Greening Buildings: How can the performance of existing commercial buildings be improved?

Understanding how to take a holistic approach to greening commercial buildings

Sustainable Built Environment National Research Centre

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Front cover: The Brisbane skyline at night.
Image: David Sparks.

Synopsis

Efforts to improve the performance of commercial buildings have often focused on encouraging green design, construction and building operation; however, the business case is not very compelling if considering the energy cost savings alone. In recent years green building has been driven by a sense that it will improve the productivity of occupants, something with even greater economic returns than energy savings. Reducing energy demand in commercial buildings in a way that encourages greater productivity is not yet well understood as it involves a set of complex and interdependent factors. This project investigates these factors and focuses on the performance of and interaction between: green design elements, indoor environment quality, tenant/leasing agreements and culture, occupant experience, and building management practices.

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Executive Summary

Efforts to reduce carbon emissions in the buildings sector have been focused on encouraging green design, construction and building operation. The business case is not very compelling if considering energy cost savings alone, but this may change with a price on carbon. In recent years green building has been driven by a sense that it will improve both building value and the productivity of occupants, which has much greater economic returns than energy savings alone. To date much of the focus has been on new buildings such as the '*Council House II*' in Melbourne, '*30 the Bond*' in Sydney, '*Green Square South Tower*' in Brisbane, '*2 Victoria Avenue*' in Perth, and '*Flinders Link Stage 5*' in Adelaide, however new buildings account for just one per cent of the total building stock.[1] Little attention has been paid to existing commercial buildings, although such buildings make up the majority of commercial building stock and are responsible for the bulk of its energy demand. An important aspect of encouraging green commercial buildings is that of conveying to developers, owners and tenants the full range of benefits that can flow to them. While they may be interested in benefits to the broader environment and society, they are more interested in the financial, functional and other direct benefits that accrue to them. Hence the complex and interdependent factors involved in reducing energy demand in existing commercial buildings in ways that encourage greater productivity need to be unravelled so they can be better understood.

This report presents the findings of an investigation of these factors, and focuses on the performance of and interaction between (1) green design elements, (2) indoor environment quality, (3) occupant experience, (4) agreements and culture, and (5) building management. This project has focused on creating a survey tool, the '*Performance Nexus*', to assist efforts to improve the energy performance of commercial buildings while fostering a productive environment, using these five interdependent factors. The tool has been developed through research, stakeholder workshops, and trials with partners to identify the key metrics of a building's performance that should be considered when designing an intervention. The project suggests that the *Performance Nexus* is a low cost, low complexity tool that can be used across the sector and around the world to encourage the greening of existing commercial buildings through a focus on enhanced productivity.

About the Research Team:

Professor Peter Newman led an experienced research team from Curtin University and the Queensland University of Technology, which was managed by emerging sustainability authors Charlie Hargroves (Curtin University) and Dr Cheryl Desha (QUT). The team includes outstanding sustainability doctoral researchers Samantha Hall and David Sparks, and was supported by researchers, Annie Matan, Shol Blustein, Kuntal Dutta, Georgina Hafteh, Tim Davies, Fiona McKeague, and Rob Salter. Professor Newman is the John Curtin Distinguished Professor and is the Director of the Curtin Sustainability Policy (CUSP) Institute. Newman is the co-author of nine books and over 200 papers on sustainability, is on the Board of Infrastructure Australia, and is the current Lead Author for Transport on the IPCC. As part of The Natural Edge Project, Hargroves and Desha have worked with a range of co-authors to publish four international books on sustainable development, selling over 80,000 copies in four languages. The books have received a Prime Minister's Banksia Award, and have been ranked 5th and 12th amongst the '*Top 40 Sustainability Books of 2010*' by the Cambridge University Sustainability Leadership Program.

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Pictured above: There is great potential to improve the performance of existing commercial buildings, which constitute the vast majority of building stock in Australian capital cities.

Introduction

A holistic approach to improving performance of existing commercial buildings

Commercial buildings are responsible for as much as 10 per cent of Australia's greenhouse gas emissions,[2] and there are numerous opportunities to make significant reductions at relatively low cost through initiatives such as improved HVAC, lighting, and office equipment.[3] Efforts to reduce carbon emissions in the buildings sector have focused largely on encouraging green design and construction of new buildings, but there is also great potential to improve the energy performance of existing buildings. Australian cities have about 21 million square metres of commercial office space spread across nearly 4,000 buildings,[4] most of which, if measured by net lettable area, consists of low-grade office buildings.[5] As the energy performance of much of this low-grade stock has yet to be improved there is growing interest in cost-effective energy management options.

Despite the significant savings to be made, the business case becomes stronger still when considering other potential benefits from the retrofitting of existing buildings, such as improving occupant satisfaction and productivity, which can offer even greater economic returns. However, efforts to improve environmental performance can have negative effects on the occupants' experience, and vice versa. This is of particular concern as energy and maintenance costs are only about 4-5 per cent of total costs over a building's life cycle, while occupants' salaries are around 85 per cent.[6] Despite this, there appears to be a lack of focus on indoor environment quality in Australian buildings, since of the 1,675 current NABERS Office ratings only 12 are for Indoor Environment.[7] This lack of focus on indoor environment quality has implications beyond the immediate health and well-being impacts on building occupants; it may also be impacting profitability. For example, in the USA, productivity losses from poor indoor environment quality are estimated to be costing as much as US$22.8 billion per year.[8]

Renting a 'green' office space does not necessarily mean that it will be a productive and healthy workplace. For example, although open plan offices can allow natural light to reach more work spaces and encourage increased interaction with colleagues and workmates, such layouts can result in distractions from noise and people passing if not properly considered in the fit-out design. Moreover, efforts to improve the thermal efficiency of buildings (such as by making the building envelope as air-tight as possible) may conflict with efforts to circulate fresh air throughout the building. Furthermore the energy intensity of buildings may vary over time due to a number of diverse factors, such as different occupant behaviour, aging equipment, or inadequate tuning and maintenance.[9] As user needs change, buildings may also be used in ways that differ from their original design intent, and this often has impacts on energy and water consumption. Design efficiencies or improvements can impact on comfort considerations related to air quality, lighting, acoustics, and temperature.

In order to improve both energy performance and productivity there is a need for a whole of building approach that involves communication between the many stakeholders and sub-contractors involved in operating buildings. Such an approach challenges standard industry practices and requires a new framework that goes beyond simply energy management.

There are many discrete elements of building performance that can be integrated and enhanced to ensure they reinforce energy efficiency and occupant satisfaction objectives. Image: Courtesy of David Sparks.

The *Performance Nexus* for commercial buildings provides such a framework, and has a selection of key performance areas, including:

- **Design elements:** Design elements can profoundly affect the energy consumption of a building, as well as its indoor environment quality and the satisfaction of its occupants. Design elements can also determine what building management options are available. This node of the *Nexus* focuses on key existing energy efficient design elements within a building and on appropriate retrofit technologies. The node considers monitoring and control technology; lighting; heating, ventilation and air-conditioning; plant and equipment; building fabric; and the tenancy design and fit out.
- **Building Management:** Building management practices can have a big impact on the overall functioning of a building, ultimately affecting energy demand, indoor environment quality and occupant experience. The management and maintenance of buildings is thus receiving more attention as a key component of building performance. This node of the *Nexus* considers the way design elements are used and maintained, and how information from the other *Nexus* nodes is used in decision-making processes. The node considers operation and management practices, reporting and evaluation, maintenance and cleaning, commissioning and tuning, management personnel, communication and education, and procurement.
- **Occupant satisfaction:** It is generally assumed that a relationship exists between the quality of the office environment and the health and well-being of its occupants, and numerous studies on environmental variables such as air quality and lighting confirm this link. It is also accepted that occupants who are dissatisfied with the indoor environment quality are more likely to say that this affects their productivity. It is therefore important to identify problem areas that are contributing to dissatisfaction in order to rectify the situation. This node considers perceived productivity; communication and reporting; training, education and guidance; and the use of controls.
- **Agreements and Culture:** Agreements can be in two forms, namely ‘hard’ and ‘soft’. Hard agreements include legal agreements such as green leases that affect the occupants of the buildings. For instance leases may include mechanisms such as covenants to repair,

break clauses, relocation notices, rent and rent review clauses, and gross versus net rental leases, that can be harnessed to improve building performance. Soft agreements include those related to organisational culture and communication practices that, when present, can contribute to improved building performance. This node considers lease agreements; ratings, mandates and incentives; commitments and targets; organisational culture; and communication and education initiatives.

