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Valuing the environmental performance of historic buildings

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ABSTRACT

Buildings account for at least one third of global greenhouse gas emissions and existing buildings constitute 98 per cent of Australia's building stock in any one year. Hence, existing buildings, many of which have high cultural heritage value, play an important role in addressing climate change and other key environmental challenges. Despite convincing evidence that historic buildings are high environmental performers, most environmental improvement initiatives within building and planning systems continue to focus heavily on operational performance. They generally fail to value broader indicators of environmental sustainability such as resource depletion, material waste and pollution. When these broader environmental benefits of maintaining existing buildings are not considered or appropriately valued, historic fabric is often removed or demolished, often replaced by newer 'green' buildings. This not only results in the loss of important cultural heritage, but also a substantial opportunity for maximising environmental outcomes. This article reviews national and international literature on environmental and cultural sustainability to highlight the broad environmental benefits of conserving historic buildings; how they can be valued; and what further research is required to ensure building and planning systems adequately address the role that buildings play within the challenge of anthropogenic climate change.

KEYWORDS

Adaptive reuse; building conservation; climate change; environmental sustainability; historic buildings; life cycle assessment (LCA)

Introduction

A growing body of work exists that explores the impact of climate change on historic sites (McIntyre-Tamwoy 2008; Smith and Rogers 2014). Research shows that impacts range from increased storm events which can damage buildings and sites, rising sea levels which can render historic neighbourhoods unliveable, and rising temperatures which can impact rare collections, demand deep renovations for improved temperature control and, in extreme cases, result in fatalities (Wait and Rankin 2016; Gannon 2012; The Guardian 2018). These are just a few examples of how climate change affects the management of historic buildings. To prepare for climate disasters, heritage managers around the world are undertaking climate change risk assessments and enacting action plans (PAHSM 2017; APT 2016).

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On the flip side, heritage managers are beginning to assess how historic buildings contribute to anthropogenic climate change. Without this examination, heritage managers are not able to fully understand or promote the value of conserving historic buildings over replacing them with new ‘green’ developments, and building conservation practice would disappear along with high-carbon industries as consumers demand better environmental outcomes.

The cultural cost of losing historic buildings would be unacceptable, so the question must be asked: what are the environmental benefits of prioritising new ‘green’ buildings over existing building stock, and what does this crisis moment; and what responses to extreme climate change mean for cultural sustainability? To answer these questions, best practice environmental sustainability needs to be defined, and the environmental value of historic buildings recognised.

Objective

This article examines the role of historic buildings within the climate change challenge and discusses ways in which historic buildings are strong environmental performers. By reviewing international and national literature in the fields of building conservation and environmental sustainability, we identify the environmental performance potential of historic buildings, and conclude with recommendations on how Australian building and conservation practice could be improved to ensure best practice cultural and environmental sustainability are achieved concurrently.

Cultural heritage

In Australia, historic buildings are valued as having cultural heritage significance (Australia ICOMOS 2013). In many countries best practice cultural heritage management is guided by the United Nations Educational, Scientific and Cultural Organization (UNESCO) who define cultural heritage as being both *tangible* and *intangible*. Tangible heritage relates to objects (e.g. buildings), historic places (e.g. landscapes), monuments and artefacts; whereas intangible heritage is associated with practices, representations, expressions, knowledge and skills. Often tangible assets are vehicles for interpreting intangible heritage; such as a building that may not have architectural value, but has intangible social value for a community.

While equally important aspects to consider, tangible and intangible heritage can present complex and separate managerial issues (Wain 2014). Similarly, Post-War buildings with curtain wall cladding, deep floor plates, minimal roof and under floor areas, and concrete and steel materials, present complex sustainability issues that differ from nineteenth century buildings. Accordingly, the scope of this article has been confined to issues relating to the management of nineteenth century buildings, which are of interest to the Australian and New Zealand contexts.

Best practice building conservation in Australia and across the globe is guided by the *Australia ICOMOS Charter for Places of Cultural Significance, The Burra Charter* (Australia ICOMOS 2013). The Burra Charter is a progressive document that has always recognised natural places as having cultural significance. Circa 2006, issues of climate change and environmental performance (as opposed to cultural connections to the environment) began entering heritage management dialogue (Barthel-Bouchier 2016). Prior to 2006, the intersectionality of cultural heritage and ecology focused on recognising that culture cannot be separated from land; that impacts on land have impacts on culture, and vice versa. More recently, the environmental focus has shifted toward the impact that buildings have on the natural environment, especially the role they play within the challenge of climate change.

