable users to quickly assess solutions as a design progresses. It assesses environmental impacts in relation to inputs of raw materials, energy and water, and outputs such as waste and emissions to air, water and land. It is designed to assist environmental decision making in the initial phase of building design by providing both an assessment of environmental impacts and a relative benchmark of building performance. It can be linked to CAD files and a life cycle inventory database, and has a template for data to be entered from other LCA packages.

LCAid links interactively with Ecotect to generate quantities of materials; its algorithms calculate waste generated and water consumed over a building's life cycle. LCAid can determine the energy cost of water from the public system and provide LCA for Australia's reticulated energy supply.

LCADesign

LCADesign was launched in 2008 after being developed by a team led by the Co-operative Research Centre (CRC) for Construction Innovation, working with universities, public works departments, the CSIRO and industry partners. Using life cycle inventory (LCI) databases to provide details on resource use including embodied pollution, water and energy use, LCADesign delivers real-time environmental assessments direct from CAD and BIM with a single "eco-point" score. At the same time, LCADesign permits testing of design concepts with comparative "eco-profiling" and the capacity to provide immediate cost variations. Users can determine the source of environmental impacts by design element, individual product, assembly or component to a level of detail that can identify specifics such as transport fuel use and emissions.

Rating Tools

Rating tools typically use modelling tools to measure a building's environmental performance, then present the results in a summary way, in the form of ratings. The tools do provide a breakdown of a building's performance which can be used to inform the design process, but the goal is to establish a relative ranking of that performance against a nominal normative level of acceptability for the purposes of accreditation, bureaucratic approval, or to provide consumers with the means to make more informed choices.

NABERS

The current incarnation of NABERS began its life as the Australian Building Greenhouse Rating (ABGR). Launched in 1998, it was a world-first initiative for rating the greenhouse and energy performance of commercial office buildings. NABERS provides a set of performance benchmarks and a promotionally oriented star rating system as a framework within which designers and building owners and operators could evaluate building performance.

NABERS is not a modelling based system but a performance-based rating system for existing buildings that provides an environmental assessment based on actual utility bills and "real world" information.

NABERS can also be used for new buildings under the "commitment agreement" model: this requires evaluation of actual performance after occupancy.

NABERS is a national initiative managed by the NSW Office of Environment and Heritage. Its rating scale was extended from 5 to 6 stars in 2011 with existing buildings performing at 5.5 or 6 star level issued with new certificates to reflect their new rating. It is now used as the basis for the mandatory Commercial Building Disclosure scheme, which applies at time of resale or lease.

Green Star

Building on the experience of BREEAM in the UK and LEED in the USA, the Green Building Council of Australia's Green Star rating scheme, launched in 2003, is setting industry benchmarks to be used during conceptual design as a means of identifying project environmental goals and performance targets. Green Star is a national, voluntary rating system. Its categories include building management, indoor environment quality, energy, transport, water, materials, land use and ecology, emissions, and "innovation". The level of objectivity of assessment varies across the categories and has led to occasional debate, e.g. in relation to timber certification and the merit of vinyl floor coverings. Although sometimes criticised as expensive to commission and operate, in the absence of stringent building code provisions Green Star has become a powerful tool for introducing measurable environmental performance into design, particularly in high-end commercial buildings. In recent years the scope of Green Star has expanded to include educational and sports facilities, and the GBCA is now developing a Green Star Communities tool.

Tools for Individual Building Elements

At the same time that building modelling and rating tools are increasing in their sophistication and complexity, tools for individual components and building elements – such as WERS (Window Energy Rating Scheme) for windows – are also on the increase.

If component or system specific assessment tools are used, the design team ideally ought to conduct a range of elemental analyses and determine how integration of the different elements affects the performance of the building as a whole. This is not as simple as summing the parts.

Conclusion

Both in Australia and internationally, much work remains to be done on methodology and tool development and in collecting base life cycle data on building materials. Australian environmental assessment and rating tools tend to focus on energy-related environmental impacts of design decisions. These tools provide pragmatic approaches to integrating the assessment of environmental performance into design processes and predicting environmental performance, but assessment of the ecological and human health impacts of design decisions will require further development of LCA tools.

In the future, tools are likely to have the potential to provide absolute predictions of a wide range of environmental performance criteria, not just energy. Tools developed overseas may be more advanced and comprehensive in their scope and in their use of LCA data, but such tools are not directly transferable to Australia because they do not reflect local environmental conditions, pressures or impacts.

EPA tools provide rigorous, systematic approaches to examining the environmental implications of building design decisions, and allow designers to identify, learn about and reduce the environmental damage due to the construction and operation of buildings. Given the increasing requirements from government and the private sector for better environmental performance, the use of these tools forms a basis for establishing accountability for, and demonstrating compliance with, emerging environmental performance standards.

It is important to remember that a tool will only give full value when the project's environmental performance scope and goals are clearly established. There needs to be a clear understanding between the design team and stakeholders of the goals of the project and their relative weighting, and a commitment to allowing time for environmental assessment from the outset of the process.

References and Further Reading

EDG note [GEN 51](#), "Life Cycle Assessment: Application in Building", by Tim Grant and Dominique Hes

EDG note [DES 70](#), "Sustainability Rating Tools: A Snapshot Study", by Dr Usha Iyer-Raniga and Kendra Wasiluk

AccuRate: <http://www.csiro.au/science/AccuRate.html>

BASIX: <https://www.basix.nsw.gov.au/information/index.jsp>

Birkeland, J, 2008, *Positive Development: From Vicious Circles to Virtuous Cycles Through Built Environment Design*, Earthscan, London

ecospecifier: www.ecospecifier.org

Ecotect: <http://usa.autodesk.com/adsk/servlet/pc/index?id=12602821&siteID=123112>

Green Building Council Australia, Green Star rating tool: www.gbcaus.org

International Living Future Institute, Living Building Challenge: <https://ilbi.org/>

NABERS: www.nabers.com.au

NatHERS: www.nathers.gov.au

Peshos, Z, and Hall, M, 2000, "An Integrated Environmental Design Approach" in *The Environmental Engineer*, vol. 1, No1, pp. 16–22

RMIT, Greening the Building Life Cycle: <http://buildlca.rmit.edu.au>

Soebarto V and Williamson, T, 1999, "Designer Orientated Performance Evaluation of Buildings" in *Proceedings of Conference Building Simulation 1999*, vol. 1, Ed(s). Nakahara, N, Yoshida, H, Udagawa, M and Hensen, J, International Building Performance Simulation Association, Kyoto, Japan, pp. 225–232

About the Author

Paul Downton BSc, BArch, PhD is an architect, writer and urban ecologist. A major contributor to the Federal Government's Your Home Technical Manual, he has been described as "an early leader in regenerative and restorative architecture and a driver of the international eco-cities movement". (Janis Birkeland)
Email: paul@ecopolis.com.au

DISCLAIMER

The views expressed in this paper are the views of the author(s) only and not necessarily those of the Australian Institute of Architects (the Institute) or any other person or entity.

This paper is published by the Institute and provides information regarding the subject matter covered only, without the assumption of a duty of care by the Institute or any other person or entity.

This paper is not intended to be, nor should be, relied upon as a substitute for specific professional advice.

Copyright in this paper is owned by the Australian Institute of Architects.