- **Indoor environment quality:** Indoor environment quality (IEQ) can have a significant impact on occupant health and productivity. Key IEQ parameters can provide valuable guidance as to how to improve conditions as part of efforts to improve energy performance. Measurements are taken in the same zones used to conduct occupant experience surveys so as to allow correlation between occupant responses and IEQ data. This node considers basic IEQ monitoring, advanced IEQ monitoring, IEQ management programs, health and well-being, and reporting and communication of results.

Improving indoor environment quality, such as through well-designed daylighting strategies, can have a significant impact on occupant satisfaction.
Image: Courtesy of NDY

The value of the *Performance Nexus* lies in its ability to identify key metrics and considerations that inform efforts to improve energy performance, as well as measuring improvements in indoor environment quality, occupant experience, and occupant involvement in building management, (which can have positive effects on productivity). The research team has worked closely with industry and government to create a short list of key metrics and considerations for each of the five nodes to save industry time and reduce the complexity and cost involved. The design of its metrics and considerations has been informed by research into best practices, stakeholder workshops, and pilot data collection in partner buildings by the research team.

An inquiry into publicly accessible databases related to commercial buildings was also conducted to assess the availability of information that might assist in improving building performance. It was found that available commercial building databases often do not consider energy or IEQ related performance metrics, making it difficult to undertake benchmarking or trend analysis. Furthermore, inconsistencies between available databases make it difficult to draw conclusions on building performance. In the absence of such data, resources including Sustainability Victoria publications and Melbourne's 1200 Buildings case studies provide industry with reference points on sustainability trends as well as usefull examples of green building initiatives. The US has been able to conduct many studies using the Energy Star and LEED databases due to open access. However, this information is not as freely available in Australia as the market is highly competitive and protective of commercial interests. Looking ahead, the situation should improve over time, as NABERS and Green Star programs continue to grow, and following the Government's *Commercial Building Disclosure* program.

Examples of holistic retrofits of existing commercial buildings in Australia

Image courtesy of QV.1 Management.

QV.1, 250 St Georges Terrace, Perth, WA

Over the course of 15 years, QV.1 has implemented a long-term indoor air quality management program focused on continual monitoring and improvement of the indoor environment, resulting in Australia's highest NABERS Indoor Environment Rating and delivering an excellent work environment for occupants. Regular IEQ Reports feed into building management processes and facilitate the following: continual improvement of building performance, analysis of trends in performance over time, correct maintenance of design elements, and early identification of potential issues.[10] Additionally, tenancy fit-out guidelines ensure tenants and contractors are aware of their role in IEQ management within the building.[11] The guidelines promote good IEQ management and specify that tenancy re-fit testing will be undertaken to ensure fit out works do not impact on building performance.

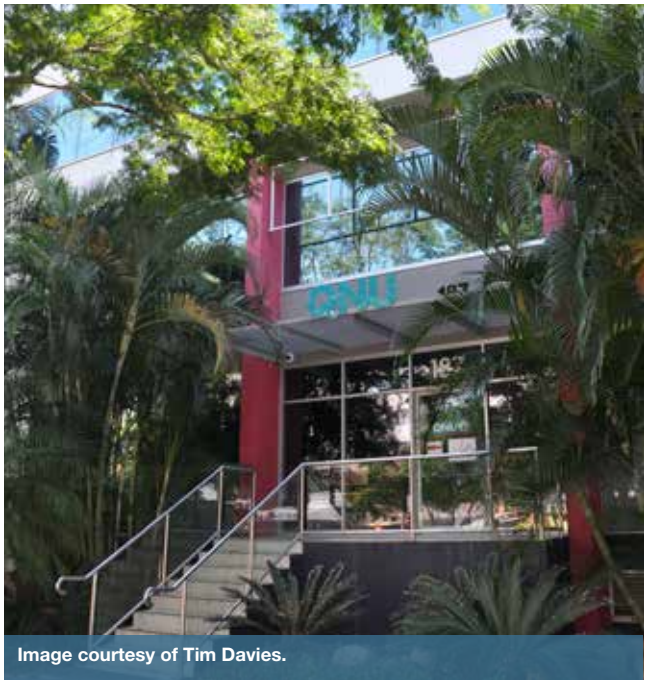

Image courtesy of Tim Davies.

187 Melbourne Street, South Brisbane, QLD

The Queensland Nurses' Union building in Brisbane underwent a low-cost refurbishment involving key energy efficiency upgrades and the installation of a new building management system (BMS). The on-site building manager now uses the BMS as a tool to educate occupants about the impact of their actions on their own comfort and on the building's energy performance.[12] This engages occupants as active participants in the operation of the building, contributing to improved energy efficiency and a reduction in thermal comfort complaints while helping to lift the performance of the building to a 4.5 Star NABERS Energy Rating.

Image courtesy of Australian Ethical.

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Trevor Pearcey House, Canberra, ACT

Trevor Pearcey House represents a leading example of passive design principles coupled with good building management practices and effective occupant education, which has helped deliver a comfortable and productive workspace while reducing energy consumption by 52 per cent.[13] The refurbishment included a number of user-controllable design elements, and, in order to ensure optimal functioning, formal 'how the building works' sessions are conducted to ensure occupants understand how to operate the building so that it is comfortable and energy efficient.[14] A post-occupancy evaluation rated the building in the top 11 per cent of buildings in the Building Use Studies dataset for user comfort and satisfaction, and indicated higher perceived productivity following the refurbishment.[15] This shows that good low-energy design, paired with educated occupants who have an active role in operating the building, can result in high satisfaction and efficient use of energy. Additionally, the office received a 6 Star Green Star Office Design Rating.

201 Charlotte Street, Brisbane, QLD

201 Charlotte Street in Brisbane reduced energy consumption by 34 per cent and secured a 3.5 Star NABERS Energy Rating through best-practice building management practices and targeted efficiency upgrades, rather than relying on major replacement of plant and equipment.[16] Despite having undergone major refurbishments and energy efficiency upgrades in 2001, a lack of commissioning and maintenance meant that by 2007 the building was performing poorly. A retrofit program therefore focused predominantly on good tuning, maintenance and reporting, along with targeted improvements to metering, monitoring, and BMCS systems, which have helped to create a high performance building that operates more efficiently.

Image courtesy of Szencorp.

40 Albert Road, South Melbourne, VIC (Szencorp)

The Szencorp building is an industry-leading example of an energy efficient refurbishment supported by good building management practices, ongoing indoor environment quality testing and post-occupancy evaluation that has helped to reduce energy consumption by 65 per cent while also contributing to high occupant satisfaction.[17] In 2006, the building ranked in the top six per cent of Australian buildings within the Building Use Studies dataset. In 2009, the building improved further, ranking in the 96th percentile for Australian buildings.[18] Perceived productivity was consistently high, and in 2009 was rated in the top ten per cent for Australian buildings. Indoor environment quality analyses and occupant surveys across several years were actively used to improve building management practices through a program of open communication and public disclosure aimed at continual improvement. Additionally, the office received a 6 Star Green Star Office Design Rating.

Image courtesy of ACF.

60 Leicester Street, Carlton, VIC (60L)

The 60L building in Carlton is a leading example of an energy efficient refurbishment that has employed innovative leasing agreements to assist energy reduction initiatives. Tenants in the building are under a ‘green lease’, which includes a legal requirement to comply with the building’s Environmental Management Plan.[19] Additionally, lease documents also include a tenancy fit-out manual and schedule, and an agreement to follow the Green Building Principles and Rules. This increases tenants’ awareness of environmental outcomes and recognises the key role of occupants in contributing to high building performance. Additionally, two separate post-occupancy evaluations have been conducted (one independent and one internal) and both indicate that the refurbishment has resulted in perceived productivity improvements.[20]

Image courtesy of FMSA.

Image courtesy of Savills Australia.

182 Capel Street, North Melbourne, VIC

The 182 Capel Street building provides a good example of low-energy design, focusing on providing an efficient envelope and passive design features in combination with energy efficient design elements. While the building has been occupied for less than a year, good building management practices are contributing to improved building performance through the commissioning phase.[21] Occupants are educated on the correct operation of the building, and are also engaged in energy reduction targets through involvement in CitySwitch.

