

# **The Performance Nexus - A framework for improving energy efficiency in existing commercial buildings by considering a whole-of-building approach**

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## **SUMMARY**

Efforts to reduce carbon emissions in the buildings sector have been 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 much greater economic returns than energy savings. Reducing energy demand in green 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 paper outlines an investigation into these factors and focuses on better understanding the performance of and interaction between: design elements, internal environmental quality, occupant experience, tenant/leasing agreements, and building regulation and management. In doing so the paper presents a framework for improving energy efficiency in existing commercial buildings by considering a range of interconnected and synergistic elements.

## **KEYWORDS**

*Commercial buildings, Energy performance, Occupant satisfaction, Building management and operation, Tenant agreements, internal environmental quality.*

## **1 INTRODUCTION**

The built environment has a significant impact on the environment and on human health. Buildings are responsible for substantial flows of energy and resources in society and may also have a significant impact on the health and well being of occupants, who spend an increasingly large proportion of their time indoors. The ‘green building’ movement has emerged in recent years - partly in response to the numerous health issues associated with indoor air quality (Burge et al., 1987; Redlich et al., 1997) - as a community of practice working to minimise the impact of the built environment on people and the natural environment to provide productive work places.

Although ‘green’ buildings are generally expected to provide a number of benefits such as reduced energy/water demand and improved occupant health and productivity outcomes, the actual performance of green buildings is often variable (Newsham et al., 2009), and health and productivity improvements are not always achieved (Kato and Murugan, 2010) or even quantifiable. Identifying opportunities to improve the energy performance of a particular building is inherently difficult as for instance interactions between environmental performance and indoor environment quality are not always apparent or well understood (Leaman and Bordass, 1999). Furthermore, commercial buildings are complex systems tenanted by equally complex occupants whose needs are diverse and continually changing, bringing into the mix a range of possible tenant agreements and building management

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systems. At this stage no single framework has been developed to inform efforts to improve the energy performance of existing commercial buildings that takes into account the complexity of the whole system of the building.

Such a framework is vital as the built environment industry has become very interested in going beyond design and construction opportunities, to consider optimising such a 'whole of building' performance, which includes the productivity of occupants during the operating life of a building (Leaman and Bordass, 2001). Productivity is an important indicator of the success or failure of a building since it determines the extent to which the building enables its occupants to function within it (Sinopoli, 2009). Productivity is also of significant interest due to the high cost of human labor, which may represent as much as 80 per cent of total business costs (Garnys, 2010) and has been estimated at over 100 times the expenditure on energy (Romm and Browning, 1998). Therefore, theoretically even a small improvement in productivity can have enormous financial benefits and may also quickly offset the cost of improving the office environment in many cases (Seppänen and Fisk, 2006).

In a general sense, productivity can be defined in terms of the quantity of outputs (work achieved) in relation to the inputs required to achieve that work (labour and materials). However, the notion of productivity in an office environment must consider other factors, such as quality of work, that are not as easily measured (Haynes, 2007). Furthermore, the specific outputs of one organisation may vary greatly from another, making it difficult to develop a common measure of productivity (Fisk and Rosenfeld, 1997). Additionally, there are myriad variables that may influence the experience of the occupant and so affect productivity, such as lighting; temperature; air quality; ergonomics; office politics; and many other factors. The extent to which each of these factors affects productivity is not easy to establish and in this project the focus is on understanding the occupant experience. Further, considering the relationship between productivity and energy performance, not all 'green' design elements or updates will support a productive environment for occupants. It is possible that efforts to improve energy and water efficiencies may negatively impact occupant experience. For example, although open plan offices can allow natural light to reach a greater number of workspaces and encourage increased interaction with colleagues, such layouts can result in distractions from noise and people passing if not considered in the fit out design.

Within this context, a desire exists within the green buildings community of practice to further investigate the issue of health and productivity within existing 'green' commercial buildings; a topic of focus as part of a current project (Project 1.1) within the Sustainable Built Environment National Research Centre (SBEnc) program 'Greening the Built Environment' (SBEnc, 2011). This research paper draws on results from this research inquiry into existing building performance, exploring the complexity of identifying and measuring a range of key considerations across five main nodes, as presented in the 'Performance Nexus'. This includes findings from a literature review, a survey pilot study, and stakeholder workshops with a variety of building designers, owners and occupiers, and building industry associations. The paper concludes with recommendations for embedding synergies within efforts to improve the energy performance of existing buildings and implications for future research.

