

# Book of Abstracts

## Architectural Science and User Experience How can Design Enhance the Quality of Life

55<sup>th</sup> International Conference of the Architectural Science Association

**2022**



ASA (ANZASCA)

### **Editors**

Dr. Parisa Izadpanahi

Dr. Francesca Perugia

Architectural Science and User Experience: How can Design Enhance the Quality of Life  
*55<sup>th</sup> International Conference of the Architectural Science Association*

**2022**

## Table of Contents

A Case Study for future re-use of buildings to reduce carbon .....	8
<i>Llewelyn Griffiths<sup>1</sup>, Emily Newmarch<sup>2</sup> and Fritha Powell<sup>3</sup></i>	
A comparative study between urban and rural play of Bhopal, India; to identify stimulating play environments.....	9
<i>Ar. Richa Raje<sup>1</sup>, Ar. Saurabh Ojha<sup>2</sup>, Ar. Akshaya Saravanan<sup>3</sup>, Ar. Priyanka Agarwal<sup>4</sup> and Ar. Ajit Kumbhar<sup>5</sup></i>	
A critical review of Biophilic design and its design framework .....	10
<i>Archie Patel<sup>1</sup>, Dr. Akari Nakai Kidd<sup>2</sup>, Dr. Astrid Roetzel<sup>3</sup> and Mark DeKay<sup>4</sup></i>	
A hygrothermal analysis of 6 Star envelope systems used in code compliant homes in Victoria .....	11
<i>Mark Dewsbury<sup>1</sup>, Freya Su<sup>2</sup>, Toba Olaoye<sup>3</sup> and Hartwig Kuenzel<sup>4</sup></i>	
A novel method established to convert Australian climate data for hygrothermal simulation .....	12
<i>Shruti Nath<sup>1</sup>, Mark Dewsbury<sup>2</sup>, Freya Su<sup>3</sup>, and Hartwig Kuenzel<sup>4</sup></i>	
A parametric approach to defining archetypes for an integrated material stocks and flows analysis and life cycle assessment of built stocks .....	13
<i>Katarina Slavkovic<sup>1</sup>, André Stephan<sup>2</sup> and Gildas Mulders<sup>3</sup></i>	
A parametric tool to quantify the life cycle embodied environmental flows of built assets .....	14
<i>André Stephan<sup>1</sup>, Fabian Prideaux<sup>2</sup> and Robert H. Crawford<sup>3</sup></i>	
A rapid relief architecture for primary schools .....	15
<i>Kate Poole<sup>1</sup> and Guy Marriage<sup>2</sup></i>	
A review of life cycle sustainability assessment studies of smart building management systems.....	16
<i>Praddeep Gobinath<sup>1</sup> and Robert H. Crawford<sup>2</sup></i>	

<b>A study on roaming behaviour of crowd in public space with the analysis in computer vision and Agent-based simulation.....</b>	<b>17</b>
<i>Yuansheng Wu<sup>1</sup>, Zipei Zhang<sup>2</sup>, Shimada Daii<sup>3</sup>, Changlin Liu<sup>4</sup>, Shaoyu Niu<sup>5</sup>, Lipeng Xia<sup>6</sup>, Liangfa Xiao<sup>7</sup> and Yasushi Ikeda<sup>8</sup></i>	
<b>Active transportation in future urban environment.....</b>	<b>18</b>
<i>Negar Nili<sup>1</sup>, Courtney Babb<sup>2</sup> and Parisa Izapanahi<sup>3</sup></i>	
<b>Adaptable and scalable housing for Australian households and stages of life.....</b>	<b>19</b>
<i>Lisa Kuir<sup>1</sup> and Paola Leardini<sup>2</sup></i>	
<b>An Architecture of Inclusion: Can the profession adapt to the diversity of design demanded by people with a disability? .....</b>	<b>20</b>
<i>Kirsten Day<sup>1</sup> and Andrew Martel<sup>2</sup></i>	
<b>An integrated regenerative-based green supply chain management in construction: towards a conceptual model .....</b>	<b>21</b>
<i>Oluwatobi Oyefusi<sup>1</sup>, Wallace Enegbuma<sup>2</sup>, Andre Brown<sup>3</sup> and Maibritt Pedersen Zari<sup>4</sup></i>	
<b>An investigation into quality management systems and factors affecting construction productivity: The New Zealand residential construction industry.....</b>	<b>22</b>
<i>Mark Kirby<sup>1</sup>, Funmilayo Rotimi<sup>2</sup> and Nicola Naismith<sup>3</sup></i>	
<b>Assessment of environmental impacts of heavy industries on eco-sensitive zones – A case of Tapi Estuary, Hazira, Gujarat .....</b>	<b>23</b>
<i>Pallabi Das<sup>1</sup>, Niharika Guleria<sup>2</sup>, Shivangi Maheshwari<sup>3</sup>, Tushalika Shishodia<sup>4</sup>, Richa Raje<sup>5</sup> and Sonal Tiwari<sup>6</sup></i>	
<b>Augmented Geelong: Digital technologies as a tool for place - A case of regional town of Geelong.....</b>	<b>24</b>
<i>Md Mizanur Rashid<sup>1</sup>, Chin Koi Khoo<sup>2</sup> and Surabhi Pancholi<sup>3</sup></i>	
<b>Can we design buildings within planetary boundaries? An exploration into using a top-down benchmarking approach for embodied carbon .....</b>	<b>25</b>
<i>Emily Newmarch<sup>1</sup>, Michael Donn<sup>2</sup>, David Dowdell<sup>3</sup>, Antony Pelosi<sup>4</sup>, Fiona Short<sup>5</sup> and Simon Twose<sup>6</sup></i>	

Circular economy software tools at the material and product level: A scoping review.....	26
<i>Santiago Muñoz<sup>1</sup>, M. Reza Hosseini<sup>2</sup> and Robert H. Crawford<sup>3</sup></i>	
Comparison of embodied greenhouse gas emissions data from environmental product declarations and the EPiC database: implications for material selection .....	27
<i>Robert H. Crawford<sup>1</sup> and André Stephan<sup>2</sup></i>	
Creating resilience through empowering self-build strategies in a Myanmar refugee camp .....	28
<i>Myint San Aung<sup>1</sup> and Annabel Pretty<sup>2</sup></i>	
Data Quality Assurance in Environmental Product Declaration Electronic Database: An Integrated Clark-Wilson Model, Machine Learning and Blockchain Conceptual Framework .....	29
<i>Oludolapo Ibrahim Olanrewaju<sup>1</sup>, Wallace Imoudu Enegbuma<sup>2</sup> and Michael Donn<sup>3</sup></i>	
Designing for extreme weather impacts on buildings.....	30
<i>Christopher A. Jensen<sup>1</sup> and Roberto Petrucci<sup>2</sup></i>	
Developing a methodology to assess potential overheating of houses in Darwin.....	31
<i>Terence Williamson<sup>1</sup>, Siti Aisyah Damiati<sup>2</sup> and Veronica Soebarto<sup>3</sup></i>	
Developing a prefabricated timber and straw-bale wall panel for Aotearoa New Zealand .....	32
<i>Min Hall<sup>1</sup></i>	
Development of a novel method to establish the hygrothermal water vapour resistance factor of construction materials for moisture management design of buildings .....	33
<i>Toba Samuel Olaoye<sup>1</sup> and Mark Dewsbury<sup>2</sup></i>	
Drivers for adaptive behavior in Human-Building Interaction: measuring the factors motivating room modifications for personal comfort.....	34
<i>Veronica Garcia-Hansen<sup>1</sup>, Francisca Rodriguez<sup>2</sup> Debra Cushing<sup>3</sup> and Glenda Caldwell<sup>4</sup></i>	
Electricity demand analysis for solar PV houses: Polyvalent heat pumps coupled with water storage tanks.....	35

*Zheng Wang<sup>1</sup>, Mark B. Luther<sup>2</sup>, Peter Horan<sup>3</sup>, Jane Matthews<sup>4</sup> and Chunlu Liu<sup>5</sup>*

**Embodied greenhouse gas emissions of structural systems for tall buildings: is there a premium for plan irregularity? ..... 36**

*James Helal<sup>1</sup>, Alireza Mehdipanah<sup>2</sup>, André Stephan<sup>3</sup>, Elisa Lumantarna<sup>4</sup> and Robert H. Crawford<sup>5</sup>*

**Emerging collaborative design platforms and the future of architectural education and practice ..... 37**

*Tristan Morgan<sup>1</sup>*

**Evaluating possible options for reusing borer-infested post-demolition timber in New Zealand ..... 38**

*Lucia Graham<sup>1</sup> and Dr Emina Kristina Petrović<sup>2</sup>*

**Extending the life: Deep energy retrofit analysis for classroom blocks in New Zealand ... 39**

*R. Crooks<sup>1</sup>, R. Phillips<sup>2</sup>, W. Enegbuma<sup>3</sup> and T. Lindsay<sup>4</sup>*

**For a philosophy of good construction: a learning experience..... 40**

*Francesco Mancini<sup>1</sup> and Paola Marrone<sup>2</sup>*

**Identifying glass for improving energy efficiency in office buildings of Addis Ababa, Ethiopia..... 41**

*Hawi Tilahun<sup>1</sup> and Avlokita Agrawal<sup>2</sup>*

**Impact of existing building air-conditioning retrofit on cost, Covid-19 transmission and energy ..... 42**

*Dominique Hes<sup>1</sup>, Jason Monty<sup>2</sup>, Grant Skidmore<sup>3</sup> and Liam McGregor<sup>4</sup>*

**Impact of the courtyard on the energy performance of conditioned office buildings in Dhaka, Bangladesh..... 43**

*Urmi Sarkar<sup>1</sup> and Avlokita Agrawal<sup>2</sup>*

**Improving Indoor Air Quality in Aged Care Ventres using a supplementary ventilation system..... 44**

*Priyadarsini Rajagopalan<sup>1</sup>, Jin Woo<sup>2</sup> and Mary Myla Andamon<sup>3</sup>*

Integrating energy retrofit to seismic strengthening to safeguard historic unreinforced masonry buildings in Aotearoa New Zealand .....	45
<i>Priscila Besen<sup>1</sup> and Paola Boarin<sup>2</sup></i>	
Integrating Indigenous lifestyle in Net-Zero Energy Buildings. A case study of energy retrofiting of a heritage building in the southwest of Western Australia .....	46
<i>Vittoria Strazzeri<sup>1</sup> and Reena Tiwari<sup>2</sup></i>	
Investigating Urban Post-Industrial Landscapes in India: A Case of Kollam, Kerala .....	47
<i>Ar. Sindhuja Sarasram<sup>1</sup>, Ar. Hind Haneefa<sup>2</sup>, Ar. Janaki S. Nair<sup>3</sup>, Ar. Mary Riannan<sup>4</sup>, Malavika Suresh<sup>5</sup>, Ar. Richa Raje<sup>6</sup> and Dr. Sonal Tiwari<sup>7</sup></i>	
Key interactions of safety egress factors in early architecture design in hospitals.....	48
<i>Maryse Fahmi<sup>1</sup>, Mahesh Babu Purushothaman<sup>2</sup> and Funmilayo Egun Rotimi<sup>3</sup></i>	
Landscape architects need to address life cycle greenhouse gas emissions in designs – A case study near Sydney, Australia .....	49
<i>Sareh Moosavi<sup>1</sup>, André Stephan<sup>2</sup> and Martin O’Dea<sup>3</sup></i>	
Learning from Practice in the Digital Age: 'Digitalisation of Heritage in New Zealand' .....	50
<i>Renata Jadresin Milic<sup>1</sup>, Peter McPherson<sup>2</sup> and Bin Su<sup>3</sup></i>	
Made to order: incrementally formed cladding systems .....	51
<i>Richard Burnham<sup>1</sup></i>	
Modelling optimal residential tree arrangement to curb energy demands under present and future climate conditions .....	52
<i>Mina Rouhollahi<sup>1</sup> and John Boland<sup>2</sup></i>	
Net zero cities: Precinct by precinct .....	53
<i>Peter Newman<sup>1</sup> and Dominique Hes<sup>2</sup></i>	
Optimizing conditioning systems in the perimeter zones of office buildings.....	54
<i>Hung Q. Do<sup>1</sup>, Mark B. Luther<sup>2</sup>, Jane Matthews<sup>3</sup> and Igor Martek<sup>4</sup></i>	
Parametric solar shading for sensitive internal environments: a workflow.....	55