500 Collins Street, Melbourne, VIC

500 Collins St in Melbourne is a high-profile retrofit that has resulted in significant energy efficiency improvements, good indoor environment quality, improved occupant satisfaction and productivity improvements. Energy efficient design elements are supported by excellent building management practices, including a 12-month commissioning process and quarterly review.[22] An Energy Management Committee, comprised of key building stakeholders and energy performance contractors, meets monthly to evaluate energy consumption in the building. Additionally, detailed pre- and post-occupancy studies were conducted with the assistance of two tenants, and show high levels of occupant satisfaction and perceived productivity improvements.[23] Furthermore, a comprehensive environmental management plan and building users' guide have been developed, providing new tenants with ESD guidelines for the design of interior fit-outs.

Image courtesy of NDY.

Image courtesy of Knight Frank.

115 Batman Street, West Melbourne, VIC

The refurbishment of 115 Batman Street focused on delivering a quality work environment and optimising building performance by incorporating passive design principles and energy efficient design elements. A building management system was installed and is used to generate monthly energy consumption reports to track consumption and identify potential issues.[24] A detailed training program was also developed to improve occupants' knowledge and understanding of the building management system. Additionally, the office received 5 Star Green Star Office As Built and 5 Star Office Interiors Ratings.

500 Bourke Street, Melbourne, VIC

A major redevelopment involving concurrent refurbishment of base building and tenancy fit out was undertaken with the aim of drastically cutting electricity and natural gas consumption and reducing annual energy costs by $600,000.[25] The redevelopment involved substantial upgrades to building plant and equipment, and the installation of a new building automation system which is used to identify energy reduction opportunities and communicate performance data to building stakeholders.[26] The case study is unique in that it provides an example of close partnership between building stakeholders, with the building owner and tenant co-investing in upgrades designed to reduce annual energy expenses in order to overcome the common split incentive problem.[27] Additionally, the lease conditions and organisational culture of both owner and tenant support high performance objectives. The redevelopment has delivered 4.0 Star NABERS Energy and 4.5 Star NABERS Indoor Environment Ratings. This highlights that good design in conjunction with cooperation between building stakeholders can deliver significant energy savings and win-win outcomes for both landlords and tenants.

Improving the Performance of Existing Commercial Buildings

Industry led Research Focus

As part of the Sustainable Built Environment National Research Centre's (SBEnrc) focus on industry-led research, three stakeholder workshops were held in the early stages of the project, hosted by SBEnrc Core members, the Western Australian Department of Finance in Perth, the Queensland Government Department of Public Works in Brisbane, and the Townsville City Council in Townsville. In the workshops the research team presented the findings of the literature review and worked with a total of 50 key stakeholders to identify areas of interest for the project to develop. The workshop format was based on the methodology of '*Collective Social Learning*', created by Emeritus Professor Valerie Brown,[28] where participants were asked to envisage their ideal green buildings and then consider the enablers and disablers of these visions. The workshops were followed by a series of working sessions with partners, to identify key areas of interest that would provide clear benefits to industry and government, which were:

- *A focus on existing commercial buildings:* A key finding from the workshops and sessions with partners was that the project needed to focus on existing building stock rather than new buildings, as existing buildings represent the bulk of the stock. According to stakeholders, it was often the case that little attention was paid to energy management in such buildings, and partners would need a strategic approach to improving the buildings' performance.
- *A holistic approach to energy management*: Stakeholders expressed an interest in the project going beyond a focus on energy technology, as it was understood that, while buildings can use leading edge technology, the way buildings are managed and used can profoundly influence the performance of that technology. Such a focus could deliver cost effective and lasting solutions with multiple benefits across the building.
- *Consideration of the impact on productivity of energy programs*: Stakeholders expressed keen interest in the project exploring the link between energy management initiatives and productivity. Understanding that productivity is difficult to quantify in practice, a focus on indoor environment quality and occupant perceptions of productivity may be a suitable proxy.

60L – A leading example of an existing building retrofit resulting in improved energy efficiency and high occupant satisfaction. Image courtesy of ACF.

- *Options for enhancing stakeholder collaboration in buildings*: It was understood that buildings are complex with many stakeholders involved, and concerns were expressed about a lack of communication between the various parties that can prevent a holistic approach to improving energy performance. Thus there was interest in seeing the project consider the various stakeholders within a building and their relative contributions to improving energy performance in a way that encouraged productivity.
- *Consideration of associated agreements*: Stakeholders expressed an interest in learning more about the various agreements that can be used to enhance energy management in buildings, such as legal instruments (e.g. leases for tenants) and structures to shape organisational culture and communication (e.g. in owner-occupied buildings).

Given this industry engagement the project has focused on:

1. Investigating '*leading efforts*' in Australia and internationally to improve the performance of existing commercial buildings and to extract lessons from this.
2. Investigating the '*key performance areas*' of existing commercial buildings in order to improve the energy performance of the building in ways that support a productive workplace.
3. Developing a '*framework for collecting data*' in a building to inform low cost, low complexity strategic interventions, so as to improve energy performance in a manner that supports a productive workplace. This allows the building's stakeholders to collect such data internally to inform their efforts to improve performance.

Benefits to Industry of the Research Project

The expectations for building performance are rapidly shifting. Owners and tenants of buildings are increasingly demanding high performing spaces that have the right 'environmental credentials'.[29] Retrofit initiatives often focus on installing more efficient equipment, but simply installing energy efficient design elements is often not sufficient to achieve energy efficiency and occupant satisfaction. There are many examples of efficient design elements that are poorly maintained or incorrectly operated by occupants, resulting in underperforming buildings with poor indoor environments. Hence this project has sought to identify key criteria to inform efforts to improve the energy performance of existing commercial buildings while also focusing on workplace productivity, design elements, indoor environment quality, occupant experience, building management, and agreements and culture. This research benefits industry by:

- *Providing a succinct tool to collect key performance data*: The *Performance Nexus*, created in this project, gives industry a valuable tool to identify key performance data to inform efforts to improve the energy performance of existing commercial buildings in a manner that supports a productive workplace. The tool has five areas of focus that are interconnected and highlight the systemic nature of the operation of such buildings.
- *Citing precedents for a holistic approach to performance improvement*: The 10 Australian case studies investigated in this research provide industry with tangible examples of holistic improvements to energy performance

and other environmental aspects of buildings, according to a range of performance factors. The case studies demonstrate how such an approach delivers multiple benefits, and they provide guidance toward the achievement of such results.

- *Providing industry with succinct capacity building materials*: Given the relatively new focus on improving the energy performance of existing commercial buildings, and the rapid growth expected in this area, the deliverables of the project provide a clear and structured set of materials to be used by industry for capacity building. The materials show how taking a holistic approach and considering a range of key factors can deliver low-cost, low-complexity options for improving energy performance in ways that also improve work conditions and streamline management practices.

- *Helping to expand the focus to include existing buildings*: Complementing research and practice on high-performing new-build projects, the deliverables from the project will support industry to also focus on existing buildings, which represent the majority of Australian building stock. The *Performance Nexus* provides a framework to investigate the performance of such buildings in a way that informs strategies to deliver multiple benefits from energy demand reduction initiatives.

- *Improving strategic positioning*: The model developed from the research enables detection of opportunities across multiple dimensions of a building's operation. The resulting detailed understanding allows building owners to plan for future retrofits with better knowledge of financial and non-financial implications. Such a model provides a valuable tool for industry leaders to improve strategic positioning in the sustainable buildings space.

- *Reporting Industry Perceptions*: The stakeholder engagement report informs industry about its own members' views on taking a holistic approach to building evaluation. The report provides guidance on the ways such evaluation may be undertaken in Australia along with consideration of key factors that enable or obstruct it.

Existing buildings represent the majority of the building stock and have great potential for holistic refurbishments to improve energy efficiency and occupant experience. Image courtesy of Savills Australia.

