Campus green buildings: Policy implications for the implementing, monitoring and evaluation of campus green building initiatives

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Abstract. Universities play a significant role in creating a sustainable future and transforming societies. As universities move towards environmental sustainability, a valuable contribution from the higher education sector is expected to accelerate the transformation of our cities. Campus green building initiatives are dramatically changing the way campuses are planned, designed, built and managed. However, prioritizing and evaluating campus green building initiatives seems understudied. The study offers an insight into the advantages of implementing green building initiatives in building operation and maintenance in campuses and provides an excellent proving ground to enhance the performance of campus buildings. A set of frameworks and policy implications in terms of investment decision making, facility management, operational quality control, and planning and design are proposed to improve the effectiveness of green building initiatives at higher education buildings. This study sheds light on performance evaluation of campus buildings, which could be used as a reference for the design, construction and operation of sustainable campus buildings. Energy dashboards, revising the automated operation of buildings, facilitating changes in staff and student behaviours, and operational energy performance certification were identified as important campus-wide energy policies.

1. Introduction

A change in mindset through a sustained, long-term effort seems necessary to achieve a sustainable future. One way to this mindset transformation is using green higher education buildings as sustainability showcases to provide examples of experimenting to solve sustainability issues. Buildings provide the physical space and facilities for campus activities, and are an important part of a university campus, while being responsible for 30% of global greenhouse gas emissions and 40% of total energy use worldwide (D. Hsu, Meng, Han, & Suh, 2017). The contribution of the building industry also accounts for one-sixth of the world's freshwater consumption, one-quarter of wood harvesting, and two-fifths of material and energy resources (Glyphis, 2001). The concept of sustainability and green buildings is a recent response to optimising building energy and resource consumption (Balaban & de Oliveira, 2017).
Greening university buildings and promoting the integration of environmental and sustainability principles enhance sustainable developments through implementing long-term sustainability goals into teaching, research, community engagement, and management of university buildings. Green higher education buildings used as testbeds could create comprehensive solutions to mitigate the current environmental challenges while providing safer and more comfortable environments with optimised use of natural resources. Green buildings at universities promote sustainability efforts in communities and support research on sustainable development issues.

1.1. Current campus sustainability studies

Campus sustainability development has attracted a number of studies in the past which attempted to propose frameworks to achieve sustainability in higher education and improve campus sustainability performance. Some studies reflected on the progress of green campus development in developing countries including initiatives related to energy and resource efficiency [4]. With an emphasis on economic sustainability, Amran, Nabiha Abdul Khalid [5] focused on ideas and solutions to promote sustainable development for the business community, particularly in developing countries such as Malaysia. Amaral, Martins [6] also presents a review of methods and tools for campus sustainability management. One study by Blewitt [7], reported the relationship between low-carbon economic development, social sustainability and higher education learning based on economic, technological and skills need criteria. Carter and Dediwalage [8] reported that the current science education is in isolation from the globalisation theory in terms of social and cultural aspects. A framework to achieve campus sustainability was proposed by Alshuwaikhat and Abubakar [9] and emphasised on university Environmental Management System (EMS); public participation and social responsibility; and promoting sustainability in teaching and research.

To train university teachers to apply sustainability criteria to their respective disciplines, Aznar Minguet, Martinez‐Agut [10] reported on a questionnaire survey on the current baseline situation for introducing sustainability across the university’s curricula. Mcmillin and Dyball [11] promoted the provision of a collaborative space within the curriculum for students, academics and managers to critically reflect on university’s sustainability performance to accelerate sustainability transformations. Sustainability development research can be broadly categorised into six classes, sustainable campus operations, sustainable research, public outreach, cooperation between institutions, curricula and sustainability reporting [12]. However, the majority of past efforts have had a great emphasis on environmental assessments when reflecting on current campus sustainability status [13].