*Elzine Braasch*<sup>1</sup>

Passive prefab: how can existing prefab systems be adapted to meet Passive House requirements? ..... 56

*Hannah Parker*<sup>1</sup> and *Guy Marriage*<sup>2</sup>

Physical environment as a factor in schools' performance and efficiency: A review of previous research ..... 57

*Paulo Vaz-Serra*<sup>1</sup>, *Neeraj Dangol*<sup>2</sup>, *Raghu Dharmapuri Tirumala*<sup>3</sup> and *Piyush Tiwari*<sup>4</sup>

Post-Pandemic Study Spaces: Post Occupancy Evaluation of BREEAM Excellence Rated University Building ..... 58

*Ozlem Duran*<sup>1</sup> and *Jing Zhao*<sup>2</sup>

Regenerative Design Performance assessment: a critical review ..... 59

*Fernando Pavez*<sup>1</sup>, *Duncan Maxwell*<sup>2</sup> and *Victor Bunster*<sup>3</sup>

Retrofit strategies influencing thermal performance in weatherboard-clad dwellings constructed before 2003 in a cool temperate climate ..... 60

*Jack Tan*<sup>1</sup>, *Phillipa Watson*<sup>2</sup> and *Mark Dewsbury*<sup>3</sup>

Smart Cities with no brain: A case for urban design studies utilising open-source platforms ..... 61

*Yang Ye*<sup>1</sup>

Study on the influence of subway entrance space layout on indoor air quality ..... 62

*Wei Wang*<sup>1</sup>, *Lei Zhang*<sup>2</sup>, *Sihan Xia*<sup>3</sup> and *Mengmeng Da*<sup>4</sup>

The role of education in the circular built environment: Analysis of Australian educational programs impact on construction and demolition waste management ..... 63

*Salman Shooshtarian*<sup>1</sup>, *Savindi Caldera*<sup>2</sup>, *Tim Ryley*<sup>3</sup>, *Tayyab Maqsood*<sup>4</sup>, *Atiq Zaman*<sup>5</sup> and *Peter SP Wong*<sup>6</sup>

The walking tourist: How do the perceptions of tourists and locals compare? ..... 64

*Swarnali Dihingia*<sup>1</sup>, *Morten Gjerde*<sup>2</sup> and *Brenda Vale*<sup>3</sup>

Thermal performance of student-built naturally ventilated remote accommodation in Fish River, NT .....	65
<i>David Kroll<sup>1</sup>, Joti Weijers-Coghlan<sup>2</sup> and Arianna Brambilla<sup>3</sup></i>	
Tools to assess internal surface mould growth: dynamic vs static.....	66
<i>Griffen Cherrill<sup>1</sup>, Michael Donn<sup>2</sup>, Nigel Isaacs<sup>3</sup> and Stephen McNeil<sup>4</sup></i>	
Towards a Post-Occupancy Evaluation linking occupant behaviour and energy consumption to mitigate the energy performance gap in residential retrofitted buildings: a literature review.....	67
<i>Luis E. Medrano-Gómez<sup>1</sup>, Paola Boarin<sup>2</sup> and Alessandro Premier<sup>3</sup></i>	
Urban dwellers' view on hazards and disasters; and, the COVID-19 pandemic: implications for resilient urban housing in the post-pandemic period .....	68
<i>Minerva Rosel<sup>1</sup> and Isidoro Malaque III<sup>2</sup></i>	
Visual environments for people living with dementia: a review of building performance criteria .....	69
<i>Jane Waterhouse<sup>1</sup>, Alessandro Premier<sup>2</sup> and Paola Boarin<sup>3</sup></i>	
What can academic research do for city-building practitioners?.....	70
<i>Fanni Melles<sup>1</sup>, Jeni Paay<sup>2</sup> and Ian Woodcock<sup>3</sup></i>	
Zeroing in: A community-based approach to the design of public space for zero-carbon living .....	71
<i>Susan J. Wake<sup>1</sup> and Pippa Sommerville<sup>2</sup></i>	

## A Case Study for future re-use of buildings to reduce carbon

Llewelyn Griffiths<sup>1</sup>, Emily Newmarch<sup>2</sup> and Fritha Powell<sup>3</sup>

<sup>1,3</sup>*Warren and Mahoney Architects, Wellington, New Zealand*

<sup>2</sup>*Victoria University, Wellington, New Zealand*

*Llewelyn.griffiths@warrenandmahoney.com<sup>1</sup>*

**Abstract:** The reduction of embodied carbon in buildings has been increasingly recognised as a high priority for the building and construction industry globally. Among the many strategies that can be implemented, adaptive reuse is frequently cited as being one of the most promising options due to extending the building's life, reducing waste and the need for large quantities of materials to rebuild the structure. However, the reuse of a structure in a seismically active country, like New Zealand, isn't as simple as stripping away the shell and adding a new one. There is a significant amount of work that is required to ensure the structure will be strong enough to meet updated building codes and last for another life cycle. To reflect on the impact of sustainable initiatives through the case study of a building reuse, this paper seeks to understand the carbon emissions from both embodied and operational contributions. The intent is to understand, what elements are key to decarbonise adaptive reuse buildings and how the design process could better accommodate carbon reduction strategies. The results are compared against international carbon targets to understand the embodied and operational carbon implementation of adaptative reuse for office buildings. These indicators can be used for the strategy of adaptive building re-use when an existing building is not designed for re-use or intended purpose. This paper is a collaboration between industry and academia to test a real-world project.

**Keywords:** Adaptive, re-use, LCA, Design.

## A comparative study between urban and rural play of Bhopal, India; to identify stimulating play environments

Ar. Richa Raje<sup>1</sup>, Ar. Saurabh Ojha<sup>2</sup>, Ar. Akshaya Saravanan<sup>3</sup>, Ar. Priyanka Agarwal<sup>4</sup> and Ar. Ajit Kumbhar<sup>5</sup>

<sup>1, 3, 4, 5</sup> School of Planning & Architecture, Bhopal, India

<sup>1</sup>[richa.raje@spabhopal.ac.in](mailto:richa.raje@spabhopal.ac.in), <sup>3</sup>[akshaya.saravanan125@gmail.com](mailto:akshaya.saravanan125@gmail.com), <sup>4</sup>[prianca0603@gmail.com](mailto:prianca0603@gmail.com),  
[5akitsmeajit@gmail.com](mailto:5akitsmeajit@gmail.com), 0000-0003-2929-6100<sup>1</sup>

<sup>2</sup> Indian Institute of Technology Roorkee, India

<sup>2</sup> [skishoreojha@ar.iitr.ac.in](mailto:skishoreojha@ar.iitr.ac.in), 0000-0001-6565-2673<sup>2</sup>

**Abstract:** Play seems to be simple and a fundamental activity. When children play, they learn – develop their physical capabilities, explore and experiment materials around them. It contributes to their physical, cognitive, social, cultural and emotional strengths and development. The purpose of this study is to examine the difference in the utilization of the current play environment between urban and rural play areas—specifically by examining children play satisfaction levels, interaction with natural elements and their frequency, analyse the relationship between the spatial features by studying the degree of affordance of the children to its immediate environment. The age group considered ranges between 6 to 12 years and data collection through playfield audit, on-site visits, survey and activities. The study suggests that children have affinity towards nature, however rural play environment offers a higher degree of affordance than urban play. The rural play builds curiosity and encourages them to invent newer opportunities with natural elements. Ironically, urban playscape senses a deficiency in creativity, which leads to a lesser connectedness towards nature. This study can become basis for designers to identify the landscape features in outdoor play areas that can create challenging, stimulating and meaningful play environments for the overall development of children.

**Keywords:** Affordance, Child development, Rural play, Urban play environment.

## A critical review of Biophilic design and its design framework

Archie Patel<sup>1</sup>, Dr. Akari Nakai Kidd<sup>2</sup>, Dr. Astrid Roetzel<sup>3</sup> and Mark DeKay<sup>4</sup>

<sup>1, 2, 3</sup> Deakin University, Geelong, Australia

{patelar<sup>1</sup>, akari.nakaikidd<sup>2</sup>, astrid.roetzel<sup>3</sup>}@deakin.edu.au, 0000-0002-5161-8236<sup>1</sup>, 0000-0002-1456-294X<sup>2</sup>, 0000-0003-3243-7744<sup>3</sup>

<sup>4</sup> University of Tennessee, Knoxville, TN, USA  
mdekay@utk.edu<sup>4</sup>, 0000-0003-4779-9510<sup>4</sup>

**Abstract:** Since the publication of Rachel Carson's *Silent Spring* in the 1960s, the architecture realm has witnessed a surge in sustainable design approaches. These have primarily focused on developing solutions that reduce negative environmental impacts. A growing body of research has identified that merely reducing the destructive impacts may not suffice to fight the global environmental crisis. In response, a number of architectural design approaches, such as biophilic design, restorative design and emotion-based nature-oriented architecture, have been developed to not only overcome the destructive environmental impacts of design and planning but also to improve human-nature interactions in the built environment. This paper critically reviews one of the most recognized approaches in the literature among the three: biophilic design. It discusses its relation to sustainability and the strengths and potentials for fostering pro-environmental behaviour. An in-depth analysis of biophilic design's emerging design frameworks follows, explicitly considering their applicability in informing the process of designing nature experiences in architecture. The paper concludes with two main shortcomings of biophilic design and outlines an area for future research.

**Keywords:** architecture design, biophilic design, Nature experiences, spatial Nature experiences.

## A hygrothermal analysis of 6 Star envelope systems used in code compliant homes in Victoria

Mark Dewsbury<sup>1</sup>, Freya Su<sup>2</sup>, Toba Olaoye<sup>3</sup> and Hartwig Kuenzel<sup>4</sup>

<sup>1,2,3</sup> *University of Tasmania, Launceston, Australia*

*mark.dewsbury@utas.edu.au, 0000-0002-3607-3637<sup>1</sup>*

<sup>4</sup> *Fraunhofer Institute of Building Physics, Holzkirchen, Germany*

*hartwig.kuenzel@ibp.fraunhofer.de, 0000-0001-8305-0262<sup>4</sup>*

**Abstract:** The correlation between energy efficient buildings and the increased risk of condensation and mould inside homes and within the built fabric of homes has been internationally recognised for more than nine decades. In the northern hemisphere, regulations and standards have been in use for more than five decades. However, the regulatory development in Australia has been tardy. Researchers at the University of Tasmania have been completing steady state, hybrid steady state and transient hygrothermal calculations and simulations for the last decade and much of this data has performed the back-bone for the “Condensation in Buildings –Tasmanian Designers’ Guide” which is referenced with the National Construction Code for Tasmania and the Australian Capital Territory. The guide is also used in Victoria. Recent research that has been exploring risks of moisture, moisture accumulation and mould growth in ‘code compliant’ 6 Star homes in Victoria. To gain an understanding of current problems in new housing and to plan recommendations for 7 Star housing, the Victorian Building Authority contracted the University of Tasmania to complete a series of hygrothermal research tasks. The first part of the research explored eleven external wall common external wall types used in external walls of Class 1 and Class 2 buildings, within NatHERS climates for Victoria. This paper reports the results of the hygrothermal analysis for the six of the simulated wall systems, demonstrated significant durability and human health risks in current construction practices.