Governments can support and underpin a holistic approach to improving the energy performance of existing commercial buildings.
Image: CazzJj at Flickr [CC-BY-2.0]

Benefits to Government of the Research Project

In addition to the industry benefits described above, the findings provide valuable insights for governments on the range of benefits from a holistic approach to building performance improvement, which can enhance future government programs. The project benefits government by:

- *Informing legislation and policy development*: The project's findings highlight areas of legislation and policy where governments (local, state or federal) can support and underpin a holistic approach to improving the energy performance of existing commercial buildings. These areas include incentives for existing buildings to undertake more holistic retrofit initiatives, and support for innovative finance arrangements (such as environmental upgrade agreements) that help overcome the split incentive issue.
- *Providing accessible data*: The review of databases included as part of this research has highlighted the lack of readily accessible data for benchmarking building performance in order to learn from other building examples. This project has highlighted a set of key metrics and considerations that could become part of mandatory reporting requirements.
- *Providing government with succinct capacity building materials*: The deliverables of the project provide a clear and structured set of materials to be used by government agencies for capacity building in this new and rapidly growing area of improving the energy performance of existing commercial buildings. The materials show how taking a holistic approach and consideration of a range of key factors can deliver low-cost, low-complexity options for improving energy performance in ways that also improve work conditions and streamline management practices.
- *Informing procurement policies*: The research results provide a clear, structured and holistic understanding of how to improve the energy performance of existing commercial buildings in a way that also supports a productive workplace. This in turn provides government agencies with valuable guidance in procuring such services and requiring such performance enhancement in the retrofitting of existing buildings.

Key Findings

The *Performance Nexus*

The project set out to produce a low-cost, low-complexity tool to support efforts to improve the energy performance of existing commercial buildings in a way that supports a productive workplace. This is a critical part of the greening agenda as buildings use a substantial amount of energy, but there are great opportunities to reduce this in ways that also create a great space in which to work. Reductions in energy consumption sometimes miss opportunities to improve the workspace, or even lower the quality of that space. In investigating such a tool the research team has focused on a number of factors influencing the energy performance of existing commercial buildings, including physical design elements, the way the building is operated and maintained, the experience of occupants, legal and non-legal agreements, the culture of the organisation, and the quality of the indoor environment.

The resulting tool, the *Performance Nexus*, guides users through a holistic approach to the building evaluation process, and ensures that key metrics and considerations are included in the process, shown in Figure 1 and outlined in Table 1. The *Performance Nexus* is particularly valuable as a pre- and post-retrofit evaluation tool that can highlight the impacts of retrofits on a workplace, identify areas that may need improvement, and identify relationships between areas that could be strengthened. Moreover, the tool is focused on identifying issues that prevent the building from achieving energy efficiency improvements in a way that also enhances the experience of occupants. The tool is complemented by a series of case studies that investigate how such metrics and considerations are used in practice to improve performance across multiple dimensions (such as design elements, occupant experience, indoor environment quality, agreements and culture, and building management).

Figure 1: The *'Performance Nexus'* for Existing Commercial Buildings: Considering the main elements that affect the performance of commercial buildings in order to strengthen efforts to reduce fossil energy consumption *and* support a productive workplace.

The *Performance Nexus* provides a framework to examine how the building can be managed to achieve the best energy-comfort balance, considering the various design elements, the indoor environment quality, the building management practices, and the agreements and culture of the organisations involved. The framework is intended to be an educational and informational tool that stakeholders can use as a first step to understanding their buildings and engaging all stakeholders to identify untapped potential for building improvements. It uses targeted questionnaires for occupants, tenants, building managers and building owners, designed to identify key systems, practices and areas for improvement. This information can be used in subsequent interventions to target energy efficiency opportunities and ensure that systems and practices in the building and tenancy support high performance objectives.

Table 1: Summary of considerations for each node of the *Performance Nexus*

Node: DESIGN ELEMENTS	
Monitoring and Control Technology Lighting Heating Ventilation and Air Conditioning Other plant and equipment Building Fabric Tenancy design and fit out	• Focusing on physical technologies and systems in the building, this node can inform design of both new buildings and retrofits. • Design elements have a large role in the building's energy demand profile, and a focus here can achieve significant energy consumption reductions that, if done holistically, may also improve indoor environment quality and occupant satisfaction. • The design elements will be a key determinate of the type and scope of the building's management practices. • Design elements are increasingly operated and affected by occupants (e.g. with individual lighting controls and operable windows).
Node: BUILDING MANAGEMENT	
Operation and management practices Reporting and evaluation Maintenance and cleaning Commissioning and tuning Management personnel, communication and education Procurement	• Building management can directly impact the energy performance of a building, while indirectly impacting the indoor environment quality and occupant experience. • Substantial reductions in energy can be achieved using existing technology, focusing on the way design elements are used and maintained, and how information from other nodes is used. • Building management is often a combination of automated systems, routine schedules and user interfaces.
Node: OCCUPANT EXPERIENCE	
Occupant satisfaction Perceived productivity Communication and reporting Training, education and guidance Use of controls	• When considered with the other nodes of the *Nexus* , occupant experience may be the most accessible way to inform efforts to create a productive workplace. • Although interpretation of survey results in the workplace is difficult, it can increase understanding about the potential response of occupants to changes to reduce energy demand. • Engaging occupants in the design of energy conservation initiatives is also a way to increase occupants' support for and involvement in such programs to assist in their implementation.
Node: INDOOR ENVIRONMENT QUALITY (IEQ)	
Basic IEQ monitoring Specialised IEQ monitoring IEQ management programs Health and well-being Reporting and communication of results	• The indoor environment quality can have a significant impact on occupant health and well-being that may affect productivity. Initiatives to reduce energy consumption need to ensure they don't negatively affect IEQ. • Monitoring and considering key IEQ parameters can provide valuable insights that enhance energy demand reduction programs. • Consideration of IEQ covers a number of parameters, including air quality and ventilation, acoustics, lighting and thermal comfort.
Node: AGREEMENTS AND CULTURE	
Lease arrangements Organisational culture Communication and education Ratings, mandates, and incentives Commitments and targets	• This covers the types of binding and non-binding agreements between the various building stakeholders such as owners, building managers, facilities managers, service providers, tenants and occupants. • It considers emerging legal instruments such as green leases that can underpin greater energy conservation and improved IEQ (e.g. covenants to repair, break clauses, relocation notices, rent and rent review clauses, and gross versus net rental leases) • It also considers social aspects including organisational culture and communication practices.

The relationship between performance elements

The *Performance Nexus* has been designed to consider both the base building and tenancies through the use of checklists, questionnaires and interview questions, tailored to particular areas of responsibility, as summarised in Table 2.

Table 2: Typical responsibilities for 'Performance Nexus' nodes in commercial buildings

AUDIENCE	Design Elements	Building Management	Indoor Environment Quality	Occupant Experience	Agreements and Culture
Base Building	Building Owner	Building Manager	Building Manager	Occupants	Building owner
Tenancy	Tenancy Representative	Property Manager	Tenancy Representative	Occupants	Tenancy Representative

The design elements node of the *Nexus* can act as an anchor point with each element being examined across each of the other four nodes. Structuring the *Nexus* in this way enables building stakeholders to assess what design elements are in place, investigate how these are being managed and maintained in the building, and consider how effective this is through the IEQ and occupant experience components, as shown in Table 3 for the case of lighting.

Table 3: Example of application of each node of the Nexus to 'lighting'

Design Element	Indoor Environment Quality	Occupant Experience	Building Management	Agreements and Culture
Is the lighting system energy efficient?	*Are the lighting levels suitable for tasks?*	*How satisfied are occupants with light levels and controls?*	*Is there a maintenance schedule for lighting?*	*Is there a fit out guide in place for lighting systems?*

The *Performance Nexus* can be used to identify links between the five key performance areas and to generate strategies for improvement, as illustrated in Table 4. For example the Szencorp building is a commercial building that was built in 1987 and underwent a major retrofit in 2005 to improve sustainability across a number of areas. Post-occupancy evaluations are often used to improve building performance. In 2009, post-occupancy evaluations of the Szencorp building were conducted, and feedback from occupants highlighted that in one area in particular the lighting levels were too low for tasks to be completed, resulting in dissatisfaction. Subsequent IEQ testing found that lighting levels were below NABERS IE standards. These results suggested that a new tenant's fit out had not properly considered the lighting layout.[11] The building owner used the post-occupancy evaluation results to inform building management practices, and lighting systems were adjusted. Follow-up IEQ testing in 2010 indicated lighting levels then met NABERS standards,[30] showing the importance of considering the impact of fit out alterations on IEQ, and highlighting the value of this process in contributing to improved building performance.