As previous studies show universities have the capacity to significantly influence the future of carbon neutrality in the building sector by adopting sustainability initiatives. Universities further benefit by adopting sustainability principles by reducing reduce operating costs and facilitate healthier and more productive staff and students as a result of sustainability transformations. Nonetheless, there is a research gap in terms of policy implications in campus planning and a systematic approach for the implementing, monitoring and evaluation of campus green building initiatives. Accordingly, this paper discussing relevant policies and rating tools that go significantly beyond minimum performance requirements from universities, particularly in Australia.

2. Policy implications for campus green buildings

The impact of the proposed green building initiatives can influence decision-makers and bring changes in policies. Improved efficiencies in operations and maintenance practices lead to increased occupant comfort, extended building life, and improved building safety. Operations and maintenance practices are the critical aspects of meeting energy improvement targets. Four strategies and frameworks are proposed to enhance the performance of campus buildings: (1) investment decision making, (2) facility management, (3) operational quality control, and (4) planning and design.
2.1. Investment decision making

The traditional energy data included the analysis of monthly and annual utility bills collected by utility companies or energy auditors [14]. The available data from the traditional energy data collections provide only a limited insight into building energy performance patterns. With the recent technological advancement of energy dashboards, energy use data can be automatically collected with high spatial and temporal resolutions. The introduction of smart meters and energy dashboards has significantly contributed to understanding building energy consumption by providing fine-grained energy consumption data [15].

The availability of comprehensive building energy information allows proper analysis and efficiently planned energy policies and energy efficiency strategies [16]. Comprehensive campus energy data also provides an opportunity to develop energy benchmarks to revise and evaluate the energy performance of campus buildings. While universities accommodate facilities for a variety of complex research and teaching activities, campus buildings are often designed as mixed-use buildings including spaces for laboratory research, administration offices, teaching rooms, and the like, with different energy demands. The data collected with high spatial resolution offers a deeper insight into energy use patterns and requirements. Instrumentation through energy sub-metering spurs on energy analysis by breaking down building aggregate energy data. High temporal resolutions of energy use intensity offer a deeper understanding of energy consumption patterns in buildings, consequently enabling building users and facility managers to identify the problematic areas. Energy dashboards with high temporal and spatial resolution should become an integral part of campus energy efficiency initiatives. Reference frameworks and guidelines need to be developed to inform policy-makers about the effectiveness of different energy data resolutions, functionalities, and capabilities in promoting campus energy efficiency.

2.2. Facility management

Campus buildings are increasingly managed and operated by the Building Management System (BMS), which controls the operation of lighting and HVAC (heating, ventilation and air-conditioning) in buildings. BMS is an intelligent microprocessor-based controller that monitors and controls the building’s technical systems and services. BMS is typically equipped with sensors that provide eyes to the operation system to actuate an optimal control of the indoor environment [17]. Building operational performance and occupant safety and comfort are ensured with BMS control systems [18] as BMS considers multiple building subsystems such as security, networking, HVAC, and lighting to ensure high building operational performance and occupant safety and comfort. Control actions of HVAC systems often take place at central facilities, ignoring individual preferences. Previous research has shown that once occupants have no control over their indoor environmental quality, perceived discomfort significantly increases [19, 20]. Setting indoor fixed temperatures and the full automation of HVAC operation often result in higher occupant thermal discomfort and dissatisfaction due to overcooling or overheating buildings. Thermal comfort was found to be the top complaint in buildings where occupants had limited or no control over their working environments [21].

In non-residential buildings where occupants do not pay utility bills, occupants may not be enthusiastic about energy savings and operate air-conditioning when rooms are unoccupied or when windows are open. However, when given appropriate options, building users tend to limit their use of air-conditioning due to several economic, as well as numerous non-economic factors, such as their proximal and distal altruistic beliefs [22]. Providing an option for occupants to have some degree of control over the operation of HVAC systems and windows are low-cost measures that lead to significant energy and cost savings. Therefore, different occupant attitudes need to be considered to avoid the concurrent operation of HVAC, and natural ventilation through opened windows, while enabling the free running of buildings during periods when the climate is suitable for natural
ventilation [21]. Data-driven decision-making algorithms that allow the manual operation of windows and HVAC systems, while avoiding the concurrent use of the air-conditioning and natural ventilation, should be implemented in building HVAC controls. An optimized algorithm for easy switching between the automated and manual HVAC operations which deactivates air-conditioning once windows are open, or rooms are unoccupied, is a prerequisite to improving campus energy efficiencies further.