Climate change

The Intergovernmental Panel on Climate Change (IPCC) is the world's leading authority on climate change issues. Since 1988, the IPCC have reviewed tens of thousands of research papers on climate science and regularly publish Assessment Reports (AR). At the time of writing there are five assessment reports, the latest being the IPCC AR5 (IPCC 2013-2014). Human induced climate change is, in short, the result of excessive levels of greenhouse gases (GHG) being released and trapped in the earth's atmosphere. These gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases (F-gases). Combined, these gases create a blanket around the earth, which results in increased air and sea temperatures. This is known as the *enhanced greenhouse effect*.

Contributing to the enhanced greenhouse effect is the unsustainable management of Earth's resources. When in balance, natural resources such as forests and the ocean act as carbon sinks, sequestering carbon dioxide and turning it into biomass. Excessive deforestation, agriculture and mining are just some activities which have resulted in the loss of 18.7million acres of forests per year across the globe (Bradford 2018) and ocean acidification leading to the wide spread death of coral reefs and sea life supported by them (GBRMPA 2018). The loss of forests and reefs result in more than species extinction; it also results in devastating feedback loops.

One example of a feedback loop is when unsustainable land use (such as native habitat loss to create arable land) leads to rising temperatures. These rising temperatures result in extreme weather events, which destroy ecosystems required to prevent temperatures from rising. To reduce the compounding effects of anthropogenic climate change and achieve ecological sustainability, humans need to act on all aspects of the feedback loop: resource depletion, land management and reducing GHG emissions.

Historic buildings and environmental sustainability

Existing buildings represent around 98 per cent of the building stock in Australia (ABCB 2016b) and thousands are heritage protected. Just in Victoria (Australia), more than 160,000 places are protected by a heritage overlay (HCV 2018). Given the long life span of buildings, the IPCC AR5 report states that retrofitting the existing stock is key to a low-emission building sector (Lucon, Zain Ahmed, and Bertoldi 2014)

The opportunity to retrofit a historic building depends on the cultural significance of the place. In Australia, places of World and National significance are protected by the *Environment Protection Biodiversity and Conservation Act* (1999) and usually demand the highest level of internal and external conservation. Places of State significance are protected by state-based Heritage Acts and demand similar levels of conservation. The majority of buildings are protected by local planning schemes, and only require the protection of exterior elements that are visible from the public realm. There are exceptions, such as when the interior of a place is specifically listed, and when proposed works, even if not visible from the public realm, detrimentally affect the significance of the place (DELWP 2018).

Buildings account for 32 per cent of total global end energy use (Lucon, Zain Ahmed, and Bertoldi 2014), so the increased effort to improve the operational energy performance of buildings has been incredibly important. Despite reports that it is difficult to improve the energy performance of historic buildings (Conejos et al. 2016), there are numerous case studies where this has been achieved successfully. Parliament House in Sydney (Australia) for example has enacted a 'Parliament House Sustainability Program', which has prevented the emission of approximately 72 tonnes of CO_2. The site benefits from 162 solar panels which have reduced non-renewable energy consumption by over 2,400 megawatt-hours (MWh/y) (Parliament of NSW 2018).

Given that carbon dioxide makes up around 65 per cent of global anthropogenic GHG emissions (Edenhofer, Sokona, and Kadner 2014, 7), it is crucial that CO_2 emissions from buildings are reduced. However, operational energy demand is just one source of the problem. Research shows that an enormous amount of GHG emissions and other environmental loadings can be indirectly associated with a building before, during and after it is operational (Treloar, Love, and Holt 2001; Langston and Shen 2007). For example, in discussing the environmental effects of the built environment, Crawford (2011) highlights pollution, resource depletion, and the production and disposal of waste as important environmental issues beyond operational performance that demand consideration.

Environmental performance of historic buildings

Crawford (2011) argues that if environmental sustainability is the true objective of a building project (rather than, for example, economic or time savings), then environmental factors beyond operational performance must be considered. Furthermore, Griffiths (2018) reminds us that environmental histories provide opportunities for rediscovering traditional solutions to the environmental crisis that Earth faces today.