Table 4 shows a sample of how each of the key performance areas in the *Performance Nexus* can be harnessed to enhance energy related initiatives.

Table 4: A sample of the interactions between various nodes of the *Performance Nexus*

DESIGN ELEMENTS – Heating, Ventilation and Air Conditioning This node focuses on the effectiveness of the HVAC design as it has a major impact on the building's energy demand and the satisfaction of occupants. HVAC systems may be responsible for up to 50% of total energy use[31] and studies show building users consider thermal comfort to be amongst the most important parameters influencing overall satisfaction with IEQ.[32]	
BM	Improving the 'maintainability' of HVAC plant and equipment is essential to ensure building management personnel are able to deliver energy and IEQ outcomes.[33] Access to plant rooms, ductwork, air-handlers and other components is imperative and good knowledge management procedures are integral to ensure optimal system performance.
AC	Implement policies that require assessment of fitout changes for their potential to impact IEQ and energy efficiency. New partitions and walls can alter ventilation patterns, and supplementary HVAC systems can work against central systems.
OE	HVAC systems are a primary determinant of occupant satisfaction, yet many offices are too cold in summer and too hot in winter. Adjusting thermostat settings by just 1°C can reduce HVAC energy consumption by six per cent and may reduce air-conditioning complaints.[34]
IEQ	Poorly designed and maintained HVAC systems can detrimentally affect indoor air quality and result in illness and reduced productivity.[35]
BUILDING MANAGEMENT This node focuses on the benefits of building management practices and procedures that can enhance HVAC system and component performance. Poorly designed and maintained HVAC systems can detrimentally affect indoor air quality and result in illness and reduced productivity.[36] Finding and fixing common faults can be integrated with an ongoing building management plan and lead to 16% energy savings from commissioning existing buildings.[37]	
DE	Investigate HVAC systems and components to ensure right-sized equipment with good part-load performance. Efficiency drops off rapidly for equipment loaded below 50% of capacity.[38] Optimise economy cycles and night purge modes[39] and ensure HVAC zones are appropriately sized and loaded to provide energy efficient HVAC operation.
OE	Actioning occupant complaints helps to assure occupants their feedback is of value and promotes open and continuing communication.
IEQ	Good building management practices, such as regular maintenance of HVAC components, filter replacement and coil cleaning can optimise energy efficiency[40] and improve indoor environment quality.[41]
AC	Maintaining offices within a narrow temperature band may consume excess energy without necessarily improving occupant comfort. Providing low-energy adaptive comfort opportunities for occupants and adjusting tenant agreements to facilitate a wider temperature band can provide comfort benefits, often achieved in naturally ventilated buildings.[42]
INDOOR ENVIRONMENT QUALITY This node focuses on IEQ parameters that are influenced by HVAC systems and how integration with other nodes can facilitate improved building performance.	
DE	IEQ parameters such as temperature, relative humidity, air velocity, and carbon dioxide should be regularly measured to indicate if HVAC systems are providing optimum conditions for occupant comfort. Actively use IEQ results to help identify if other design elements may be impacting IEQ (for example building fabric, glazing, or shading elements).
OE	Temperature has a direct impact on the satisfaction and productivity of occupants; however the ideal temperature can vary between individuals and groups depending on preference and activity. Providing temperature control of ±2°C may increase work performance by 3-7% and could be achieved with energy-efficient desk-mounted devices.[43]
BM	Poorly maintained HVAC systems are common and are associated with increased prevalence of building-related illness.[44] Implement an IEQ management program incorporating ongoing professional IEQ monitoring and physical inspection of HCAV equipment and ensure results inform building management practices to facilitate continual IEQ improvement.
AC	Tenant agreements and fit out guidelines can set out requirements for IEQ testing before and after any fit out works to prevent negative impacts on IEQ and ensure that tenants and contractors are made aware of their responsibilities.
BM: Building Management DE: Design Elements OE: Occupant Experience IEQ: Indoor environment Quality AC: Agreements and Culture	

OCCUPANT EXPERIENCE This node focuses on the occupant experience as a result of HVAC system performance. Understanding the experience of occupants can help identify potential problem areas, inform building management practices, and guide initiatives to improve energy and IEQ performance.	
DE	Use the occupant experience survey to assess whether occupants are aware of HVAC controls and other design elements such as operable windows, blinds, shading elements, or vents that can impact energy efficiency and thermal comfort.
IEQ	Conduct a regular occupant experience survey to check thermal comfort and satisfaction with air quality and compare results against IEQ measurements to identify potential problem areas.
BM	Measuring air quality (carbon dioxide, carbon monoxide, particulate matter, VOC.s Formaldehyde) can show levels of toxins and air quality inside buildings that are impacting the health of occupants. Air flow and ventilation rates are important to ensure adequate levels of fresh air are entering the building.
AC	Provide education on low-energy comfort options available to occupants and consider implementing a clothing policy that allows staff to adjust clothing choices to suit ambient conditions.
AGREEMENTS AND CULTURE This node focuses on how lease arrangements and office culture can impact building performance through interactions with heating, ventilation and air-conditioning systems.	
DE	Repair and alterations clauses can allow a building owner to withhold consent for alterations that negatively impact the energy efficiency or indoor environment quality of the premises. Energy performance of tenants or of building systems can also be considered in rent and rent review clauses to encourage energy efficient HVAC design and operation.
OE	Actively using results of the occupant experience survey to identify issues and respond to occupant needs will improve health and productivity. Occupants are less susceptible to environmental stressors when well-being needs, such as sensory variability and supportive workplace cultures, are met.[45]
IEQ	Fit out guidelines can specify materials and equipment requirements for tenancy and base buildings areas to ensure IEQ performance is not compromised. Tenant agreements can be used to enforce compliance,.
BM	Tenant agreements and good communication between building stakeholders can assist with aligning HVAC plant operating schedules to occupancy hours to ensure equipment is only operated when required.
BM: Building Management DE: Design Elements OE: Occupant Experience IEQ: Indoor environment Quality AC: Agreements and Culture	

In the next section we highlight the objectives for each node. These have been distilled from the literature, tested in partner buildings, and build on the above insights regarding barriers to accessing data. The sample summaries that follow demonstrate the complexities of taking a holistic approach to building performance evaluation, and the need for a systematic approach to inquiry in order to avoid missing opportunities. The node objectives are as follows:

Design Elements

- *Monitoring and Control Technology*: To investigate the type of monitoring and control systems suitable for the building and ensure they are tied into the reporting process – Basic metering options available at reasonably low cost allow building operators to manually monitor energy use for specific equipment (such as boilers and chillers) or in a defined area (such as a particular floor or tenancy). Advanced energy monitoring and control technologies offer more detailed monitoring, control and reporting options and can interface with other building systems and meters.
- *Lighting*: To investigate the type of lighting system installed and to identify areas for potential improvement in technologies used – Lighting systems are made up of a number of subsystems, which each contribute to the efficiency and suitability of the overall system. It is important to consider other nodes of the *Performance Nexus* as, for example, the most energy efficient bulb will not necessarily deliver lower energy use optimally if the space

is already over-lit, if lights are left on when a space is not in use, and if lighting systems are poorly maintained.