Occupant behavior has been shown to significantly influence the energy consumption of HVAC, lighting, and appliances in buildings [23]. Energy unaware behaviors can contribute to an additional one-third of the total energy consumption in buildings [24]. Accordingly, occupant behavior and control of various devices such as artificial lighting and HVAC systems are considered to have a significant impact on building energy consumption.

Another viable strategy is transparency in energy performance data to identify areas of concern more effectively and consequently, to call for decisive actions to improve energy performances [25]. There is often a large gap between the intended and the measured post-occupancy building energy performance [26]. The communication of reliable and first-hand energy performance data not only to facility managers but also to building users through accessible energy dashboards is a critical aspect of improving building energy efficiency [27].

In building science, human, building and computer interactions (HBCI) describe the inter-relationships between human beings, buildings, and computers (see Figure 5.1). Often in buildings, one of the two elements, human or computer interactions with buildings is underutilized. Campus buildings are often centrally managed and ignore occupant preferences, and psychological and physiological differences. Central automated operation of buildings often results in a high level of energy wastage due to overcooling, overheating and underutilizing natural ventilation when the climate is suitable. Traditional building operation is based on human and building interactions, which also often results in energy wastage in buildings like those on university campuses where occupants are not responsible for paying for their utility bills, which may result in wasting energy through uncaring behaviors. Leaving a room with lights switched on, or running AC when windows are open are two examples of the most common environmentally unsustainable behaviors by building users.

![Figure 1. Human-building-computer interactions adapted from [1]](image)

One way of improving HBCI interactions to optimize both energy use and occupant satisfaction in buildings is a two-way communication of data. If real-time building energy data is communicated to building users, it motivates the change of behaviors and enhances the responsibility of building occupants. Similarly, if occupant real-time sensations and requests for changes in indoor environmental conditions are clearly communicated to BMS, on-time actions would significantly increase occupant satisfaction and, consequently, productivity and health.
The communication of energy data to building users is an effective strategy to incentivize energy-efficient occupant behavior. Presenting real-time and monthly energy use to building occupants offers an excellent proving ground for them to understand their impacts on energy consumption. A detailed real-time energy breakdown motivates building users to implement energy efficiency strategies. For example, users can track the effects of energy saving efforts, such as turning off the lights at night and using energy-saving modes on their computers.

Staff and student engagement in conjunction with changes in building energy operations are vital to improving building energy efficiencies. User-centered building operation and maintenance is the key to realizing the full energy savings potential of operations and maintenance efforts. User-centered building operations and maintenance, adequate training for maintenance staff, and creating energy efficient cultures for building occupants are essential components of campus energy efficiency initiatives. Smart meters and sustained occupant engagement can be used as social marketing for occupant behavioral change to ensure that goals of reducing peak demand and overall energy consumption are achieved [29].

Keeping occupants informed not only about energy use but indoor environmental data, such as temperature, would further engage occupants and encourage energy behavior change. The lack of information available to building users about savings and benefits has been widely recognized as a barrier to promoting green buildings in Australia [30]. Informing occupants and involving them in the operation of buildings seems to be an effective energy efficiency initiative in campus buildings. Considering human factors and user-centered design further pushes campus energy efficiency through the implementation of data-driven energy efficiency strategies. These arguments suggest that once HBCI is balanced, both occupant satisfaction and energy efficiency are optimized.

2.3. Operational quality control

The concept of green buildings is broad and needs to be probed to be fully understood, particularly in the debatable scope of green building certifications. There is a danger that green building labels become more advertisements for marketing purposes for building owners and a commercial product for certifying agencies. The boom of green certifications has been sustained by the development of building standards and codes that are supposed to promote environmentally friendly buildings. The deceptive use of green building certification to encourage a false perception about the environmental impact of buildings has a negative impact on the future of green buildings, mainly if obtained from private organizations.