Environmental history

In a growing field of research defined as environmental history, the research of conservation architects, historians and social anthropologists highlights how centuries-old knowledge on land management and traditional building design has been lost or colonised (Lerum 2015; Pascoe 2014; Griffiths 2018). Lerum writes,

> as one delves into the fertile ground between the future and the past, sincere interest in advanced building designs leads to an understanding of the necessity to learn from the past, to question the present and to build a sustainable future. (Lerum 2015, Introduction)

For Australians, questioning our colonial history is crucial if we are to learn from Aboriginal culture, which managed to sustainably maintain the environment for more than 60,000 years prior to colonisation. Pascoe write:

> Colonial Australia sought to forget the advanced nature of the Aboriginal society and economy, and this amnesia was entrenched when settlers who arrived after the depopulation of whole districts found no structure more substantial than a windbreak and no population that was not humiliated, debased and diseased. This is understandable because as evidenced by the earlier first-hand reports, villages were burnt, the foundations stolen for other buildings, the occupants killed by warfare, murder and disease, and the country usurped. It is no wonder after 1860 most people saw no evidence of any prior complex civilisation. (Pascoe 2014, 18)

While emerging and innovative research on sustainable building design is essential, it must also be remembered that traditional land management and building design techniques were also often highly sophisticated and may be relevant today. Building conservation provides an opportunity to rediscover traditional knowledge, conserve cultural heritage and contribute to improved environmental outcomes.

Passive design

Natural ventilation has been a human concern ever since humans made the relationship between sickness and poor air quality (Matson and Sherman 2014); and heating and cooling have always been essential for survival. Prior to the availability of reliable electricity, buildings were designed to be vented, heated and cooled using passive means.

In Victorian and Edwardian-eras, structures, sophisticated methods for venting, heating and cooling were informed by the science of thermodynamics: the relationship between gas, pressure and energy. In 1900, the engineering firm Robert Boyle & Son published 'The Boyle System of Ventilation' (Robert and Son 1900). It was one of many catalogues published by manufacturers and engineers in Europe at the time that detailed how passive ventilation could be incorporated into the design of a building.

The Boyle system was described as follows:

> The 'Boyle' system of ventilation is a natural one, and utilizes the never-ceasing movement or natural force which exists in the atmosphere as an unfailing motive power, in conjunction with the difference in temperature of the internal and external atmosphere. As applied to buildings, it consists of BOYLE'S PATENT Self-acting 'AIR-PUMP' VENTILATOR which removes the pressure of the external air from the top of the outlet shaft and creates, under every condition of the weather, a continuous and powerful exhaust at the higher parts of the building; combined with BOYLE'S IMPROVED AIR-INLETS, fixed at the lower levels, admitting the air directly through the walls in an upward direction at a low velocity, purified, and warmed or cooled as required, ensuring constant change of air and perfect diffusion of the fresh air-supply in strict accordance with the natural laws which govern ventilation … (Robert and Son 1900, 11)

In most buildings, the 'stack effect', described above, was used to create enough pressure for fresh air to be drawn in via wall and floor vents, or venting towers; through the building over a heating, cooling or purification source; and out via chimney stacks, stair wells, ceiling and roof ventilators (Figure 1). Ventilators and air inlets were often decorative and disguised by the aesthetic quality of a building. However, vents were not 'out of sight out of mind'. Occupants were required to operate elements (such as closing wall vents in winter or ensuring certain openings were larger than others, depending on the direction of the breeze); hence requiring occupants to understand how systems operated to maximise efficiency.

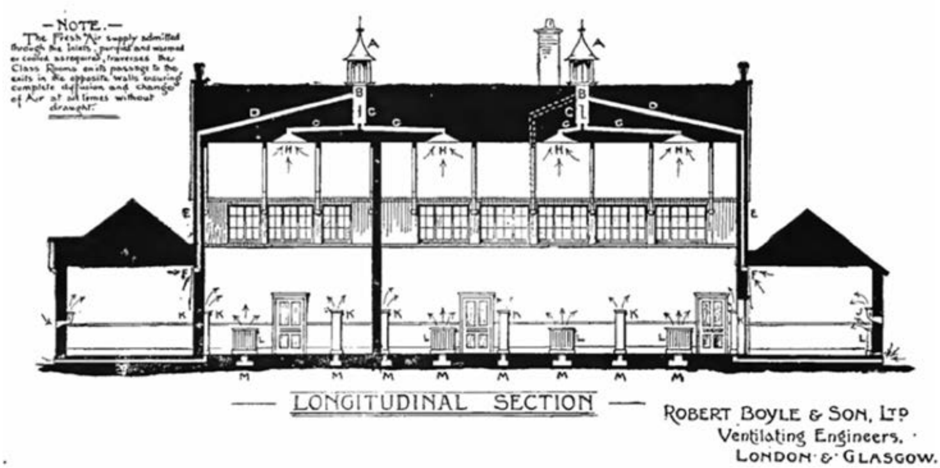

Figure 1. How ventilation was incorporated into a nineteenth century building according to the 'Boyle system of ventilation' (Robert and Son 1900, 50).