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## **2 METHOD**

The research methodology for this project comprises a semi-qualitative, mixed method approach to explore the body of knowledge surrounding the improvement of energy performance in existing commercial buildings to identify apparent gaps. To date this has included a comprehensive literature review followed by stakeholder engagement workshops. Stakeholder engagement workshops were held during late 2011 in Brisbane, Perth and Townsville with project partners and interested parties, including engineers, architects, sustainability consultants, academic, government and project partners of the SBEnrc research project.

The workshops were used to draw from the knowledge and experience of project partners and identify a range of challenges for the research team to consider, ensuring the project was guided towards tangible outcomes. Workshop participants were guided through a facilitated process of identifying key considerations and priorities for the research team to explore. The workshop format was based on the ‘Collective Social Learning’ methodology designed by Emeritus Professor Valerie Brown (Brown, 2008). Participants were first asked to imagine the ideal green building, without limitations or consideration of barriers. Participants were then asked to identify enablers and disablers that help or hinder the full realisation of that vision. From here, participants were then asked to brainstorm what could occur to reduce the disablers and increase the enablers. Key findings included the need for a multi-variate approach that goes past simply an energy performance focus to include aspects of occupant experience and behavior, tenant agreements and legal instruments, and the internal environmental quality.

## **3 RESULTS**

### **Summary of Literature Review findings**

The review of literature on whole of building performance and green buildings identified several important considerations. For the purpose of this short paper, they are summarised here:

- There are many examples of buildings – in Australia and overseas – that are achieving good outcomes with regard to one or more areas including improved environmental performance (in particular energy conservation), indoor environment quality (IEQ), and occupant experience (e.g. Turner and Frankel, 2008; Paevere, and Brown, 2008; Sustainability Victoria, 2009),
- There is a recent emergence of literature documenting the challenge of complex interactions existing between design elements, IEQ and occupant experience (for example Leaman and Bordass, 1999; Bell et al., 2003), and
- Where environmental performance gains are made, this is not necessarily accompanied by improvements in IEQ (Leaman et al. 2007) or in health and productivity (Kato and Murugan, 2010).

### **Summary of Workshop findings**

Strategic engagement with project partners and interested parties was used to draw upon the knowledge and experience of the green building community of practice. A full description of workshop findings is provided in the project report. In summary, the first key finding of the workshops was a suite of perceived needs for applied research that could directly inform and enhance industry and government practices and policies, as follows:

- Evidence of the benefits of green buildings and the importance of post-occupancy evaluation of buildings;
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- Clarity surrounding how to holistically measure the performance of buildings, and designing buildings for future use and adaptability/flexibility;
- A need for standardised post-occupancy evaluation methodologies;
- Communication of the benefits of increased collaboration and partnership between stakeholders (architects, engineers, consultants, tenants, owners, occupiers); and
- Education for operators of buildings and stakeholders.

When considering the post-occupancy evaluation of commercial buildings, particularly existing buildings, workshop participants determined that building performance and occupant productivity were influenced by complex interactions between:

- Design elements (e.g. HVAC systems, lighting, windows, etc.)
- Indoor environment quality (e.g. air quality, noise, lighting quality, etc.)
- Occupant experience (e.g. occupant satisfaction, perceived productivity, etc.)
- Building management (e.g. monitoring and control systems); and
- Tenant agreements (e.g. ‘green leases’, quiet possession, etc.)

#### **4 DISCUSSION**

From the literature findings and workshop results, it is clear that current ‘high performance’ design for a ‘green building’ does not necessarily result in whole-of-building high performance. Despite strong achievements in energy conservation in commercial buildings to date, reducing energy demand and associated greenhouse gas emissions in a way that supports greater productivity is currently poorly understood. One of the key barriers to whole-of-building performance improvement appears to be that the relationships involve a set of complex and interdependent factors.

Relationships exist between design elements and building management systems, and between these and IEQ. These factors all influence, for better or worse, the building occupants’ experience. Occupant behavior may also be influenced by a variety of tenant agreements, which in turn may influence design elements and IEQ, and so on. In order to create high performance buildings, all of these nodes and their various interactions must be considered. Furthermore, each node must reinforce and support the others. If the IEQ implications of design elements are not properly considered, and if measures aren’t in place to ensure tenants operate design elements correctly, high performance objectives will not be met. If building managers are not operating a building as it is intended, high performance objectives will not be met.