However, the market for green building certification in the building industry, and particularly in universities, is emerging all over the world. In Australia, Green Star certifications are awarded to buildings that fulfil rating and certification standards in various areas such as sustainable sites, energy efficiency, water efficiency, materials and resource use, indoor environmental quality, emissions, and project and environmental management. Primarily, the purpose of obtaining green building certifications is to provide convincing proof that buildings have reached futuristic environmental goals and are performing at their best potential. The existing performance gap between the predicted and the measured energy performance in many green-certified buildings sets up a framework for investigating and finding practical solutions. Many buildings obtain certifications during construction and pre-occupation stages based on intended design and project documentation and are not based on actual performance during post-occupation.

The major impediment restraining green buildings appears to be costs, and obtaining green certifications creates an additional cost elevation due to implied elaborate processes of certification. Subsequently, more is expected from green certifications than just a label. The development of green buildings has a direct link with imposing rigorous standards of performances and impartial certification bodies, which will help users and investors understand how much more superior the
performances of green buildings are over conventional structures. Many green certifications seem to be deceptive, which often arises from a misunderstanding of the definition of green buildings and certifications. Many green buildings fail to achieve their proposed performance goals during post-occupancy stages. All over the world, the popularity of green buildings is growing, and as such, there is a concern to understand how green a green building is. Green certifications should provide more explicit information about what is green, and what benefits building investors and users would gain by green buildings.

Deficiencies in building operations and maintenance practices result in reduced performance efficiency and increased operating costs and energy use, as well as low occupant satisfaction. Operational performance certification is a means of rating building performances during post-occupancy periods. Obtaining operational green building performances, concerning both energy and occupant satisfaction on a regular basis evaluates the real performance of buildings but also identifies measures to improve building performances. Some countries have opted for a period of five to ten years for the validity of performance certifications [31]. Another rationale behind regular operational green building performances is that buildings age, and occupants change over time; therefore, building performance certifications have limited validity timeframes.

Energy performance certifications during post-occupation evaluate the actual energy performance of buildings including operational and managerial deficiencies. Operational energy performance certifications in particular use metered energy data and actual energy consumption, as well as the percentage of energy use from renewable sources [32]. The degree of efficiency depends on many factors including: local climate; the design of the building; construction methods and materials; systems installed to provide HVAC or hot sanitary water; building appliances and equipment; and operation and maintenance practices [31]. Energy performance certification can help reach energy targets and improve energy efficiency by implementing rules to achieve a specified level of energy performance. Some other associated benefits of energy performance certifications include lowering operation costs and improved documented information about the building, which can be used for future energy auditing [31]. Energy performance certification may also result in enhanced user awareness of energy and environmental issues to promote energy saving behaviors [33].

In the same way, occupant satisfaction performance certifications also offer an ample opportunity to overview and enhance building performances. Only after the building is occupied and facility management takes control of building operations can one investigate whether the building has been tailored to a particular user [34]. Admittedly, the current industry seems to be unable to detect and deal with post-handover problems effectively, and often slow and imperfect managerial actions from facility management result in a failure to make significant improvements. Following problem detections in buildings, effective communication between building occupants, designers, contractors, and facility management needs to be undertaken to control and manage issues and achieve remarkable improvements. What is more, lessons learned from occupant perspectives from buildings benefit both organizations and also the whole industry by identifying problems that need more attention, related mainly to new building technologies and operation techniques. The culture of regular occupant feedbacks, energy evaluations and continuous improvement measures, if adopted by the industry, is a promising green campus initiative to assist in enhancing the quality of the living-built environments and energy efficiency in both new and existing buildings.