**Keywords:** Condensation, Mould, Hygrothermal, Energy Efficiency.

## A novel method established to convert Australian climate data for hygrothermal simulation

Shruti Nath<sup>1</sup>, Mark Dewsbury<sup>2</sup>, Freya Su<sup>3</sup>, and Hartwig Kuenzel<sup>4</sup>

<sup>1, 2, 3</sup> *University of Tasmania, Launceston, Australia*

*mark.dewsbury@utas.edu.au<sup>2</sup>, 0000-0002-3607-3637<sup>1</sup>*

<sup>4</sup> *Fraunhofer Institute of Building Physics, Holzkirchen, Germany*

*hartwig.kuenzel@ibp.fraunhofer.de, 0000-0001-8305-0262<sup>4</sup>*

**Abstract:** The correlation between energy efficient buildings and the increased risk of condensation and mould inside residential and non-residential buildings has been known for some time. Since the 1990's transient calculation methods have been developed to initially calculate the flow of heat and moisture. These tools were then improved to calculate risks associated with mould growth, which causes building decay and affects human health. Internationally, frameworks, standards and guidelines are being developed establishing boundaries and requirements to limit too much user interaction with input and output variables. Key input variables include the exterior and interior climates and the physical attributes of construction materials. In 2018, collaborative research between the Germany and Australia identified a lack of suitably formatted Australian climate data for hygrothermal simulation. Parallel research was also exploring matters regarding water vapour diffusion resistivity properties of Australian construction materials and the development of more appropriate interior climate parameters. This article focusses on the development of a novel method, developed in 2019, to convert Australian government sanctioned climate data into a suitable format for transient hygrothermal simulation. The tool became known as AusHygro 1 and included options for including rain data and hourly interior temperature and relative humidity conditions.

**Keywords:** Condensation, Mould, Hygrothermal simulation, Climate data.

# A parametric approach to defining archetypes for an integrated material stocks and flows analysis and life cycle assessment of built stocks

Katarina Slavkovic<sup>1</sup>, André Stephan<sup>2</sup> and Gildas Mulders<sup>3</sup>

<sup>1, 2, 3</sup>*Université Catholique de Louvain, Louvain-la-Neuve, Belgium*

*katarina.slavkovic@uclouvain.be<sup>1</sup>, andre.stephan@uclouvain.be<sup>2</sup>, gildas.mulders@uclouvain.be<sup>3</sup>  
0000-0002-5563-1016<sup>1</sup>, 0000-0001-9538-3830<sup>2</sup>, 0000-0001-5060-269X<sup>3</sup>*

**Abstract:** Archotyping is a method for developing representative models of groups of buildings or infrastructure assets that share similar attributes. They typically focus on buildings and often support a single assessment method, such as urban building energy modelling, regardless of other significant flows (e.g. materials). Simplifications in developing archetypes and the inability to represent the distribution of flows across scales of the built environment reduce the precision of a model, which is critical in conducting a robust assessment that yields useful results. This paper aims to present an archotyping approach that supports an integrated life cycle assessment and material flow analysis of stock assets. As such, developed archetypes represent buildings, infrastructure, vegetation and soils. Built assets are defined as nested sets of assemblies, elements and materials. To improve reliability, we couple material compositions with geometrical data through the use of geographic information systems. We present the procedure for defining archetypes, and apply it to a building and transport infrastructure asset. The high resolution of the proposed archotyping approach enables a very high data granularity. This granularity enables a more detailed modelling of different scenarios, as well as dynamic life cycle assessment, and provides a high spatial resolution.

**Keywords:** Digital twin; buildings; infrastructure; GIS.

## A parametric tool to quantify the life cycle embodied environmental flows of built assets

André Stephan<sup>1</sup>, Fabian Prideaux<sup>2</sup> and Robert H. Crawford<sup>3</sup>

<sup>1</sup> *Université Catholique de Louvain institution, Louvain-la-Neuve, Belgium*

*Andre.Stephan@uclouvain.be, 0000-0001-9538-3830<sup>1</sup>*

<sup>2,3</sup> *The University of Melbourne, Melbourne, Australia*

*fprideaux, rhcr@unimelb.edu.au, 0000-0002-4959-3615<sup>2</sup>, 0000-0002-0189-3221<sup>3</sup>*

<sup>2</sup> *KU Leuven, Leuven, Belgium*

**Abstract:** The construction and maintenance of buildings and infrastructure assets are the main drivers of raw material extraction and are responsible for significant embodied environmental flows such as energy and water use as well as greenhouse gas emissions. It is critical to empower actors of the built environment with advanced tools to quantify the life cycle environmental performance of different designs to inform design decisions. This paper presents one such parametric tool, EPiC Grasshopper, developed as a plugin for the Rhinoceros 3D and Grasshopper 3D environment. EPiC Grasshopper is a bottom-up parametric tool that operationalises the Environmental Performance in Construction (EPiC) Database of hybrid environmental coefficients for construction materials. The paper presents the architecture of EPiC Grasshopper, verifies its calculations and validates its output by comparing its application to a case study house in Australia to figures from a previous study. Results validate the plugin and show minor variations of the total life cycle embodied energy (-2%) at a whole building level as well as very minor variations in the contribution of each material to the total life cycle embodied energy, as compared to the figures from the previous study (maximum 1.7% of variation). The visualisation of results directly within the Rhinoceros 3D and Grasshopper 3D environment is also showcased. Future research includes demonstrating the parametric aspect of EPiC Grasshopper and developing more advanced functionalities. This will enable actors of the built environment to include life cycle embodied environmental performance directly into their workflows in a streamlined yet advanced manner.

**Keywords:** EPiC Grasshopper; bottom-up; embodied carbon; model.

# A rapid relief architecture for primary schools

Kate Poole<sup>1</sup> and Guy Marriage<sup>2</sup>

<sup>1,2</sup> *Victoria University of Wellington, Wellington, New Zealand*  
{katejaapoole@gmail.com<sup>1</sup>, guy.marriage@vuw.ac.nz<sup>2</sup>}

**Abstract:** A natural disaster will inevitably strike New Zealand in the coming years, damaging educational facilities. Delays in building quality replacement facilities will lead to short-term disruption of education and create the risk of long-term inequality for the affected students. The Christchurch earthquake demonstrated the issues arising from a lack of school planning and support. This research proposes a system that can effectively provide rapid, prefabricated primary schools in post-disaster environments to continue education for children in the short term while using construction that is suitable until the total replacement of the given school is completed. The expandable prefabricated architecture meets the strength, time, and transport requirements to become a robust, rapid relief temporary construction adaptable to any area within New Zealand. This design solution supports personal well-being and mitigates the risk of educational gaps, PTSD linked with anxiety and depression, and many other mental health disorders that can impact students and teachers after a natural disaster.

**Keywords:** Prefabrication, rapid relief, Primary School, New Zealand, permanent.

## A review of life cycle sustainability assessment studies of smart building management systems

Praddeep Gobinath<sup>1</sup> and Robert H. Crawford<sup>2</sup>

<sup>1,2</sup> *The University of Melbourne, Melbourne, Australia*  
{p.gobinath<sup>1</sup>, rhcr<sup>2</sup>}@unimelb.edu.au, 0000-0002-3912-1323<sup>1</sup>, 0000-0002-0189-3221<sup>2</sup>

**Abstract:** The uptake of smart building management systems has increased in recent years, in both new and refurbished buildings, aided by technological advances such as smart sensors, Internet of Things (IoT), cloud-based computing and data-driven control approaches. Many studies have reported the energy saving potential of employing systems which leverage indoor environmental and occupancy information collected in real-time to better manage building services. The increased uptake of these systems means that natural resource demands and environmental effects associated with the extraction of raw materials, processing and manufacture, installation, maintenance, and replacements as well as the supporting supply chain activities have increased the embodied environmental impacts of buildings. However, these embodied impacts are often overlooked in most studies that consider the environmental benefits of smart building energy management systems. The economic feasibility of these systems is also underreported, which is important given the additional hardware and services necessary to fulfil the functional requirements of these systems; studies that reported the cost effectiveness of deploying these systems are often based on simple payback calculations. In addition, from a social perspective, the production of these systems involves many raw materials, the extraction and processing of which may potentially be associated with challenges such as human rights violation and human health concerns. Accordingly, this study reviews existing research on the life cycle sustainability assessment of smart building management systems. The findings highlight the lack of comprehensive studies on the life cycle sustainability assessment of smart building management systems in buildings.

**Keywords:** Life cycle sustainability assessment; smart building; smart building management system; office building.

## A study on roaming behaviour of crowd in public space with the analysis in computer vision and Agent-based simulation

Yuansheng Wu<sup>1</sup>, Zipei Zhang<sup>2</sup>, Shimada Daii<sup>3</sup>, Changlin Liu<sup>4</sup>, Shaoyu Niu<sup>5</sup>, Lipeng Xia<sup>6</sup>, Liangfa Xiao<sup>7</sup> and Yasushi Ikeda<sup>8</sup>

*<sup>1, 2, 3, 4, 5, 6, 7</sup> Keio University SFC, Tokyo, Japan  
{wuys@keio.jp<sup>1</sup>}*

*<sup>8</sup> The University of Tokyo, Tokyo, Japan*

**Abstract:** People-flow in densely populated modern cities is a non-negligible factor to consider during urban space design. However, in the early phase of design, architects mainly deal with the static states of the human body. Other factors, such as duration and environment, should be considered when analysing crowd behaviour. The common methods for design presentation are drawings, sketches, models, etc. Dynamic visualisation of pedestrian behaviour might help architects have a better understanding of the design performance. Agent-based simulation has been explored by many researchers. Most of their pedestrian models have planned routes with origin and destination. Thus, we would like to propose a pedestrian model embedded with roaming behaviour that reflects the decision-making process when exploring unfamiliar places. Previously, computer vision and agent-based simulation were different research streams. This paper discusses the initiative to study crowd behaviour using computer vision and agent-based simulation and examined the accuracy and validity of agent-based simulation by comparing the results from computer vision. Overall, this research aims to improve the accuracy of the agent-based simulation by utilizing the data extracted from surveillance video.

**Keywords:** Agent-based Simulation; Computer Vision; Crowd Behaviour; Data Visualisation.

## Active transportation in future urban environment

Negar Nili<sup>1</sup>, Courtney Babb<sup>2</sup> and Parisa Izapanahi<sup>3</sup>

<sup>1,2,3</sup> Curtin University, Perth, Australia  
{negar.nili<sup>1</sup>, c.babb<sup>2</sup>, parisa.izapanahi<sup>3</sup>}@curtin.edu.au

**Abstract:** Transportation has become one of the integral components of cities that directly affect several aspects of human life, such as economy, communication, and environment. Cities are facing growing challenges and demand for urban transportation due to population growth, which causes harmful impacts on living conditions. Thus, authorities are seeking solutions to improve the urban environment and enhance living conditions. Active transportation (AT), specifically walking and cycling are valuable modes of sustainable transportation that can mitigate the environmental impacts of motorised transportation and improve urban environment and people's health. AT could apply technologies to facilitate the mode of transportation, improve other aspects of urban environments and contribute toward urban sustainability. Adopting technology to reduce AT barriers and make it a transport option for more people with different abilities and needs could transform the urban environment into a place that is environmentally sustainable and much more liveable. This paper investigates people's attitudes toward applying technology to increase AT. An online survey was conducted to explore general public reactions toward the applications. The general public survey results made it possible to identify which factors need more interference to meet users' needs. This survey outcome demonstrates that applications that improve safety and facility of AT are the most encouraging. The findings provide new and updated knowledge for designers, urban planners, and decision-makers on the design system to use technology in future.