In considering the interrelationships between the five nodes identified during the workshops (design elements, occupant experience, indoor environment quality, building management and tenant agreements), a whole system framework was developed to highlight the dynamic and complex relationship between the nodes. The ‘Performance Nexus’ represents a proposed framework for the consideration of five key areas of commercial building performance. The nodes of the Performance Nexus build upon and draw connections between existing tools, such as NABERS and Green Star, which are well-recognised tools that have been successful in increasing the uptake of more energy-efficient and ‘green’ design. As such, it is important to build on the success of these tools and strengthen the interactions between elements of building design, management, and behavior to help deliver further energy and health/productivity improvements.

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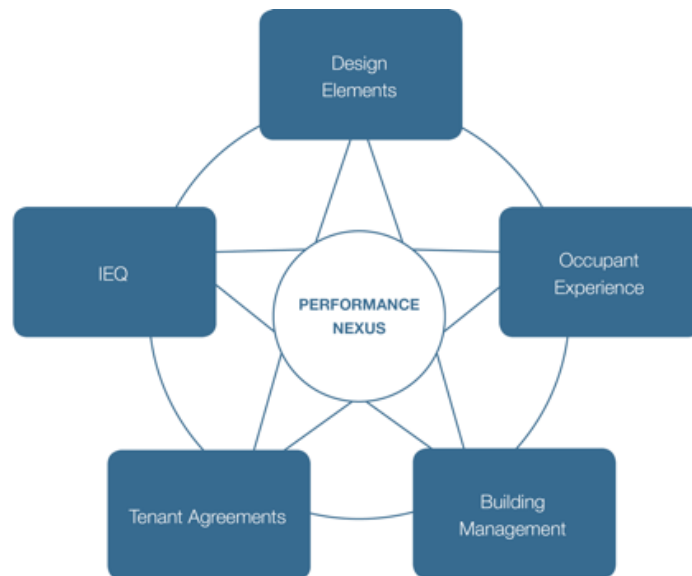


Figure 1. Performance Nexus Diagram

The Performance Nexus represents a framework for understanding how to achieve a high performance commercial building, and is being investigated as a framework for improving the energy performance of existing commercial buildings. Each of the nodes interacts with other elements to influence the performance of buildings, and understanding, where:

- **Design Elements:** Design elements can impact the indoor environment, occupant experience and can dictate what building management and tenant agreement options are available. Design elements include features such as HVAC systems, lighting/ day-lighting methods, building materials and layout.
- **Indoor Environment Quality:** Indoor environment quality is influenced by the design elements and can have a significant impact on the health and productivity of building occupants. Building management practices influence IEQ and tenant agreements can be used to influence IEQ outcomes. IEQ parameters of interest include:

*Physical measurements*

- Air temperature
- Relative humidity
- Air speed
- Ambient Sound
- Illuminance

*Chemical measurements*

- Carbon dioxide
- Carbon monoxide
- Particulate matter
- Formaldehyde
- VOCs

*Biological measurements*

- Airborne microbials

- **Occupant Experience:** The experience of occupants in the buildings being studied is an important measure of the performance of the building. Surveying building occupants to gather data on their experiences with the building’s indoor environment, design elements, and building management practices provides insight into the influence of the office environment on respondents’ perceived productivity.
- **Building Management:** Building management practices can have a profound impact on the overall functioning of the building, impacting the indoor environment and occupant experience. Building management can include the operation of an actual Building

Management System (BMS) and a facility of building manager on site responsible for the maintenance and operation of the building.

- **Tenant Agreements:** A range of existing legal instruments can influence the performance of commercial buildings and underpin greater energy conservation and improved IEQ across the full lifecycle, including design, operation and management, and demolition. There are a number of emerging efforts to use legal mechanisms and instruments to encourage greater energy conservation and improved IEQ, including ‘green leases’, quiet possession; inherent defects (including obligations to repair and keep in the same condition); covenants to repair; break clauses; relocation notices; gross versus net rental leases (e.g. tenants metering); and single versus multi tenanted conditions and what arises with regard to care of the building.

Within the current project, extensive case study analysis process is currently being undertaken, along with the collection of data in existing partner buildings, to further inform this framework.

## 5 CONCLUSIONS

It is concluded that the Performance Nexus diagram provides a useful framework for considering core components of whole-of-building performance, and their interactions. It also provides a platform to investigate opportunities for embedding synergies within building performance evaluation tools to ensure interrelationships between the five nodes of the Performance Nexus are considered and optimised:

- For design professionals, the framework provokes consideration of a whole system design approach to achieve high performance buildings.
- For facility and building managers, the framework can assist in understanding where environmental performance may impact upon occupants, and where occupants may impact upon environmental performance.
- For a government and policy audience, the framework can assist in understanding where leverage points exist that may strengthen environmental and health/productivity outcomes, and highlights the importance of tenant agreements in attaining high performance buildings.
- For building occupants, the framework can assist in considering the merits of potential leased spaces as places conducive to productive work environments.