- *Heating, Ventilation and Air-Conditioning*: To investigate the configuration of the current HVAC system and identify areas for improvement – There is an increasing expectation that HVAC systems will be energy efficient while also meeting high indoor air quality and comfort standards. Features of HVAC systems that should be considered include economy cycles when conditions are suitable, variable speed drives for pumps, the replacement of constant air volume systems in fans by variable air volume systems, HVAC zoning, and the size of the system. Other initiatives to consider include efficient duct designs and layouts, the use of energy recovery systems, and selecting efficient equipment with a high coefficient of performance. These can contribute to further energy savings and ensure the system is well suited to occupant requirements.
- *Other Plant and Equipment*: To investigate if efficiency initiatives for other plant and equipment have been implemented or can be improved – Using high efficiency pumps and fans, and motors with variable speed drives, can deliver significant savings. Other choices to consider include options for escalators and elevators (such as standby power, efficient control algorithms, regenerative braking systems, and alternative use of stairs), hot water systems (such as efficient fixtures), switching off unnecessary computers, reducing and consolidating equipment, and improving the server environment.[46]
- *Building Fabric*: To investigate if the building fabric can be further optimised for climatic conditions to improve occupant satisfaction. Building fabric and structure refers to the roof, walls, and fenestration, as well as external shading features and other exterior elements. These features affect both the energy use and physical environment inside a building. They can contribute to a number of problems associated with poor indoor environment conditions, such as poor thermal comfort, poor ventilation, problem lighting and glare. Implementing passive energy efficiency strategies (such as insulating external walls, retrofitting with efficient glazing, adding external shading features, and altering the reflectivity of the building fabric so that it is optimised for the climate) can help reduce solar heat gain and better control daylighting. Operable windows may also contribute to natural ventilation and energy efficiency when implemented as part of a ventilation strategy.
- *Tenancy Design and Fit Out*: To investigate if the design and fit out is conducive to energy efficiency and occupant satisfaction. Options include open plan form, surface colour, noise controls, plant installations, internal blinds and partitions, and location of walkways. There can be individual controls over indoor environment conditions such as temperature and lighting, with controls in accessible locations and education of occupants about use.

Occupant Experience

- *Perceived Productivity*: To identify areas and systems that may contribute to dissatisfaction in the workplace. Occupants who are dissatisfied with indoor environment conditions are more likely to say that these affect their productivity. Productivity is influenced by a complex interaction of physiological, psychological, social, managerial and individual factors[47] and is inherently difficult to define and to measure in an office

environment.[48] Therefore proxies such as perceived productivity, health complaints, and absenteeism can be used instead to assess building performance in relation to productivity. Studies have also shown that lower job satisfaction rates are linked to higher rates of absenteeism[49] and staff turnover.[50] The *Performance Nexus* does not directly ask staff to rate their productivity, but rather how supportive the environment is for productivity.

- *Communication and Reporting*: To investigate if systems are in place to provide occupants with feedback about building operation, and to identify if occupants are satisfied with how issues related to the feedback they provide have been resolved. When occupants feel heard and feel as if they have some control over their comfort, they may be more likely to tolerate temporary discomfort.[51]
- *Training, Education and Guidance*: To investigate whether occupants are aware of design elements in a building that might contribute to improved satisfaction, and how much they know about using individual controls for these elements. Effective training and education for occupants on energy efficient behaviour and correct building operations is essential if buildings are to perform optimally. The way occupants interact within a building can have impacts at a tenancy level, but base building energy consumption can also be affected. When occupants are properly informed and engaged in building operation, low energy designs can achieve high rates of occupant satisfaction.
- *Use of Controls*: To investigate whether occupants use individual controls to modify their environment. Occupants can dramatically affect the energy performance of a building through their interaction with design elements and building operation. Controls may be available for features such as lighting systems, HVAC, external shading features, internal blinds, and power management features. There is growing evidence that some degree of individual control is important for occupant satisfaction and well-being. Perceived comfort increases when occupants have some control over their environment, and even small personal adaptive changes can greatly improve comfort.[52]

Indoor Environment Quality

- *Manual IEQ Monitoring*: To provide a basic level of understanding of the indoor environment and identify problem areas. Basic IEQ parameters, such as temperature, lighting levels and carbon dioxide, can be monitored using handheld equipment by suitably trained facilities management or building management personnel, or potentially by a suitable occupier representative. Handheld equipment is somewhat inaccurate, although it can be a low cost way to help identify potential problem areas and provide a basic level of understanding of the indoor environment when performed regularly and systematically. It is important to ensure equipment is regularly calibrated to avoid incorrect readings. Basic-level testing should be performed by building managers on a regular basis, supported by advanced-level testing, periodically and whenever issues are discovered using basic-level testing.
- *Specialised IEQ Monitoring*: To establish a detailed understanding of the indoor environment, and to inform commissioning or tuning activities in the building. More sophisticated measurement of IEQ parameters by environmental services contractors provides optimal outcomes for indoor environment

quality and occupant satisfaction. Measured parameters may include the abovementioned factors as well as chemical and biological testing using advanced monitoring equipment by specially trained operators. Testing may be a once-off measurement or as part of a planned monitoring strategy, however ongoing measurement provides a greater understanding of the indoor environment and can help deliver optimal performance improvements.

- *IEQ Management Programs*: To determine if there is a planned IEQ management strategy. This includes consideration of the extent of IEQ building management programs that are sufficient to provide the necessary certainty of measurements and results, and to manage buildings for optimal outcomes. Similarly to energy management programs, ongoing measurement and management of IEQ inside buildings beyond the usual risk assessment levels delivers optimal results and can improve overall performance.
- *Health and Well-Being*: To investigate the extent of data on health and well-being in the buildings. Although physical IEQ parameters do not directly quantify productivity, they do assess factors that can directly affect the health, well-being and potential productivity of building occupants. Considerations include the type and extent of health and well-being data collected, such as data on absenteeism and health costs, which can be crosschecked with IEQ measurements (although it needs to be recognised that taking sick leave is more tolerated, even encouraged, in some organisations). Health complaints and reported IEQ issues related to factors such as thermal comfort, visual comfort and air quality can be tracked and reviewed.
- *Reporting and Communication of Results*: To establish the extent of documentation of IEQ and how it is communicated within and beyond the building. Reporting and communicating IEQ results to key stakeholders and decision-makers can ensure maintenance practices are improved to help achieve indoor environment and occupant satisfaction outcomes. Considerations include the extent of communication of the collected data with building owners, operation and maintenance personnel, contractors, and tenancy managers.

Building Management

- *Operation and Management Practices*: To investigate if key operation and management practices are being used to help improve energy performance and occupant satisfaction. Considering that some of the principal sources of inefficiencies in commercial buildings are HVAC and lighting technology, it makes sense to examine these areas first to identify if significant efficiencies can be achieved, before outlaying money on major refurbishments. Matters to consider include aligning equipment runtimes to occupancy schedules, identifying if equipment is the right size, and ascertaining whether passive design features such as operable windows and external shadings are being used when suitable.
- *Reporting and Evaluation*: To investigate if the performance of design elements is monitored and if data from reporting practices are fed into decision-making processes. Data on building performance can indicate when design elements are operating unnecessarily, which can lead to immediate savings. Considerations include whether key performance metrics are measured and with what frequency, and if performance targets are set. These can include energy, IEQ or occupant satisfaction targets. Questions consider whether data reporting is

user-friendly and actionable so that it facilitates good decision-making processes by building management.

- *Maintenance and Cleaning*: To investigate if maintenance practices are conducive to energy efficient operation and improved indoor environment quality. Even the most efficient buildings will consume excess energy if they are not maintained efficiently. Matters considered include the existence of planned maintenance strategies that implement preventive maintenance rather than maintenance in reaction to faults or breakdowns, and the extent of maintenance documentation to ensure good knowledge transfer. They also include previous modifications that have altered maintenance and/or cleaning schedules, and evidence of good cleaning procedures (for example, of fans, dampers and condenser coils).
- *Commissioning and Tuning*: To investigate which systems within the building have undergone commissioning and what the level of understanding is of the building's history and dates of commissioning, re-commissioning or retro-commissioning. Commissioning generally takes place in the first year following the delivery of a new building, but existing buildings may undergo re-commissioning and retro-commissioning to improve performance or resolve problems that may have occurred over time. Considerations include the regularity and extent of commissioning and subsequent tuning, including lighting and HVAC, which are common sources of faults.
- *Management Personnel, Communication and Education*: To establish the key stakeholders responsible for building management, and the existence of incentives and education programs to encourage improved building performance. The ownership and management structures of buildings can have a significant impact on the performance, and different stakeholders have different interests in the space. Considerations include the existence of training for management personnel, as lack of awareness and education may prohibit uptake of energy efficiency actions.
- *Procurement*: To investigate if procurement practices encourage energy efficient equipment and improved IEQ. Matters considered include whether procurement practices specify that upgrades and refurbishments should meet predetermined energy efficiency requirements. It is possible to specify that suppliers of products or services to the building must meet minimum environmental performance standards, and that tenancy fit-outs use low-toxicity materials and furnishings.