**Keywords:** Active transportation, Technology, Urban Environment.

# Adaptable and scalable housing for Australian households and stages of life

Lisa Kuiri<sup>1</sup> and Paola Leardini<sup>2</sup>

<sup>1,2</sup>*School of Architecture, The University of Queensland, Brisbane, Australia*  
*l.kuiri@uq.edu.au*<sup>1</sup>

**Abstract:** The housing sector in Australia continues to be dominated by construction methods based on a linear take-make-waste model: an unsustainable approach for using materials on a planet of finite natural resources and increasing population. Demand on materials for new house construction is exacerbated by the fact that contemporary Australian houses are the biggest in the world; making way for these new larger houses in suburbs, old houses are often demolished, reducing materials to rubble in landfill, as they are generally regarded by owners as functionally obsolete and are not easily adaptable to accommodate their lifestyle needs and aspirations. A transition to a Circular Economy is needed in the design and construction of Australian housing, to keep materials in use for longer by increasing the longevity of a building lifecycle or allowing materials to be used again at the building's end-of-life. Prefabrication represents an effective pathway to implement circularity in construction allowing adaptable buildings to be designed for assembly of components with reversible connections that could be easily disassembled for spatial reconfiguration on site or reuse in other buildings. This paper discusses the benefits of combining the two key circular design principles of adaptability and disassembly for developing housing types that suit spatial needs of typical Australian households at different stages of their life by the construction process of incremental growth. The study employs qualitative methods including case study analysis of contemporary adaptable, incremental housing projects and traditional vernacular housing built for growth, through the lens of circular design.

**Keywords:** adaptable housing; scalable housing; Design for Adaptability; incremental housing.

## An Architecture of Inclusion: Can the profession adapt to the diversity of design demanded by people with a disability?

Kirsten Day<sup>1</sup> and Andrew Martel<sup>2</sup>

<sup>1,2</sup> *University of Melbourne, Parkville, Australia*  
*dayk<sup>1</sup>, aamartel<sup>2</sup>@unimelb.edu.au,*  
*0000-0002-3372-229<sup>1</sup>, 0000-0003-2008-7636<sup>2</sup>*

**Abstract:** From the 1840s, Australia encouraged the committing of people with disabilities to institutions and asylums. By the 1970s the preference was to house people in group homes—domestic in scale but still institutional in design and regulation. Consequently, knowledge of designing for people with disabilities within the architectural profession was low and teaching the design skills required within universities negligible. The United Nations Charter of Rights for People with Disability (adopted by Australia in 2009), and the introduction of the National Disability Insurance Scheme (2014), have highlighted the need for education and knowledge among architects and architectural students. The tendency has been to conform to existing regulations, rather than being a driver of innovation. New references in the National Standard of Competency for Architects around designing for disability require demonstrating these competencies by graduates. Using the experience of the inclusion of Indigenous competencies in the National Standard, this paper explores the difficulties the profession and teaching institutions may encounter around identifying people with lived experience working in architecture, or as design teachers. Issues around who is allowed to speak for—and engaging with people with an intellectual disability or neurodiversity pose serious challenges to rectifying decades of neglect.

**Keywords:** Architecture; Design; Disability; Inclusion.

## An integrated regenerative-based green supply chain management in construction: towards a conceptual model

Oluwatobi Oyefusi<sup>1</sup>, Wallace Enebuma<sup>2</sup>, Andre Brown<sup>3</sup> and Maibritt Pedersen Zari<sup>4</sup>

<sup>1,2,3</sup> *Victoria University of Wellington, Wellington, New Zealand  
{Oluwatobi.Oyefusi<sup>1</sup>, Wallace.Enebuma<sup>2</sup>, Andre.Brown<sup>3</sup>}@vuw.ac.nz,*

<sup>4</sup>*Auckland University of Technology, Auckland, New Zealand  
Maibritt.Pedersen.Zari<sup>4</sup>@aut.ac.nz*

**Abstract:** In construction, Green Supply Chain Management (GSCM) is considered an effective management tool that aims to integrate environmental sustainability thinking into the built environment from design to the end-of-life management stage. Despite the numerous benefits of GSCM practices in construction, greenhouse emissions, energy consumption, climate change, and other drivers of negative environmental change continues to increase. This shows that green is not enough to reduce negative environmental impacts. Hence, we need to make a fundamental transition towards regeneration that redefines the construction supply chains by not only trying to limit negative environmental impacts but to develop a built environment that ensures continuous improvement, bringing together human and natural systems. This study aims to develop and validate a conceptual model that articulates how each phase of GSCM could shift from a green to a regenerative paradigm. A validation questionnaire survey was designed to validate the conceptual model based on a set of validation statements. The results of the analysis of the responses of the invited experts showed that five out of the six validation statements have at least a mean score of 4.00. This shows that the developed model is comprehensive enough to facilitate the implementation and adoption of regenerative practices in the built environment. Apart from bridging the current gaps in green practices in construction supply chains, findings from this research are expected to act as a strategic response to climate change, restore and maintain our ecological capacity and create a mutually beneficial relationship between people and the place.

**Keywords:** Top-Down Benchmark, Embodied Carbon, Commercial, Early Design, Life Cycle Assessment, Planetary Boundaries.

# An investigation into quality management systems and factors affecting construction productivity: The New Zealand residential construction industry

Mark Kirby<sup>1</sup>, Funmilayo Rotimi<sup>2</sup> and Nicola Naismith<sup>3</sup>

<sup>1, 2, 3</sup>*Auckland University of Technology, Auckland, New Zealand*  
{mark.kirby<sup>1</sup>, funmilayo.ebun.rotimi<sup>2</sup>, nicola.naismith<sup>3</sup>}@aut.ac.nz

**Abstract:** Poor construction productivity is described as a systemic issue globally. In New Zealand (NZ), it is known as a substantial and enduring socio-economic problem. Among the numerous factors, quality is often correlated as a contributory factor to improving construction productivity. However, yet explicitly explored in the NZ residential construction sector as a more comprehensive strategic management approach. Thus, the aim of this study is to provide new insights into strategies for improving construction productivity from a quality management perspective in the NZ residential construction subsector. This preliminary literature review uses a mixture of Q1 and Q2 journals and selected 38 papers using the keywords “construction productivity, improvement, factors, residential construction, and quality management”. A range of papers was chosen to span 40 years in research from the mid-1980s to 2021, with the largest representation of papers within the last 10 years, as the topic became more prolific globally. The preliminary literature review findings highlight that quality management systems are positively linked to improved productivity and further defined the characteristics of quality management systems thought to benefit the NZ residential construction sector. Theoretically, it is hoped that this research makes a valuable contribution to the existing productivity literature.

**Keywords:** Construction productivity; quality management; management strategies; residential building.

## Assessment of environmental impacts of heavy industries on eco-sensitive zones – A case of Tapi Estuary, Hazira, Gujarat

Pallabi Das<sup>1</sup>, Niharika Guleria<sup>2</sup>, Shivangi Maheshwari<sup>3</sup>, Tushalika Shishodia<sup>4</sup>, Richa Raje<sup>5</sup> and Sonal Tiwari<sup>6</sup>

*1, 2, 3, 4, 5, 6 School of Planning and Architecture, Bhopal, India  
ar.pallabi@gmail.com, niharikaguleria@gmail.com, shinnimaheshwari@gmail.com,  
tusha.96@gmail.com, richa.raje@spabhupal.ac.in, sonal@spabhupal.ac.in*

**Abstract:** The Tapi estuarine landscape is defined by its funnel shape, tidal inundations, salt marshes, and mangroves, making it a unique habitat for coastal eco-processes. Such eco-systems help in mitigating oceanic currents and safeguarding the mainland. Owing to its proximity to the sedimentary basin and strategic placement along the Gulf of Khambat, this region is continuously being utilized for industrialization and trade. Over the last 35 years, Hazira has seen a shift in land-use from an ecologically rich region to an industrial landscape devoid of nature. This study aimed to analyse and evaluate the impacts of heavy industries on the natural environment and the lives of the local inhabitants. The methods adopted were on-site data collection through traverse surveys and interviews of the locals to document the current practices and status of the estuarine landscape. This data was further validated using GIS applications and several empirical maps were developed. Industrialization of the river edges has led to depreciation of the estuarine ecology and destruction of natural heritage. The industries block access to the river edge completely, disconnecting people from the river which has left the locals bereft of their riparian culture and traditional economy. Their health is greatly compromised due to the pollution from the industries. Industries are essential for the growth of economy but not at the cost of residents and fragile ecosystems of an area. Landscape architects, designers, and planners play a crucial role in developing strategies to deal with spread of industries in eco-sensitive areas.

**Keywords:** Mangrove-ecology, Estuarine-landscape, Industrial-landscape, Riverfront-reclamation

## Augmented Geelong: Digital technologies as a tool for place - A case of regional town of Geelong

Md Mizanur Rashid<sup>1</sup>, Chin Koi Khoo<sup>2</sup> and Surabhi Pancholi<sup>3</sup>

<sup>1, 2, 3</sup> Deakin University, Geelong, Australia

{md.rashid<sup>1</sup>, chin.khoo<sup>2</sup>, surabhi.pancholi<sup>3</sup>}@deakin.edu.au

0000-0002-7427-240X<sup>1</sup>, 0000-0001-5686-9133<sup>2</sup>, 0000-0002-8649-2813<sup>3</sup>

**Abstract:** To address global competitiveness, contemporary cities are investing into creating and establishing a unique brand identity by revitalisation and resurrection of the past using heritage structures that sets them apart from other locations. In this context, application of digital technologies has unravelled new opportunities in terms of augmenting the experience of space. However, despite their increasing application for branding purposes, there still exist few key questions to be explored in depth: How to define the role and significance of digital technologies such as augmented reality (AR) platforms as a place making tool for developing an informed and inclusive community? What are the key opportunities and challenges in the process of integration of digital resurrection of lost heritage structures aimed at facilitating place making? This design research sets out to address these questions by an initial investigation for the digital resurrection of the industrial past in the regional Geelong. This design-based research develops an early AR platform and applies qualitative methodology for the analysis of data collected from questionnaire surveys from two public workshops based on the applications of the proposed AR platform as showreel and initial AR model. The findings of this paper will provide valuable insights for local and regional decision-making in terms of opportunities and challenges in integrating AR for past resurrection of current heritage structures for developing a sense of place. This outcome introduces a novel way to comprehend digital technologies as a key tool for facilitating place making in developing communities that are inclusive and informed.