2.4. Planning and design

Predominantly, natural and mixed-mode ventilation are not firmly established practices in Australian non-residential buildings. Many researchers had emphasized the barriers to the practice of green buildings strategies; however, little research has been conducted investigating natural ventilation in Australian buildings. Active cooling is required to provide comfort in all Australian climates at least for some time of the year, yet the use of passive cooling, which utilizes the cool outdoor temperature
for cooling indoor environments is climatically appropriate for at least some time in the year for many Australian climates. Nonetheless, less is known about reasons why natural ventilation, particularly in non-residential buildings has not been used to its full potential. A well-designed ventilation system that operates a combination of natural ventilation and active cooling (also known as mixed-mode) avoids significant energy consumption of year-round air conditioning while maximizing occupant comfort. With consideration of climate change scenarios and the predicted global warming, it is very likely that the number of days that need active cooling would increase; subsequently cooling energy demands, and electricity peak loads would also grow in the near future. As a result, relying on natural ventilation for delaying or eliminating the predicted increasing energy demands has become critically important.

As discussed in previous chapters, the lack of thermal comfort models and lack of an optimized framework for control systems are two significant challenges facing mixed-mode ventilation in buildings. Investing in mixed-mode ventilation in campus buildings provides an excellent opportunity for testing these relatively new systems and learning from living laboratories to develop both thermal comfort models and optimized control systems, thereby allowing an integrated design approach at university levels to make buildings greener and more energy efficient. More campus buildings with mixed-mode ventilation are recommended to offer case studies for researchers and building performance assessors for further investigations, and to improve energy efficiency at campuses.

Regulatory frameworks and Australian rating systems are another parallel measure that can further increase the popularity of natural ventilation in Australian non-residential buildings. Building performance certifications should also address ratings for natural ventilation and free running of buildings. The ambition of green buildings is to cut building energy demand as much as possible, but currently, many buildings with only air-conditioning systems are awarded the highest available green building ratings in Australia. It seems clear that the current energy conservation regulations and standards, mainly when reviewing green certification documents, have failed to fulfil long-term climate protection policies.

It is noteworthy that a building that has a strong response to climate is significantly difficult to find in Australia. Australian building designers even those interested in green buildings priorities first low costs, international styles, and neighborhood rather than thermal comfort and energy consumption. Australian green building ratings seem unable to administer aspects such as embodied energy or free running of buildings [35]. In the residential building sector, Australian governments have been more successful in taking the lead by introducing the Nationwide House Energy Rating Scheme (NatHERS) and providing ratings for homes based on potential heating and cooling energy use, using the NatHERS simulation software.

The introduction of NatHERS as an initiative has had significant impacts on the energy efficiency of residential buildings, yet the establishment of consistent objectives and processes within the planning system underpins standard legislation and policy to improve energy efficiencies of non-residential buildings. Similar energy rating schemes addressing building rating based on free running in non-residential buildings seems imperative to push green building revolutions forward at a faster pace. The current green star ratings for non-residential buildings are based on the efficiency of appliances relatively more than the physical properties of buildings or utilizing mixed-mode ventilation. This issue has resulted in many of the highest rated green buildings still relying on year-round active cooling systems. By pushing green building designers away from international styles and somewhat towards applying localized natural ventilation design principles, advocates will pick up the baton of innovative designs and reinventing Australian green buildings.
3. Conclusion

Under campus-wide sustainability initiatives to manage energy consumption and CO2 emissions, implementing corporate strategies, policies, and operational procedures are necessary. The key carbon management strategies include monitoring building energy use changes and patterns, monitoring and analysis of energy efficiency measures and refurbishments, developing and implementing energy reduction awareness among staff, students and the wider community, and developing energy reduction guidelines. Based on this study, some key carbon management strategies for campus building design and operation were proposed including monitoring building energy use changes and patterns, monitoring and analysis of energy efficiency measures and refurbishments, developing and implementing energy reduction awareness among staff, students and the wider community, and developing energy reduction guidelines. The study suggests some policy implications for campus green buildings in terms of investment decision making, facility management, operational quality control, and planning and design. The policies discussed in this study should guide policymakers and relevant stakeholders on the essential steps in implementing robust and ambitious schemes as a means of improving building performances.

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