Lerum (2015) investigated several nineteenth century European buildings and meticulously details how sophisticated traditional knowledge was lost with the emergence of modernism, only to be rediscovered in the twenty-first century during the rise of 'environmentally sustainable design'. According to Lerum, the clean line aesthetic of modernism stripped away basements, attics, fireplaces and decorative building elements (such as wall vents, turrets and ceiling roses), which were all used to provide passive heating, cooling and ventilation to traditional buildings. An example of passive air-conditioning can be seen in the design for Parliament House Melbourne (Australia). In 1859, JG Knight devised a cooling system that eventually included a venting tower in the garden. The tower was concealed in the form of a decorative temple-folly and remains today (VHD 2018).

A review of Lerum's work, and common catalogues such as Boyle and Sons', reveals the value in investigating nineteenth century buildings, identifying what elements were originally designed to improve indoor environmental quality, and determine which elements can be restored. Restoring a building so it can passively heat and cool, as it was originally designed to do, would reduce its energy requirements; improve indoor air quality; and achieve positive conservation outcomes. Furthermore, Berg and Fuglseth (2018) make the point that when building occupants consciously engage with the efficient operation of a building, then behavioural change is possible, further increasing the opportunity to improve environmental outcomes.

Other passive forms of keeping nineteenth century buildings cool included window shades, verandas, and landscaping. Landscaped gardens were important for providing shade and cool environments around buildings. However, dirt roads have now been replaced with concrete and asphalt; garden spaces are generally smaller, if existent at all; and often surfaces are non-permeable. As temperatures have become more extreme due to anthropogenic climate change, urban environments are becoming 'heat islands' because concrete and other hard surfaces act as thermal storage, holding heat for long periods (Santamouris 2001, 48). Due to an increase in hard surfaces, stormwater (which ends up in the ocean) is more regularly polluted with debris and chemicals washed out in the rain. The heat island effect and water pollution are other examples of feedback loops, which could be improved if traditional landscaping was reinstated around buildings. The historic mansion, Rippon Lea in the suburbs of Melbourne (Australia), is an example of how sophisticated methods for water irrigation were developed in the nineteenth century. A lake was included in the garden design, which connected to stormwater pipes so water was always available to irrigate the substantial grounds, and rainwater tanks held water for use in the mansion. Recent plans to restore the intricate irrigation system aim to disconnect Rippon Lea from mains water, thus conserving both the environment and cultural heritage elements of the site (The Age 2003).

Nineteenth century buildings were designed prior to the availability of mains power and water, and relied on both simple and highly sophisticated means for keeping a site comfortable. Many of these passive systems have been compromised by unsympathetic alterations, and the knowledge of how they operated has been lost over time. Reviewing the original design of historic buildings and restoring original features may help to improve their environmental performance.

Embodied energy

The IPCC AR5 report (IPCC 2013-2014) states that in 2010 the operational energy use from residential and commercial buildings contributed 32 per cent of total global final energy use; and that across the globe, operational energy demand (i.e. the use of energy for appliances, cooking, space heating, water heating, cooling and other electrical equipment) averaged around 32.4 peta-watts per hour (PWh) (one petawatt is equivalent to one billion million watts, or 1,000,000,000,000 kilowatts). While these numbers are staggering, the same report highlights that most GHG emissions (6.02Gt) are indirect from electricity use in buildings (Lucon, Zain Ahmed, and Bertoldi 2014, 678).

Indirect energy is the energy required to support the production or supply of a service. For example, to provide energy to a house, a large amount of energy is spent in energy production, resource extraction, processing, manufacturing and transport. Embodied energy (EE) is a term that encompasses both direct and indirect energy requirements of a product through all processes (i.e. traceable backwards from the finished product to consideration of raw materials) (Treloar, Love, and Holt 2001) (Figure 2).