**Keywords:** Digital narrative; Reconstruction; Memory; Placemaking.

## Can we design buildings within planetary boundaries? An exploration into using a top-down benchmarking approach for embodied carbon

Emily Newmarch<sup>1</sup>, Michael Donn<sup>2</sup>, David Dowdell<sup>3</sup>, Antony Pelosi<sup>4</sup>, Fiona Short<sup>5</sup> and Simon Twose<sup>6</sup>

<sup>1</sup> *Victoria University of Wellington, Wellington, New Zealand*  
*{Emily.newmarch<sup>1</sup>, Michael.donn<sup>2</sup>, Antony.pelosi<sup>4</sup>}@vuw.ac.nz*

<sup>3</sup> *Building Research Association of New Zealand, Wellington, New Zealand*  
*David.dowdell@branz.co.nz*

<sup>5</sup> *Warren and Mahoney Architects, Christchurch, New Zealand*  
*Fiona.short@warrenandmahoney.com*

**Abstract:** The way we build, occupy, and dismantle architecture contributes heavily to the global problem of climate change. Accounting for the embodied emissions from buildings is just as important as measuring operational emissions. It's widely recognised that including Life Cycle Assessment (LCA) during design can inform decisions to reduce emissions. However, it is difficult to complete a LCA during the early stages and to define appropriate targets for achieving a project that is within the planetary boundaries (a concept involving earth system processes). Therefore, there is a need for benchmarks that respond to the scale of design decisions and allocate carbon emission targets for different building elements. To support designers in early decision making, this paper explores how a top-down benchmarking approach can be applied to both the building and elemental levels of LCA results. Functional units are applied using full-time employee to create a cap. The approach is applied to typical and non-typical building typologies from the same case study, a koala rehabilitation centre in Queensland, Australia. The case study was selected to form a discussion around the application of top-down building and elemental benchmarks in commercial architecture practice and test limitations. The paper asks the question: how can top-down benchmarks best support early design decisions to reduce the environmental impact of a building? The results show that whilst top-down benchmarks are good at connecting building scale benchmarks with a global carbon budget, the sharing principles used to achieve the benchmark limit their application on non-typical building typologies.

**Keywords:** Top-Down Benchmark, Embodied Carbon, Commercial, Early Design, Life Cycle Assessment, Planetary Boundaries.

## Circular economy software tools at the material and product level: A scoping review

Santiago Muñoz<sup>1</sup>, M. Reza Hosseini<sup>2</sup> and Robert H. Crawford<sup>3</sup>

<sup>1,2</sup> Deakin University, Geelong, Australia

{Smunozvela<sup>1</sup>, reza.hosseini<sup>2</sup>}@deakin.edu.au, 0000-0003-2249-7831<sup>1</sup>, 0000-0001-8675-736X<sup>2</sup>

<sup>3</sup>The University of Melbourne, Melbourne, Australia  
rhcr@unimelb.edu.au, 0000-0002-0189-3221<sup>3</sup>

**Abstract:** There has been an increasing interest towards measuring the environmental performance of circular economy (CE) strategies. To this end, a wide range of software tools (STs) has been developed, each one with different guidelines that rely on specific indicators and approaches to measure the environmental performance of CE strategies. An overview of this topic is, however, missing in the literature. This paper aims to address this gap by providing an updated picture of the research landscape on current indicators and STs available for measuring the environmental performance of CE at the material/product level. A scoping review is conducted to provide a comprehensive list of available STs for measuring the environmental performance of CE strategies at the material and product level, and identifying the overarching guidelines and indicators STs are based on. Findings demonstrate a comparative analysis of the benefits and weaknesses of each ST and overarching guidelines. Besides providing a list of the most common environmental assessment techniques, this scoping review explores the level of expertise required for each ST based on the STs interactions, available guidelines and learning sources. This paper contributes to the field by providing an updated picture of current STs. As the first attempt of this kind, this article reveals the availability of STs for measuring the environmental performance of CE at the material and product level, providing a fertile ground for future research. In practical terms, a comprehensive point of reference for measuring the environmental performance of CE is offered for policymakers and practitioners.

**Keywords:** life cycle assessment, circular economy, tools, indicators.

## Comparison of embodied greenhouse gas emissions data from environmental product declarations and the EPiC database: implications for material selection

Robert H. Crawford<sup>1</sup> and André Stephan<sup>2</sup>

<sup>1</sup> *The University of Melbourne, Melbourne, Australia  
rhcr@unimelb.edu.au, 0000-0002-0189-3221*

<sup>2</sup> *Université Catholique de Louvain, Louvain-la-Neuve, Belgium  
andre.stephan@uclouvain.be, 0000-0001-9538-3830*

**Abstract:** Architects and other construction industry professionals are increasingly seeking to reduce the embodied greenhouse gas (GHG) emissions of construction projects. To support this goal, reliable and comprehensive data is needed on material performance. There are various sources of this data currently being used, including Environmental Product Declarations (EPDs), and material life cycle inventory (LCI) databases, such as the Environmental Performance in Construction (EPiC) Database. Many LCI databases rely on manufacturer-specific data (common also with EPDs) but suffer from inherent data gaps. The EPiC Database is unique as it uses macro-economic input-output data, as part of a hybrid approach, to fill the gaps in LCI and EPD data to ensure comprehensive supply chain coverage. Due to this, data can vary considerably between EPDs and the EPiC Database. However, no study has compared these two data sources. The aim of this study was to compare the embodied GHG emissions coefficients provided by EPDs and the EPiC Database and assess the effect on material selection decisions. EPDs for Australian ready-mix concrete products were analysed and compared to hybrid GHG emissions coefficients for equivalent products within EPiC. It was shown that while hybrid coefficients are generally always higher than coefficients from EPDs, the overall trend between products was relatively consistent. On average, EPD coefficients represent 78% of the equivalent hybrid coefficient, ranging from 38 to 115%, highlighting the incompleteness associated with EPD data. The large variability in GHG emissions coefficients between EPD products of similar type means that product specific EPD data may not provide any more guidance to material selection than what the generic EPiC product data provides. EPiC data may provide very useful initial guidance for material selection, while comparison of materials based on EPDs from different manufacturers may be misleading, also questioning the compliance of EPDs with the requirements of the international standard EN 15804.

**Keywords:** Embodied greenhouse gas emissions; environmental product declaration; EPiC Database; hybrid life cycle assessment.

## Creating resilience through empowering self-build strategies in a Myanmar refugee camp

Myint San Aung<sup>1</sup> and Annabel Pretty<sup>2</sup>

<sup>1,2</sup> *School of Architecture, Unitec Te Pūkenga, Auckland, New Zealand*  
*myintsan98@gmail.com<sup>1</sup>, apretty@unitec.ac.nz<sup>2</sup>, 0000-0001-7004-0356<sup>1</sup>, 0000-0001-6786-301X<sup>2</sup>*

**Abstract:** Currently, around 82 million people are displaced globally, and refugees are among the most vulnerable and in need of support. Around 1.1 million refugees from Myanmar are situated in large refugee camps between Myanmar, Thailand and Bangladesh, many living in such conditions for up to 30 years. Long-term design solutions are needed to solve the refugee crisis in Myanmar, and architecture has the solution for creating meaningful place-making for the refugees who are still trapped in these camps. Through a comprehensive vernacular design approach and a holistic solution, architecture can help mitigate the quality of life of refugees. The design project will be approached with the mindset of refugees' involvement and allowing them to create their own set of rules and use their own skill sets. Alongside this, a vernacular traditional construction system will be developed to adapt to those skill sets and be appropriate to environmental conditions. The goal is to achieve an architectural solution that provides a better living environment and enhances the prospects of refugees' lives. As well as re-imagining current camps to create a resilient and self-sufficient community where one feels a sense of belonging and can express, educate and prepare themselves for the future.

**Keywords:** Bamboo, Traditional Construction, Refugee Communities, Myanmar

# Data Quality Assurance in Environmental Product Declaration Electronic Database: An Integrated Clark-Wilson Model, Machine Learning and Blockchain Conceptual Framework

Olundolapo Ibrahim Olanrewaju<sup>1</sup>, Wallace Imoudu Enebuma<sup>2</sup> and Michael Donn<sup>3</sup>

<sup>1,2,3</sup> *Victoria University of Wellington, Wellington, New Zealand*  
*oludolapoolanrewaju2012@gmail.com*

**Abstract:** Construction materials environmental product declaration (EPD) is becoming an essential data source for whole building life cycle assessment (WBLCA). In recent years, EPD programme operators have begun to digitalise the existing EPDs into a more useful data format through an electronic database. Therefore, it is essential to ensure the quality of EPD inserted in this electronic database in order to produce a reliable WBLCA. This paper aims to develop a conceptual framework for data quality assurance (DQA) in the EPD electronic database. The paper methodology is divided into two phases. Firstly, existing works of literature were examined to reveal the methods or technologies that can support DQA in an electronic database. Secondly, ten EPDs were reviewed to ascertain the data structure of existing EPDs, which will be used to determine the data to be extracted in the EPD electronic database. The information generated was used to develop a conceptual framework for a DQA embedded database design for construction materials EPD. The paper revealed that the Clark-Wilson model, blockchain and machine learning could enhance DQA in EPD electronic database. These findings have direct implications for the development of future electronic databases for EPDs. Future studies would leverage this conceptual framework to develop a working prototype for the EPD electronic database.

**Keywords:** Clark-Wilson model, Data Quality Assurance, Blockchain, Environmental Product Declaration.

## Designing for extreme weather impacts on buildings

Christopher A. Jensen<sup>1</sup> and Roberto Petruzzi<sup>2</sup>

<sup>1,2</sup> *University of Melbourne, Melbourne, Australia*  
*cjensen@unimelb.edu.au, rpetruzzi@unimelb.edu.au*

**Abstract:** In line with climate projections, extreme weather events have increased in Australian cities both in number and severity. Such events include heavy rainfall along the east coast, cyclone events along the north-west coastline and in far north Queensland, bushfires in the southeast and heatwaves across the continent. Current scientific modelling provides medium to high confidence that the effects of climate change will exacerbate these events even further. Much of the impact of these events is on private dwellings, in many cases in coastal, rural, or remote regions. Contemporary residential built environmental sustainability design in Australia commonly employs mitigation strategies seeking to reduce the potential impacts of long-term climate change, with regular reference to predictions of increased temperatures and sea level rise. However, extreme weather events are occurring now, and regulations and voluntary rating tools should be proactively addressing these critical issues. Despite extensive work on preparedness for extreme weather by researchers and Governments, practical design guidance is minimal with adaptation strategies relying on generic regulations and standards creating challenges for providing appropriate, cost-effective solutions specific to each different project location. This research reviews the regulatory and voluntary mechanisms currently in place in Australia that address extreme weather and highlights the gaps in design guidance and site-specific adaptation strategies to reduce impact of extreme weather on Australian houses.

**Keywords:** Extreme Weather; Climate Change; Building Design; Mitigation; Adaptation.

## Developing a methodology to assess potential overheating of houses in Darwin

Terence Williamson<sup>1</sup>, Siti Aisyah Damiati<sup>2</sup> and Veronica Soebarto<sup>3</sup>

*The School Architecture and Built Environment, The University of Adelaide, Adelaide, Australia  
{terence.williamson<sup>1</sup>, sitiaisyah.damiati<sup>2</sup>, veronica.soebarto<sup>3</sup>}@adelaide.edu.au*

**Abstract:** The inability of the home environment to avoid overheating can result in discomfort and may have adverse effects on occupants' health and wellbeing. Overheating is defined as the extent to which a space exceeds an upper threshold of an acceptable thermal condition. Although identified as a potential issue, assessing a house design for overheating is not required by the National Construction Code. This paper will present a novel methodology to assess overheating in the Darwin region based on extensive house monitoring of 58 dwellings over extended periods with over 7400 comfort assessments provided by 103 householders. The methodology characterises the overheating performance of houses operating as either Free-Running (FR) or Naturally Ventilated (NV) based on the adaptive comfort characteristics of the occupants. The estimation of effective temperature ( $ET^*$ ) is adopted as the index to assess the degree of overheating. This methodology is proposed to be used for the Nationwide House Energy Rating Scheme (NatHERS) for the Darwin region.