Building management practices such as regular cleaning and maintenance are integral to energy efficiency and improved occupant satisfaction. Image: Lisa F. Young

Agreements and Culture

- *Lease Agreements*: To investigate whether the terms of the lease facilitate good indoor environment quality and energy efficient operation of the building. It is important to ascertain a building's ownership and leasing structure (whether owner-occupied, single tenanted or multiple tenanted), as this will determine the potential for lease agreements to be used to improve building performance. Considerations include rent and outgoings (a gross lease lessens the incentive for individual tenants to improve energy performance); financial incentives; rent review clauses, which can require tenants or owners to meet certain energy efficiency targets; and the term of a lease. They also include break and relocation clauses, which can facilitate environmental upgrades; and repair and alterations clauses, which can allow a building owner to withhold consent for alterations that reduce a building's energy efficiency or indoor environment quality.
- *Organisational Culture*: To investigate how supportive the various building stakeholders' corporate cultures are of sustainability and energy efficiency. The way that different companies engage with energy efficiency strategies is influenced by their organisational culture. If companies are not defining environmental objectives as a corporate commitment at a management level it is unlikely energy efficiency will be seen as a priority. Matters considered include how the behaviour of staff in a building is linked to building management processes, and how this is linked to the occupying organisation's approach to communication, monitoring and evaluation.
- *Communication and Education Initiatives*: To investigate the types of communication, education and behaviour change programs in place in the building. Many stakeholders can be involved in the management and operation of a building and communication breakdowns between these stakeholders may occur. Considerations include the communication between building owners, managers and tenants, and the extent of meetings and participation in building management committees that discuss building performance, and documented feedback to stakeholders on building performance.
- *Ratings, Mandates and Incentives*: To investigate the type of performance tools and rating systems used in the building, and access to incentive programs. A wide range of rating systems designed to improve the performance of new and existing buildings can be used to structure this investigation. Considerations include whether occupiers are demanding higher performance, requests for action on mandates and incentives such as environmental upgrade agreements, and the extent of any requests for financing to help fund environmental improvements to existing buildings.
- *Commitments and Targets*: To investigate the existence of commitments and targets related to energy and indoor environment quality performance. Matters considered include the extent of targets for building performance measures in areas such as energy, IEQ performance and occupant satisfaction; public disclosure of goals and targets; and the existence of energy management plans. Questions also examine whether energy services companies have been engaged to meet targets through an energy performance contract, and whether these also focus on meeting indoor environment quality targets to ensure energy efficiency initiatives do not negatively impact upon occupant experience.

The research team experienced a number of challenges when seeking to access data on the performance of commercial buildings in the course of researching the *Performance Nexus* nodes. These challenges highlight barriers that must be overcome in the process of obtaining necessary data to enhance the performance of existing commercial buildings in Australia, namely:

- *Potential risks of liability due to underperformance*: The research team was often faced with difficulty in accessing data across the nexus due to the fear that this data might uncover underperformance that in turn may cause risks to various building stakeholders. In a market where space is increasingly leased with expectations about environmental performance, owners are reluctant to share data before successful results can be shown. This has been a key barrier to the research project's efforts to support the industry to improve energy performance efforts. In response the team focused on collecting and reviewing data confidentially, according to a clear structure that set out the key performance data that needed to be collected.
- *Time and funding pressures*: For older buildings where a facility or building manager is responsible for multiple buildings, the priority is often to ensure that the building is comfortable and operating adequately rather than seeking to improve its performance. While new-build or high-profile buildings attract attention and funding, these are the exceptions for Australian building stock. Given the rising costs of energy and greenhouse gas emissions this may change in the future, with a greater focus being placed on reducing the energy consumption of existing buildings in a way that delivers multiple benefits.

Energy efficiency initiatives such as encouraging occupants to use stairs instead of elevators can be supported and reinforced by focussing on organisational culture in conjunction with communication and education initiatives.
Image courtesy of NDY.

- *Privacy risk*: It is important when collecting data about occupant experience to recognise that questioning people about their perceived productivity and health in the workplace may be a problem if the answers they give can be perceived to affect their position in the organisation. In some workplaces there may be restrictions on such interaction with occupants, which may lead occupants to give false answers out of fear of repercussions if management were to identify their comments. Hence such questionnaires need to be administered in a way that keeps results anonymous, either through an online platform, or through a third party under confidentiality requirements, such as a university with its ethics requirements.

Sample Summary of Detailed Case Studies

40 Albert Road, South Melbourne, VIC (Szencorp)

The Szencorp building is an industry-leading example of an energy efficient refurbishment supported by good building management practices, ongoing indoor environment quality testing and post-occupancy evaluations.

This has helped reduce energy consumption by 65 per cent compared to pre-refurbishment levels and maintain consistently high performance over a period of years.[53]

The refurbishment of the building included a wide array of energy efficient design elements and extensive energy metering connected to a quality building management practices.[54] Good building management practices including commissioning, continual monitoring, and open communication of performance to building stakeholders, has helped to continually refine building systems so as to deliver high energy efficiency and improved building performance.

Comprehensive occupant surveys and IEQ measurements undertaken in 2006 and 2009 indicated good indoor environment quality and high levels of occupant satisfaction.[55] Importantly, where results indicated any dissatisfaction, this was actively used by the building owner to identify issues and improve performance. For example, this process helped to identify that increased education about the building controls, and occupants' ability to influence these controls, could contribute to improved satisfaction.[56]

This case study highlights the benefit of considering multiple nodes of the *Performance Nexus* and analysing performance across multiple years.

BUILDING PROFILE

- 5 storeys, 1,215 m^2
- Constructed 1987

DESIGN ELEMENTS

- High quality building management system
- Sub-metering – 59 individual meters to monitor energy use
- Occupancy sensors – interface with lighting and HVAC
- T5 lamps and electronic ballasts
- Full-height, double-glazed windows
- External shading

BUILDING MANAGEMENT

- Ongoing tenant feedback informs continuous performance reviews
- Automating the process by building analytical 'smarts' into the building management and metering systems
- Public accountability – 'warts and all reporting' of building performance is published annually

OCCUPANT EXPERIENCE

- Occupant Surveys (2006, 2009)

AGREEMENTS AND CULTURE

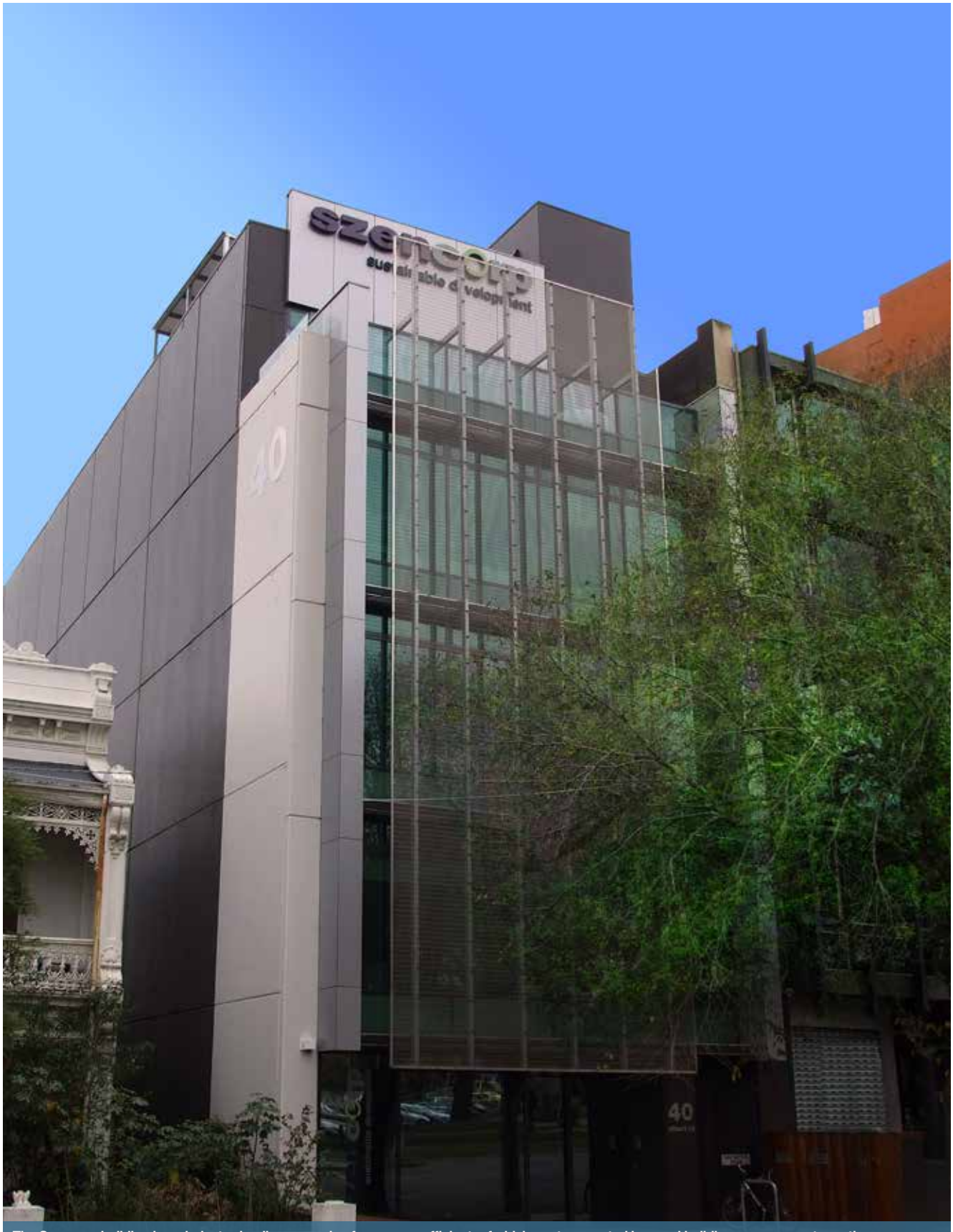
- Communication and education
- Transparent reporting process