The IPCC AR5 report states that buildings account for 7 per cent of total direct global GHG and a much higher 51 per cent of global *final* (as opposed to operational) energy consumption. As demonstrated, focusing solely on operational energy demand will not

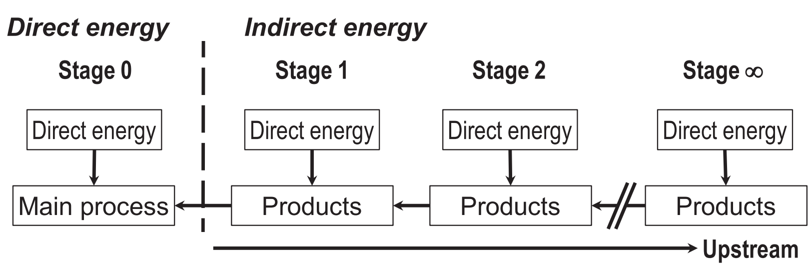

Figure 2. General model of embodied energy showing the main process, and associated direct and indirect energy requirements (Treloar, Love, and Holt 2001, 51).

satisfactorily address GHG emissions from the building sector, because operational energy demand is only a small percentage of the entire picture. To obtain more reliable data, and in turn enact more effective change, GHG mitigation efforts should consider the energy demand and GHG emissions associated with the full building life cycle. Considering EE is particularly important for the conservation of historic buildings, because this is one area where they perform extremely well environmentally. Adaptive reuse of a historic building will typically result in less GHG emissions than constructing a new building, because the majority of energy associated with extraction, manufacturing, transportation and construction using new materials is avoided. Using a comprehensive life cycle analysis technique, Rauf and Crawford (2015) have demonstrated that 'the longer a building lasts, the lower its annual life cycle embodied energy demand'. Rauf and Crawford conclude that by maximising the life of an existing building and its constituent materials, large demands for energy can be avoided.

Resource depletion, material waste and pollution

Traditional passive design techniques and embodied energy are ways in which historic buildings perform extremely well environmentally, but are not environmental indicators commonly recognised or valued (Boarin 2016; Conejos et al. 2016). In addition to these environmental indicators, historic buildings perform well regarding reducing resource depletion, material waste and pollution.

Conserving historic buildings for reuse means that virgin materials are not extracted from the Earth, and the demand for materials and the indirect energy, pollution and waste associated with a replacement building are automatically reduced. Furthermore, materials used to construct nineteenth century buildings are more likely to be renewable or less carbon intense, such as timber or bricks made from locally sourced materials, compared to modern highly processed building products.

At the other end of a building's life cycle, when a building is conserved rather than demolished, construction waste is prevented. Whilst recycling construction waste has become more common over the past decade, it remains that 40 per cent of waste in Australian landfill is from the construction industry alone (MRA Consulting 2016; Udawatta et al. 2015).

Conserving historic buildings with traditional techniques and materials also reduces the presence of harmful pollutants (Hunt and Suhr 2013; Crawford 2011). Volatile organic compounds (VOC) are regularly present in modern construction materials, such as glues and paints. Materials frequently off-gas for months or years post construction, impacting the health of occupants and releasing emissions into the atmosphere (Brown 2002). Traditional materials such as lime render, mineral paint, linseed putty and beeswax are all low-VOC materials commonly used to restore historic buildings. The use of these materials is safer for building occupants and the environment, and results in less pollutants (Hunt and Suhr 2013).

Quantifying the environmental impact of conserving historic buildings

While building conservators have long argued the environmental benefits of conserving historic buildings, the industry has suffered from a lack of quantifiable data. Research now shows that life cycle assessment (LCA) is one of the most effective methods for evaluating the environmental impact of historic buildings, as it is a systematic approach to assessing a product or service from cradle to grave. Assessments consider material extraction, transport of materials, the construction process, maintenance and eventual demolition (Berg and Fuglseth 2018). LCA is a powerful decision-making tool when considering the environmental benefits of restoring a historic building or replacing it with an energy-efficient new build. Limitations do exist however regarding the amount of available data for historic materials and consistency around data in general.

Norwegian researchers Berg and Fuglseth (2018) use LCA to compare the environmental benefits of (1) retaining a historic building without any upgrades; (2) sensitively upgrading the historic building to meet current Norwegian energy standards; and (3) constructing a new dwelling of a similar size and materials. The researchers found that the environmental pay-back period for replacing the historic building with a new, energy-efficient one is over 50 years; and that construction of the new building would cause 10 times more GHG emissions than refurbishment of the existing building.

Similarly, Rauf and Crawford (2015) used a case study building in Melbourne, Australia and LCA to demonstrate that the longer a building lasts, the lower its annual life cycle embodied energy demand. Their research is supported by the findings of Fay, Treloar, and Iyer-Raniga (2000) who found that for a residential building with a service life of 75 years, annual life cycle embodied energy decreased by 15 per cent compared to a building service life of 50 years. The decrease was 25 per cent for a service life of 100 years.