**Keywords:** House overheating, Darwin, energy efficiency assessment.

## Developing a prefabricated timber and straw-bale wall panel for Aotearoa New Zealand

Min Hall<sup>1</sup>

<sup>1</sup> *Unitec Institute of Technology, Auckland, Aotearoa New Zealand*  
*mhall2@unitec.ac.nz*<sup>1</sup>, 0000-0001-8374-5179<sup>1</sup>

**Abstract:** Making greater use of materials that sequester carbon, like timber and straw, is one way of reducing carbon emissions in the construction industry. In Aotearoa New Zealand building with straw bales has been perceived as a fringe technique, undertaken mostly in rural locations and often by owner-builders. For the past twenty years, however, and in the face of escalating climate change, practitioners have looked to prefabrication to advance the process of building with straw. Prefabricated timber and straw-bale wall panels have been developed in Europe, the United Kingdom, North America and Australia. They have been used to construct stand-alone houses, medium density housing, schools and medium scale commercial projects. This paper reports on Project Pātūtū, a research project aiming to develop a straw-bale panel system suitable for use in Aotearoa. International examples have been investigated before designing six panel options. Scale model panels were built and analysed in terms of their suitability for both community participation in the construction process and mainstream commercial construction. A small house was designed using the panels and analysed in terms of compliance with building regulations and the practicalities of construction.

**Keywords:** Prefabrication; straw-bale; low carbon.

# Development of a novel method to establish the hygrothermal water vapour resistance factor of construction materials for moisture management design of buildings

Toba Samuel Olaoye<sup>1</sup> and Mark Dewsbury<sup>2</sup>

<sup>1,2</sup> *Architecture and Design, University of Tasmania, Inveresk, Launceston 7250, Australia*  
{toba.olaooye<sup>1</sup>, mark.dewsbury<sup>2</sup>}@utas.edu.au,  
0000-0003-2773-9043<sup>1</sup>, 0000-0002-3607-3637<sup>2</sup>

**Abstract:** For nearly a century, it has been acknowledged that the nexus of envelope design, material choices and interior conditioning patterns can lead to surface and interstitial mould and condensation. Both of which affect building durability and occupant health. In Australia, the development of hygrothermal building regulations has been deferred based slow, which has resulted manufacturers reticence to obtain and publish construction material hygrothermal properties, such that high quality hygrothermal simulations can occur. This paper reports the results of the research completed to develop a novel methodology for acquiring high-quality water vapour diffusion resistivity data for input into hygrothermal simulation software. The method involves establishing a new hygrothermal laboratory, international round robin validation of the new laboratory and the design of a new experimental methodology to quantify relative humidity dependent water vapour diffusion resistivity properties for construction materials. Construction material relative humidity dependent hygrothermal boundary curves were established, using a new harmonic adjustment method. Hygrothermal simulations were then completed using single point and multivariable relative humidity water vapour diffusion resistivity values. The results show that there are significant differences in simulated moisture accumulation and the mould growth risk between hygrothermal simulations using single point and multi-point water vapour diffusion resistivity values.

**Keywords:** hygrothermal simulation; gravimetric measurement; water vapour diffusion resistivity; hygrothermal boundary curve; pliable membranes.

## Drivers for adaptive behavior in Human-Building Interaction: measuring the factors motivating room modifications for personal comfort

Veronica Garcia-Hansen<sup>1</sup>, Francisca Rodriguez<sup>2</sup> Debra Cushing<sup>3</sup> and Glenda Caldwell<sup>4</sup>

<sup>1, 2, 3, 4</sup> *Queensland University of Technology, Brisbane, Australia*  
{v.garciahansen<sup>1</sup>, f2.leonard<sup>2</sup>, debra.cushing<sup>3</sup>, Gg.caldwell<sup>4</sup>}@qut.edu.au

**Abstract:** With the ubiquity of sensors, architectural science has started incorporating embedded and network technologies to simplify procedures to monitor energy conservation indoors contributing to the emerging field of Human-Building Interaction (HBI). Automated building systems are now more common as the algorithms to predict the characteristics of the room environment increase in accuracy. And yet, high building performance is still not achieved as occupants modify the environment to increase personal comfort. Although some studies have proposed alternative procedures to identify personal comfort and refine predictive algorithms, the drivers motivating or deterring a person to modify their environment are still understudied. As a result, architectural science endorses energy-efficient solutions that may not fully respond to occupants' requirements for indoor comfort. This study presents the findings of a semi-systematic literature review (n = 20) seeking to map recurrent questions and tools to investigate the role of perceived control of the environment on adaptive behaviors for comfort. Four descriptors (demographic, psychographic, sensory/biometric, and situational) were selected and contextualized to structure the evidence base. Methodological innovations presented in the literature, including the addition of work-related constructs, the use of biometric devices, and the implementation of participatory approaches are highlighted. Typical applications and suggestions for an improved research design intervention are condensed into a preliminary instrument to be tested in the field. Implementing those suggestions might lead to a better evaluation of energy and user outcomes as multifactorial outputs and a broader understanding of the individual and social dimensions of personal comfort in shared environments.

**Keywords:** Human-building interaction, personal comfort, perceived behavioral control, measurements

## Electricity demand analysis for solar PV houses: Polyvalent heat pumps coupled with water storage tanks

Zheng Wang<sup>1</sup>, Mark B. Luther<sup>2</sup>, Peter Horan<sup>3</sup>, Jane Matthews<sup>4</sup> and Chunlu Liu<sup>5</sup>

<sup>1, 2, 3, 4, 5</sup> *Deakin University, Geelong, Australia*

{wangzheng<sup>1</sup>, mark.luther<sup>2</sup>, peter.horan<sup>3</sup>, jane.matthews<sup>4</sup>, chunlu.liu<sup>5</sup>} @deakin.edu.au

**Abstract:** As a result of the increasing adoption of rooftop solar photovoltaic (PV) systems in homes and the mismatch between peak residential load and peak harvested solar energy, a considerable percentage of harvested energy fails to be consumed in homes, resulting in low PV self-consumption. This is further compounded by recent rules and limits, which control how much of the excess PV power can be exported back to the electrical grid and may also force some available solar energy to remain unharvested. To address these issues, a combined system is proposed in which a polyvalent heat pump coupled with water storage tanks produces and stores hot and cold water by using PV power for heating, cooling, and domestic hot water use. Annual hourly thermal loads for heating and cooling of a typical Australian house located in Geelong, Victoria, are determined using TRNSYS. The house's annual hourly electricity consumption is calculated based on energy data, measured with a smart meter, and harvested solar energy, measured with a PV system controller. Results show that by working with relevant setpoint temperatures of water tanks and control strategies of the polyvalent heat pump, the proposed combined system reduced the annual grid energy demand by about 28%. In addition, the PV self-consumption and self-sufficiency were increased to 31.39% and 64.57%, respectively. This study demonstrated that this proposed combined system could effectively increase the PV self-consumption and self-sufficiency and reduce the grid electricity use of the house, thus reducing the burden on the electrical network.

**Keywords:** Solar PV; self-consumption; heat pump; water storage tanks.

## Embodied greenhouse gas emissions of structural systems for tall buildings: is there a premium for plan irregularity?

James Helal<sup>1</sup>, Alireza Mehdipanah<sup>2</sup>, André Stephan<sup>3</sup>, Elisa Lumantarna<sup>4</sup> and Robert H. Crawford<sup>5</sup>

<sup>1,4,5</sup>*The University of Melbourne, Melbourne, Australia,  
{james.helal<sup>1</sup>, elu<sup>4</sup>, rhcr<sup>5</sup>}unimelb.edu.au,  
0000-0002-8211-1454<sup>1</sup>, 0000-0002-2854-856<sup>4</sup>, 0000-0002-0189-3221<sup>5</sup>*  
<sup>2</sup>*WSP Australia, Melbourne, Australia,  
alireza.mehdipanah@wsp.com, 0000-0003-0162-1098<sup>2</sup>*  
<sup>3</sup>*Université Catholique de Louvain, Louvain-la-Neuve, Belgium  
andre.stephan@uclouvain.be, 0000-0001-9538-3830<sup>3</sup>*

**Abstract:** In mitigating the effects of climate change, life cycle assessment (LCA) has been proposed as a design tool to facilitate the choice of structural typologies, materials and floor plan layouts for tall buildings. Existing studies that use LCA to compare alternative structural systems for tall buildings adopt regular floor plans, whereby their centres of mass, stiffness and strength coincide throughout the building height. Thus, existing comparative LCA studies of structural systems exclude torsionally unbalanced tall buildings. The aim of this paper is to demonstrate the detrimental influence of plan irregularity on the embodied greenhouse gas emissions (EGHGE) of structural systems for tall buildings. This influence is evaluated using three finite element models of structural systems with varying degrees of plan irregularity for a 15-storey building scenario. The eccentric placement of shear walls is amplified across the alternative structural designs for each scenario, yet the materials and typology are kept constant to isolate the influence of plan irregularity on the EGHGE of the structural systems. All three structural systems comprise reinforced concrete shear walls and a moment-resisting frame that consists of band beams, columns and one-way slabs. A hybrid life cycle inventory analysis method is used to quantify the EGHGE of the structural systems. The findings of this study provide an initial estimation of the EGHGE premium for plan irregularity and confirm the need to reduce and eliminate these irregularities in the aim of minimising the EGHGE of structural systems for tall buildings.

**Keywords:** embodied environmental flows; high-rise; premium for height; structural systems.

# Emerging collaborative design platforms and the future of architectural education and practice

Tristan Morgan<sup>1</sup>

<sup>1</sup> Curtin University, Perth, Australia

<sup>1</sup> Aurecon Group, Australia

<sup>1</sup> Intensive Fields Lab, Perth, Australia

<sup>1</sup>tristan.morgan@curtin.edu.au, 0000-0002-7140-7428

**Abstract:** In 2017, Susskind and Susskind said that the future of the professions would move beyond the comfort of routine task automation and towards transformative re-configuration with an increased focus on demystification, democratization, and decomposition. At the same time, the rise of digital ‘superusers’, highlights the critical role of transdisciplinarity if the design professions are to be equipped to contribute to solving complex global challenges – wicked problems – such as climate change and resource scarcity.

Collaborative digital platforms, typically accessed via web-based interfaces and enhancing, rather than replacing, existing digital toolboxes, have emerged as catalysts of this transformation, at once democratizing access to specialist knowledge, whilst also providing users with toolsets that enable them to embed their own knowledge and experience within the platforms. This is different to the neo-materialist and parametricism-driven concerns of the first and second digital turns, where the focus was often on embedding material and crowd behaviours into modelling software. A focus on user interface and experience supports demystification of professional knowledge. Non-specialists can operate the tools and extract their own insights from large spatial datasets autonomously. Such affordances indicate an emergent future where traditional professions are decomposed into their constituent parts, re-configured into platform components that are accessed on-demand by professionals.

This paper identifies a future construction industry that is increasingly systematised, enabling cross-organisational collaborative practice and discusses these emerging platforms within the context of a continuing teaching project at an urban scale, demonstrating impact on design methods and outcomes.