INDOOR ENVIRONMENT QUALITY

- Comprehensive IEQ testing (2006, 2009)

KEY OUTCOMES

- 65 per cent energy reduction
- Maintained high occupant satisfaction and perceived productivity
- Maintained high indoor environment quality
- 5 Star NABERS Energy
- 6 Star Green Star Office Design v1



The Szencorp building is an industry-leading example of an energy efficient refurbishment supported by good building management practices, ongoing indoor environment quality testing and post-occupancy evaluations.
Image courtesy of Szencorp.

QV.1, 250 St Georges Terrace, Perth, WA

The QV.1 Building in Perth is a 43-storey office tower constructed in 1991. The building owners have implemented a long-term indoor air quality (IAQ) management program focused on continual monitoring and improvement that has helped secure a 5 Star NABERS IE Rating.

The program consists of periodic air quality assessment as well as physical inspection of HVAC plant and equipment, which helps to identify future problems and facilitates the analysis of trends in performance over time.[57] Good building management practices ensure these results are actively used to improve maintenance and operational practices, and to guide preventive measures such as regular coil cleaning, filtration replacement, damper adjustment and cleaning practices.[58] This improves both energy efficiency and occupant health.

Long-term carbon dioxide measurements across all floors in combination with assessment of HVAC system operation has also allowed building management to fine-tune outside air supply to ensure consistently lower median and peak carbon dioxide concentrations throughout the building; equivalent to a 150 per cent improvement on Australian Standard 1668.[59]

Additionally, tenancy fit-out guidelines specify that testing will be undertaken before and after any fit out works to prevent negative impacts on air quality. This ensures that tenants and contractors are made aware of their individual IEQ responsibilities. A Green Committee, comprised of building management staff and sustainability representatives from tenant organisations, keeps occupants informed of energy and IEQ performance and provides a forum to collaborate on future initiatives.

This case study highlights the benefits of creating strong links between indoor environment quality measurement, agreements and culture, and good building management practices, ensuring IAQ results feed into building maintenance and operation procedures.

BUILDING PROFILE

- 43 storey, 60,500 m^2
- Constructed 1991

DESIGN ELEMENTS

- High quality building management system
- Active CO_2 monitoring
- Sub-metering
- Energy efficient HVAC plant and equipment, including VSD, economy cycle
- Zoned HVAC (internal, intermediate, and perimeter)
- Efficient lighting system, including photosensors

IEQ

- Long-term IAQ management program
- Physical inspection of HVAC components
- Tenancy re-fit testing

BUILDING MANAGEMENT

- IAQ results inform building management practices
- Excellent maintenance and cleaning practices
- Good documentation and knowledge transfer processes

AGREEMENTS AND CULTURE

- Tenant meetings communicate IEQ results and importance.
- Tenancy fit out guide
- Tenancy re-fit IEQ testing

KEY OUTCOMES

- 5.0 Star NABERS IE Rating
- 5.0 Star NABERS Energy Rating

Good building management practices and a long-term indoor air quality management program focused on continual monitoring and improvement has helped secure a 5 Star NABERS Indoor Environment rating for QV.1.
Image Courtesy of QV.1 Management

Trevor Pearcey House, Canberra, ACT

Trevor Pearcey House, owned by Australian Ethical Investment (AEI), is a refurbished two-storey building originally constructed in the 1980s. It represents a leading example of passive design principles coupled with good building management and effective occupant education to deliver a comfortable and productive workspace.

Individual control of comfort systems is available to more than half the building occupants,[60] so AEI conducts formal 'how the building works' sessions for new staff to ensure occupants understand how to operate the building in a comfortable and energy efficient manner. These sessions have improved occupants' understanding of the building, and contributed to high employee satisfaction.[61] An initial post-occupancy evaluation in addition to internal staff surveys and feedback processes have helped identify IEQ issues that were contributing to occupant dissatisfaction, and this has allowed building management to quickly respond to issues.[62]

The refurbished building delivered significant energy and water use reductions, resulting in cost reductions of $22,500 per year.[63] Good post-construction commissioning also identified design and mechanical issues that had energy and IEQ impacts and helped contribute to improved building performance.[64] Initial energy reduction targets were set for the post-refurbishment building, and energy use is now monitored and reported annually via the company's Sustainability Report.[65] These measures have resulted in a high performance energy efficient building that also provides a high quality environment for occupants. Occupants play an active role in operating the building and can take initiative to improve comfort conditions, resulting in high satisfaction and low energy use.

BUILDING PROFILE

- 2 storey, 1,100m^2
- Constructed in 1980s

DESIGN ELEMENTS

- Natural ventilation strategy
- Operable double-glazed windows
- Building management system
- Natural daylighting with external shading

BUILDING MANAGEMENT

- Post-construction commissioning
- Reporting energy use (annually)

OCCUPANT EXPERIENCE

- BUS Occupant Survey
- Annual staff survey

AGREEMENTS AND CULTURE

- Organisational commitment to sustainability
- Initial energy reduction target
- Sustainability Committee
- Occupant education
- Building user guide

KEY OUTCOMES

- 52 per cent energy reduction[66]
- Rated in the top 11 per cent of office buildings for user comfort and satisfaction (BUS Survey)[67]
- Positive feedback with regard to productivity, health and comfort
- 6 Star Green Star Office Design v2

Trevor Pearcey House is a leading example of passive design principles coupled with good building management and effective occupant education to deliver a comfortable and productive workspace.
Images courtesy of Australian Ethical Investment Ltd.

Conclusion

This project has focused on creating a tool, the *Performance Nexus*, to assist efforts to improve the energy performance of existing commercial buildings while fostering a productive environment, using five key interdependent factors. The tool has been developed through research, stakeholder workshops, and trials with partners, to identify the key metrics of a building's performance that need to be considered when designing an intervention. The project suggests that the tool is a low cost, low complexity approach that can be used across the sector and around the world to encourage the greening of existing commercial buildings through a focus on enhanced productivity.

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Sustainable
Built Environment
National Research Centre

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. Established on 1 January 2010, the SBEnrc is a key research broker between industry, government and research organisations for the built environment industry.

The SBEnrc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building with significant support from public and private partners around Australia and internationally.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of Centre outputs. The Centre integrates research across the environmental, social and economic sustainability areas in programs respectively titled Greening the Built Environment; Developing Innovation and Safety Cultures; and Driving Productivity through Procurement.

Among the SBEnrc's objectives is to collaborate across organisational, state and national boundaries to develop a strong and enduring network of built environment research stakeholders and to build value-adding collaborative industry research teams.

SBEnrc Core Partners:

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