It is concluded that consideration of each of the five nodes of the Performance Nexus is necessary to strengthen the positive interrelationships that exist between environmental performance, indoor environment quality and occupant experience in pursuit of high performance buildings. Future research will involve collection of building data under each of the five nodes to further inform this framework for whole-of-building performance.

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## 6 REFERENCES

- Bell, J., Bergman, R., Garcia-Hansen, V., Mabb, J., and Morawska, L. 2003. Occupant health and productivity: an Australian perspective. In: Summary Book of The CIB 2003 International Conference on Smart and Sustainable Built Environment (SASBE 2003), 19-21 November, 2003, Brisbane.
- Brown, V. 2008. Leonardo's Vision: A guide to collective thinking and action. SENSE, Rotterdam.
- Burge, S., Hedge, A., Wilson, S., Bass, J.H. & Robertson, A. (1987) Sick Building Syndrome: A Study Of 4373 Office Workers, *Annals of Occupational Hygiene*. 31(4A), 493-504.
- Fisk, W.J. and Rosenfeld, A.H. 1997. Estimates of Improved Productivity and Health from Better Indoor Environments. *Indoor Air*, 7(3), 158-172.
- Haynes, B.P 2007. An evaluation of office productivity measurement. *Journal of Corporate Real Estate*, 9(3), 144-155.
- Garnys, V.Y.T 2010. A productive day at the office?. *The Australian Building Services Journal*, 2, 40-41.
- Kato, H. and Murugan, A. 2010. Performance & perceptions of green buildings: A study based on the experiences of working, renting and owning Green Star certified buildings. Institute of Sustainable Development and Architecture, Bond University, Australia.
- Leaman, A. and Bordass, B. 1999. Productivity in buildings: the killer variables. *Building Research and Information*, 27(1), 4.
- Leaman, A. & Bordass, B. 2001. Assessing Building Performance in Use 4: The Probe occupant surveys and their implications. *Building Research & Information*, 29, 129-143.
- Leaman, A., Thomas, L. and Vandenberg, M. 2007. Green Buildings: What Australian building users are saying. *Ecolibrium*, 6(10), 22-30.
- Newsham, G.R., Mancini, S. & Birt, B.J. 2009. Do LEED-certified buildings save energy? Yes, but... *Energy and Buildings*, 41(8), 897-905.
- Paevere, P. & Brown, S. 2008. Indoor Environment Quality and Occupant Productivity in the CH2 Building: Post-Occupancy Summary. CSIRO Report No. USP2007/23, available at [http://melbourne.vic.gov.au/Environment/CH2/Evaluation/Documents/CH2\\_Post\\_Occupancy\\_Summary.doc](http://melbourne.vic.gov.au/Environment/CH2/Evaluation/Documents/CH2_Post_Occupancy_Summary.doc)
- Redlich, C.A., Sparer, J. & Cullen, M.R. 1997. Sick-building syndrome. *The Lancet*, 349(9057), 1013-1016.
- Romm, J. and Browning, W. 1998. Greening the building and bottom line. Rocky Mountain Institute Boulder, CO.
- SBEncr 2011. Project 1.1 - Design and Performance Assessment of Commercial Green Buildings. Sustainable Built Environment National Research Centre, available at <http://www.sbenrc.com.au/research/greening-the-built-environment/design-and-performance-assessment-of-commercial-green-buildings>
- Seppanen, O. A. and W. J. Fisk 2006. Some Quantitative Relations between Indoor Environmental Quality and Work Performance or Health. *HVAC&R Research*, 12(4), 957.
- Sinopoli, J. 2009. How Do We Measure The Performance Of A Building? Smart Buildings LLC, available: [www.smart-buildings.com/pdf/howdowemeasure0809.pdf](http://www.smart-buildings.com/pdf/howdowemeasure0809.pdf).
- Sustainability Victoria 2009. Employee Productivity in a Sustainable Building: Pre- and Post-Occupancy Studies in 500 Collins Street, available at [www.resourcesmart.vic.gov.au](http://www.resourcesmart.vic.gov.au)
- Turner, C. and M. Frankel 2008. Energy Performance of LEED for New Construction Buildings. New Buildings Institute, Vancouver, WA.
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