**Keywords:** Transdisciplinarity, Digital Technology, Zero Carbon, Collaboration.

Architectural Science and User Experience: How can Design Enhance the Quality of Life  
55<sup>th</sup> International Conference of the Architectural Science Association

2022

## Evaluating possible options for reusing borer-infested post-demolition timber in New Zealand

Lucia Graham<sup>1</sup> and Dr Emina Kristina Petrović<sup>2</sup>

<sup>1, 2</sup> *Victoria University of Wellington, Wellington, New Zealand*  
*grahamlucia7@gmail.com<sup>1</sup>, emina.petrovic@vuw.ac.nz, 0000-0003-3446-093X2*

**Abstract:** Overconsumption contributes to irreversible environmental damage. The issues arise from resource extraction, processing, and disposal. Therefore, there is an urgency to develop techniques and strategies to keep materials in the loop for longer. Reusing reclaimed building materials could be a pivotal method to reduce overall material waste and decrease the need for new extraction, looking at demolition waste as a potential reservoir for future materials. The specific focus of this paper is the investigation of the opportunities for extending the lifespan of demolition timber. Post-demolition timber is found in a range of different conditions. One consideration is whether the timber infested with wood-boring insects (borer) should be recovered. A sustainable evaluation has been made on the most suitable treatment of borer, considering toxicity and energy involved, and identifying microwaves as an effective solution. Although reusing timber post borer infestation may not apply to an extensive range of situations, this work shows that there are real possibilities for the non-toxic treatment of the issue for in-situ timber. Borer thrives in climates with high levels of humidity, and with climate change, humidity levels in New Zealand are expected to increase, which will lead to an increase in borer. It was found that more work is needed to bring the application of microwave treatment to the mainstream market. The overarching aim of this paper is to stimulate others to explore waste material proactively, as waste material will play a vital role in the sustainable development of the construction industry.

**Keywords:** C&D Waste, circular economy, reuse, microwaves.

## Extending the life: Deep energy retrofit analysis for classroom blocks in New Zealand

R. Crooks<sup>1</sup>, R. Phillips<sup>2</sup>, W. Enebuma<sup>3</sup> and T. Lindsay<sup>4</sup>

<sup>1, 2, 3, 4</sup> *Victoria University of Wellington, Wellington, New Zealand*  
*rubscrooks@gmail.com<sup>1</sup>*

**Abstract:** Architects and other construction industry professionals are increasingly seeking to reduce the embodied greenhouse gas (GHG) emissions of construction projects. To support this goal, reliable and comprehensive data is needed on material performance. There are various sources of this data currently being used, including Environmental Product Declarations (EPDs), and material life cycle inventory (LCI) databases, such as the Environmental Performance in Construction (EPiC) Database. Many LCI databases rely on manufacturer-specific data (common also with EPDs) but suffer from inherent data gaps. The EPiC Database is unique as it uses macro-economic input-output data, as part of a hybrid approach, to fill the gaps in LCI and EPD data to ensure comprehensive supply chain coverage. Due to this, data can vary considerably between EPDs and the EPiC Database. However, no study has compared these two data sources. The aim of this study was to compare the embodied GHG emissions coefficients provided by EPDs and the EPiC Database and assess the effect on material selection decisions. EPDs for Australian ready-mix concrete products were analysed and compared to hybrid GHG emissions coefficients for equivalent products within EPiC. It was shown that while hybrid coefficients are generally always higher than coefficients from EPDs, the overall trend between products was relatively consistent. On average, EPD coefficients represent 78% of the equivalent hybrid coefficient, ranging from 38 to 115%, highlighting the incompleteness associated with EPD data. The large variability in GHG emissions coefficients between EPD products of similar type means that product specific EPD data may not provide any more guidance to material selection than what the generic EPiC product data provides. EPiC data may provide very useful initial guidance for material selection, while comparison of materials based on EPDs from different manufacturers may be misleading, also questioning the compliance of EPDs with the requirements of the international standard EN 15804.

**Keywords:** Embodied greenhouse gas emissions; environmental product declaration; EPiC Database; hybrid life cycle assessment.

## For a philosophy of good construction: a learning experience

Francesco Mancini<sup>1</sup> and Paola Marrone<sup>2</sup>

<sup>1</sup> Curtin University, Perth, Australia

*Francesco.mancini@curtin.edu.au, 0000-0001-7119-7056<sup>1</sup>*

<sup>2</sup> Università degli Studi RomaTre, Rome, Italy

*paola.marrone@uniroma3.it*

### Abstract:

1. The knowledge of construction techniques handed down its wealth of experience through manuals and codes of practice for a long time. The manuals of the past not only supported the construction through technical information but also expressed a 'philosophy' of good construction by transferring construction principles and rules into the project.

2. The themes of good construction were enriched in the twentieth century by numerous objectives, among which the most significant are the industrialization and systematisation of building processes and the challenges of sustainability, from energy efficiency to the recycling of materials, to building regeneration.

In university education, however, the transmission of knowledge on construction stayed limited to lessons on the elements and construction techniques that declined in the various materials.

3. While the recent global spread of computerization ensured the wide availability of technical information sources online, this phenomenon did not produce, per se, innovative, integrated and sustainable building solutions.

4. The author hypothesises that today's technical information is not ethically committed to clarifying the complex aspects of construction in sustainable terms.

The proposed thesis considers architecture, like medicine, a "practice based on science and operating in a world of values" (Cosmacini, 2008).

**Keywords:** Sustainable Construction. Architecture, Education, Learning Experience

## Identifying glass for improving energy efficiency in office buildings of Addis Ababa, Ethiopia

Hawi Tilahun<sup>1</sup> and Avlokita Agrawal<sup>2</sup>

<sup>1,2</sup> *Indian Institute of Technology, Roorkee, India*  
*h\_tilahun@ar.iitr.ac.in<sup>1</sup>, avlokita@ar.iitr.ac.in<sup>2</sup>*

**Abstract:** Despite numerous international guidelines for energy-efficient practices worldwide, Ethiopia is still in its early stages. Ethiopia has many types of climates that necessitate the use of specific energy studies to guide building design. As a building envelope component, fenestration design significantly impacts total energy demand (heating, cooling, and lighting). The fenestration design determines the natural light and heat exchange between the indoor and outdoor environments. This study aims to identify the best glass type for air-conditioned office buildings in Ethiopia's humid subtropical climate and provide a scientific basis for selecting glass materials in early design decisions. The study employs a simulation-based approach for comparative analysis of glass type using total energy consumption as performance criteria. According to the study, the VT (Visual transmittance) of the glass type determines the energy performance of the glass. In this case, window glass with a high visual transmittance performs significantly better than glass with a lower VT (Visual transmittance). The U-value and SHGC (Solar heat gain coefficient) have been found to have less impact on building energy performance.

**Keywords:** Humid subtropical climate of Ethiopia; energy efficient building; fenestration design; glass type.

## Impact of existing building air-conditioning retrofit on cost, Covid-19 transmission and energy

Dominique Hes<sup>1</sup>, Jason Monty<sup>2</sup>, Grant Skidmore<sup>3</sup> and Liam McGregor<sup>4</sup>

<sup>1</sup>City of Melbourne, Melbourne, Australia;

<sup>1</sup>[dominique.hes@melbourne.vic.gov.au](mailto:dominique.hes@melbourne.vic.gov.au), 0000-0001-6495-9059

<sup>2,3,4</sup>The University of Melbourne, Melbourne, Australia

**Abstract:** The BREATH (Building Retrofit for Efficiency, Air quality, Thermal comfort and Health) project was a research pilot led by the City of Melbourne in partnership with Cbus Property, the University of Melbourne, AG Coombs, SEED engineering, AURECON and Westaflex. It was a rapid retrofit project that tested various air conditioning and ventilation retrofit options with the express purpose of reducing airborne particulates and infection transmission, but also considering the energy and cost consequences. The work was undertaken within an existing building. Open windows, conventional air conditioning, ceiling-mounted HEPA filters, and displacement ventilation were included in this initial pilot. Personal air was also showcased but not integrated into the overall research. Results indicate that some recommendations to reduce transmission may have impacts on power demand. Leaving the windows open on a floor of the 10-story test building led to an estimated 12% increase in air conditioning energy consumption. The best option for reducing transmission risk and improving energy consumption appeared to be a low-level displacement supply air system; provided the workers exercised social distancing and the stratified room temperature profile was maintained. The lower energy consumption of displacement ventilation was estimated to increase the NABERS rating of the building by 0.5 stars. The most cost effective and simplest approach to improvement was in-ceiling fan filtration units, these reduced transmission risk with minor increases in energy consumption if appropriately dimensioned. This paper looks at what these possible interventions mean for office buildings retrofit improvement.

**Keywords:** Air Quality, HVAC, Energy and cost.

## Impact of the courtyard on the energy performance of conditioned office buildings in Dhaka, Bangladesh

Urmi Sarkar<sup>1</sup> and Avlokita Agrawal<sup>2</sup>

<sup>1,2</sup> *Indian Institute of Technology Roorkee, Uttarakhand, India*  
{u\_sarkar1, avlokita2}@ar.iitr.ac.in

**Abstract:** The challenge for building design is to maintain comfort inside while the weather outside changes unexpectedly. Therefore, air conditioning (AC) has become an essential component in office buildings as it provides a comfortable indoor environment while also being the primary source of energy consumption growth. Recent studies have emphasized the application of courtyard as a passive design strategy to reduce building energy use in tropical climates, particularly for cooling demand. Unconditioned buildings usually have a positive impact on courtyard design. This study investigates the effectiveness of courtyard design for a fully air-conditioned and mixed-mode naturally ventilated office building in the tropical context of Dhaka, Bangladesh. A typical office building model was developed using Design Builder software, according to the ASHRAE 90.1 standard. Both scenarios fully air-conditioned building and change over mixed-mode control ventilation (same space in different times) were compared in terms of total end-use to observe how the courtyard affected total energy performance. The courtyard was combined with several passive envelope design strategies, including insulation in the wall and roof, shading on the roof, self-shading over the wall, cavity wall, jaali (lattice) walls, and low-E glass. According to the simulation results, a single courtyard design might not be efficient, but a courtyard that integrates different passive design strategies will be efficient in fully air-conditioned and mixed-mode control buildings in Bangladesh's tropical environment.

**Keywords:** Humid-tropical climate; courtyard; air conditioned-mixed mode control; energy-efficient building.

## Improving Indoor Air Quality in Aged Care Ventres using a supplementary ventilation system

Priyadarsini Rajagopalan<sup>1</sup>, Jin Woo<sup>2</sup> and Mary Myla Andamon<sup>3</sup>

<sup>1, 2, 3</sup>RMIT University, Melbourne, Australia

{priyadarsini.rajagopalan<sup>1</sup>, jin.woo<sup>2</sup>, mary.andamon<sup>3</sup>}@rmit.edu.au  
0000-0001-7445-0985<sup>1</sup>, 0000-0002-6151-8220<sup>2</sup>, 0000-0003-2979-277X<sup>3</sup>

**Abstract:** Several studies demonstrate the importance of indoor air quality on health, well-being and productivity of occupants. However, much of the research on indoor environments focuses on adult workers in offices, students in school settings, and typical residential buildings. A significant proportion of Australia's population consist of old people in aged care homes who are vulnerable to worsening indoor air quality. This study monitored the air quality and ventilation in the common rooms of aged care centres and explored the benefits of adding a fresh filtered air ventilation system in the rooms. The results of the monitoring showed that the addition of fresh filtered air ventilation system reduced the indoor CO<sub>2</sub> concentration levels by as much as 1000ppm. This study improved the understanding on how various design and operating conditions affect ventilation rates and air quality in aged care settings.