Case studies that use LCA for assessing the environmental performance of historic buildings are rare, but where they exist the results strongly support the argument that historic buildings perform well environmentally. LCA is especially relevant for comparing GHG emissions, but it is also possible to assess other impacts such as resource depletion, material waste and pollution (Crawford 2011; Dahlstrøm et al. 2012).

Discussion

Life cycle assessment is a technique that comprehensively analyses the environmental performance of a building, taking into consideration cradle to grave impacts. When used to compare the environmental impact of conserving a historic building over replacing it with a new energy-efficient one, studies show that conserving buildings typically results in substantially less adverse environmental impacts, thus achieving both environmental and cultural sustainability objectives.

Furthermore, conservators and historians have shown that conserving cultural heritage provides a cultural and educative opportunity founded deeply on the principles of environmental, cultural, social and economic sustainability. Many historic sites were designed with a sophisticated understanding of passive heating and cooling, and built from local or low-carbon materials. Restoring original features of a historic site can provide the opportunity to educate about traditional and sophisticated ESD techniques. Furthermore, historic sites provide the opportunity to utilize contemporary tools such as LCA to provide an evidence-based pathway toward a truly greener future.

Despite this evidence, building codes, planning policies and sustainability rating schemes across the globe continue to focus heavily on the operational performance of buildings, rather than broader environmental impact indicators such as embodied energy, resource depletion, material waste and pollution (Berg and Fuglseth 2018; Conejos et al. 2016; Akande 2015; Yung and Edwin 2012). The focus on operational performance is detrimental to historic buildings for several reasons. Not only are consumers ill-informed about the environmental value of conserving historic buildings (thus contributing to the demand for replacement with new builds), but also planning and construction systems fail to recognise and encourage conservation over new builds.

As an example, new buildings and major works in Australia must adhere to the National Construction Code (NCC), under which the Building Code of Australia (BCA) Parts 1 and 2 regulate building construction. If works apply to more than 50 per cent of an existing building (known as 'major works'), then the entire building must comply with the BCA. Major works to a heritage protected building must also be compliant with the BCA. In 2006, a new section (Section J) was added to the BCA with the aim of addressing climate change issues (ABCB 2016a). Section J is the only part of the BCA dedicated to addressing climate change, but it focuses solely on the operational performance of buildings and not broader environmental issues.

Similar issues exist with sustainability rating schemes, such as Green Star (Boarin 2016), which are powerful marketing tools that influence how consumers 'act green' but also mostly focus on operational performance and new products. Accordingly, even when a consumer recognises the environmental potential of conserving a building, the system that governs environmentally sensitive building and planning may work against them as it provides no mechanism for factoring in the embodied energy of the existing building.

Conclusion

The 2016 Paris Agreement (of which Australia and New Zealand are signatories) states that if temperature rise this century is not capped between 1.5 and 2 degrees Celsius above pre-industrial levels, then the impacts are almost certainly going to be catastrophic. Many scientists and researchers believe that 2°C is dangerously high and that more demanding targets are required. To truly address anthropogenic climate change, urgent action is required and recognising the environmental performance of historic buildings within building and planning regulations, and sustainability rating schemes, is one way that critical issues like this can be better addressed.

By reviewing existing literature on cultural and environmental sustainability, this article has emphasised the myriad of ways in which historic buildings are strong environmental performers. While national and international evidence exists to support this argument, existing building and planning regulations that seek to address environmental sustainability in Australia and across the globe continue to focus heavily on operational performance and new builds.

Reducing GHG emissions associated with operational performance is an important but small step towards seriously addressing the role that buildings play within the challenge of anthropogenic climate change. A paradigm shift in the Western understanding of ecological sustainability is required, where cradle to grave impacts need to be quantified and systematically addressed. Life cycle assessment provides the opportunity for this level of assessment and should be prioritised as part of any environmental sustainability analysis. Furthermore, research in the field of environmental and cultural history provides opportunities for relearning sophisticated traditional knowledge regarding environmental sustainability, much of which was lost due to colonisation, industrialization and excessive consumption of the Earth's resources.

This article highlights the need both nationally and internationally for a review of existing building and planning regulations, including heritage planning, and environmental sustainability rating schemes. Data gained from the review would not only provide a new pedagogical opportunity for conservation practice, but could also be used to develop a framework for an improved building and planning system that identifies and values the high environmental performance potential of historic buildings.

Disclosure statement

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