**Keywords:** aged care centre; air quality; ventilation; CO<sub>2</sub> concentration.

# Integrating energy retrofit to seismic strengthening to safeguard historic unreinforced masonry buildings in Aotearoa New Zealand

Priscila Besen<sup>1</sup> and Paola Boarin<sup>2</sup>

<sup>1</sup> *Te Wānanga Aronui O Tāmaki Makau Rau, Auckland University of Technology, Auckland, New Zealand  
priscila.besen@aut.ac.nz*

<sup>2</sup> *Waipapa Taumata Rau, University of Auckland, Auckland, New Zealand  
p.boarin@auckland.ac.nz*

**Abstract:** Energy retrofitting historic buildings can help improve their indoor environmental quality, protect them from decay and obsolescence, reduce their energy use and related GHG emissions. However, in Aotearoa New Zealand, there are currently no policies to regulate energy retrofit in historic buildings and no substantial examples of this practice. On the other hand, there are significant regulations and practical examples of seismic retrofit, especially of unreinforced masonry (URM) buildings. As several seismic upgrade projects are taking place in the country, this study explores the potential of applying energy retrofit concurrently with seismic strengthening. The research investigated three case studies, which are listed heritage URM buildings located in different climates in New Zealand. Their current performance was investigated, and retrofit scenarios were analysed through energy simulation and hygrothermal modelling. Energy models demonstrated a potential reduction of up to 92% in heating demand when comparing the most comprehensive retrofit scenario with the baseline in the coldest climate studied. The potential energy savings from each intervention were then balanced against their heritage impact to assess the most appropriate solutions for each building. The study highlights the benefits of encouraging energy retrofit concurrently with seismic strengthening, so that historic buildings are more resilient not only to seismic threats, but also to a changing climate.

**Keywords:** Energy Retrofit; Unreinforced Masonry Buildings; Integrated Retrofit; New Zealand Heritage.

## Integrating Indigenous lifestyle in Net-Zero Energy Buildings. A case study of energy retrofitting of a heritage building in the southwest of Western Australia

Vittoria Strazzeri<sup>1</sup> and Reena Tiwari<sup>2</sup>

<sup>1,2</sup> Curtin University, Perth, Australia  
{Vittoria.Strazzeri<sup>1</sup>, R.Tiwari<sup>2</sup>}@curtin.edu.au

**Abstract:** Net-zero energy buildings (NZEBS) are defined as highly performing buildings with minimal energy demand, which is balanced by on-site renewable energy production. NZEBs are integrated within many national energy policies worldwide as an effective tool to decarbonising the construction sector. The Council of Australian Government endorses the concept in the Trajectory for low energy buildings (2019). Energy retrofitting against the zero-energy target offers energy-saving potential in terms of operational and embodied energy. Besides, heritage buildings retrofitting contributes to heritage management. However, the current approach to heritage buildings retrofitting aims almost exclusively to protect the physical structure and presents technical challenges concerning intervention on the building fabric. The study presents a case study of energy retrofitting of a State Heritage registered, in the south-west of WA, Carrolup Mission, which has significant cultural value for Aboriginal people. We targeted a single building assessed to be highly prioritised for the local community. We tailored the retrofitting strategy by integrating architectural design and architectural technology. We assessed the effectiveness of the retrofitting strategies against the net-zero energy target, and their impact on the buildings and the landscape. The analysis is based on building energy performance simulation (BEPS), and employs primary energy indicators to assess the building's energy performance. The outcome is a methodological path and best practice for energy retrofitting heritage buildings against net-zero energy targets in the south-west of WA. This study highlights the relevance of including architectural consideration in energy retrofitting heritage building against energy neutrality, with a specific focus on space quality and lifestyle.

**Keywords:** NZEBs, energy efficiency, building energy retrofitting, building heritage, Australian heritage.

## Investigating Urban Post-Industrial Landscapes in India: A Case of Kollam, Kerala

Ar. Sindhuja Sarasram<sup>1</sup>, Ar. Hind Haneefa<sup>2</sup>, Ar. Janaki S. Nair<sup>3</sup>, Ar. Mary Riannan<sup>4</sup>, Malavika Suresh<sup>5</sup>,  
Ar. Richa Raje<sup>6</sup> and Dr. Sonal Tiwari<sup>7</sup>

<sup>1,2,3,4,5</sup> *Masters of Landscape, 2021-2023, Department of Landscape,  
School of Planning and Architecture, Bhopal, India  
{sindhuja.s.sarasram<sup>1</sup>, hindhaneefa<sup>2</sup>, janakinair<sup>3</sup>, riannansilvester<sup>4</sup>,  
malavikasuresh<sup>5</sup>}@gmail.com<sup>1</sup>*

<sup>6,7</sup> *Asst. Prof., Department of Landscape, School of Planning and Architecture, Bhopal, India {richa.raje<sup>6</sup>,  
sonal<sup>7</sup>}@spabhopal.ac.in, 0000-0003-2929-6100<sup>6</sup>, 0000-0001-8921-6876<sup>7</sup>*

**Abstract:** In India, Industrialization had its beginnings in its colonial history. Several industrial campuses were established in coastal, or riverine belts due to the presence of water as a resource, and for ease of transportation. Such industrial centres as anchor points have witnessed the growth of these urban cores in the decades since, affecting riparian health in proportion to development. The city of Kollam, Kerala is one such example, where a cotton mill established in pre-independent India has been sited neighbouring a sensitive mangrove ecosystem along the Ashtamudi estuary that has been declared a Ramsar wetland. The campus is now non-functional and under neglect since 2008, due to various issues centred around outdated machinery. In this study, effects of industrialization and urbanization in transforming the estuary and mangrove ecosystem of the wetlands were assessed. Data collection was carried out in terms of traverse survey, visual-spatial mapping, quadrat analysis of vegetation. Physiological maps were made to understand natural topography of the area through on-site observations and validated with the help of GIS applications. The results indicated depletion of the mangrove vegetation, consequent decrease in local biodiversity, and disconnect between locals and the water edge. Landscape architects, designers and planners have a role in providing solutions that mitigate urban issues with sensitivity. In Kollam, adaptive re-use of the industrial campus for recreation, symbolizing the dependant livelihood on water and its supporting biodiversity, and promotion of sensitive eco-tourism to re-establishing the connectivity between humans and water were arrived at as primary landscape development strategies.

**Keywords:** Post-industrial-landscape; urbanization; estuarine-ecosystem; adaptive-reuse.

## Key interactions of safety egress factors in early architecture design in hospitals

Maryse Fahmi<sup>1</sup>, Mahesh Babu Purushothaman<sup>2</sup> and Funmilayo Egun Rotimi<sup>3</sup>

<sup>1,2,3</sup> *Auckland University of Technology, Auckland, New Zealand*  
{maryse.fahmi<sup>1</sup>, mahesh.babu<sup>2</sup>, funmilayo.egun.rotimi<sup>3</sup>} @aut.ac.nz, 0000-0001-5062-272x<sup>2</sup>

**Abstract** The primary building performance assessing factor for large and complex buildings such as hospitals is the safety of its occupants during emergencies such as fire. Previous research had identified multiple factors in the architectural design of fire emergency evacuations at hospitals. However, globally, fatalities have resulted from fire accidents in hospitals indicating that more factors have complex interactions on the performance and patient safety during fire emergencies. This paper highlights additional factors that influence the architectural design of hospitals to ensure safe egress for occupiers including critical care patients. The research follows a narrative inquiry methodology within the constructivism epistemology and interpretivism framework. The method considers data triangulation consisting of a systematic literature review that explores previously published papers and is substantiated by the limited semi-structured interviews, which provide a realistic understanding of the topic. These interviews are followed by narrative analysis and the results are presented by system dynamics mapping. The research has concluded a total of 9 key factors directly affecting the safety of evacuation in hospitals with the novel factors of patients' mobility rate and evacuation conditions being the most influential factors that need to be considered. The practical implication of this research is that it provides a better understanding of the necessity to include the patients' mobility while designing for safe evacuation in hospitals during fire emergencies.

**Keywords** Safe egress; evacuation; hospitals; fire.

## Landscape architects need to address life cycle greenhouse gas emissions in designs – A case study near Sydney, Australia

Sareh Moosavi<sup>1</sup>, André Stephan<sup>2</sup> and Martin O’Dea<sup>3</sup>

<sup>1</sup> *Belgian Fund for Scientific Research (F.R.S.-FNRS), Brussels, Belgium*

<sup>1,2</sup> *Université Catholique de Louvain, Brussels, Belgium*

*{sareh.moosavi<sup>1</sup>, andre.stephan<sup>2</sup>}@uclouvain.be, 0000-0002-4819-2772<sup>1</sup>, 0000-0001-9538-3830<sup>2</sup>*

<sup>3</sup> *CLOUSTON Associates – a division of Beveridge Williams, Australia*  
*mod@clouston.com.au*

**Abstract:** It is often believed that green infrastructure assets are net carbon sinks and this may have contributed to the lack of consideration of embodied greenhouse gas emissions by landscape architects. However, these embodied emissions cannot be ignored. This paper aims to demonstrate the significance of life cycle greenhouse gas emissions in park design and the need for landscape architects to address them. We use a hybrid life cycle inventory approach to quantify the life cycle embodied greenhouse gas emissions of the 26 000 m<sup>2</sup> Willowdale park, a greenfield development near Sydney, Australia. We take into account operational emissions associated with lighting, operating barbecues and mowing, as well as carbon sequestration in soils and trees. All original quantities are sourced from primary data. Results show that life cycle embodied greenhouse gas emissions are significant, at 1 419 tCO<sub>2</sub>e over 50 years (55 kgCO<sub>2</sub>e/m<sup>2</sup>). Initial embodied greenhouse emissions from the day the park opened represent almost 73% of life cycle emissions. It takes 47-48 years for the trees and the soil to sequester enough carbon to offset embodied and operational emissions. In other terms, for almost the first five decades, this park remains a net carbon emitter. These results demonstrate the need for landscape architects to understand embodied emissions in construction materials. Equally, they need to plant as many climate-resilient trees that sequester enough carbon to offset embodied greenhouse gas emissions in shorter timeframes. Using a detailed and comprehensive life cycle assessment model is critical to achieving climate positive outcomes.

**Keywords:** Embodied carbon; Carbon Sequestration; Life Cycle Assessment; Landscape Architecture.

## Learning from Practice in the Digital Age: 'Digitalisation of Heritage in New Zealand'

Renata Jadresin Milic<sup>1</sup>, Peter McPherson<sup>2</sup> and Bin Su<sup>3</sup>

<sup>1, 2, 3</sup> *School of Architecture, Unitec Te Pūkenga, Auckland, New Zealand*  
{*rjadresinmilic*<sup>1</sup>, *bsu*<sup>3</sup>}@unitec.ac.nz, 0000-0001-8642-790X<sup>1</sup>

**Abstract:** The use of modern digital technologies not only facilitates and improves conservation practices and processes but also enables the creation of a digital database. However, it is not applied as much as it might be, internationally and in New Zealand. Some of the reasons for this are (lack of) education and a negligible number of professional or academic papers in local journals, but also the fact that it is not yet recognised as an important element in the protection of architectural heritage in local practice, nor in the circles of heritology theorists.

This paper contributes to this relevant and needed topic that has not received much attention in academia so far. A case study – Unitec Research Project 'Digitalisation of Heritage in New Zealand' (2020-2022) seeks to achieve both academic and practical value in advancing knowledge about heritage in New Zealand: to provide a means for enhancement of New Zealand's current state of knowledge in the practice of archiving heritage buildings; to be useful for the end-user; and to aid in learning about the built environment. Preliminary results of the project's Phase Three (2022) are planned to be presented at the ASA2022 conference. The methodology is a 2-stage study and includes a survey (electronic questionnaire) and focus groups. The focus of Phase Three of the research project is to establish: *What levels of understanding of Digital Heritage (tools, equipment, software) there is in our professionals/ architects/ heritage architects?*, and *What heritage buildings would they prioritise to be digitally recorded (what would be their criteria for the selection)?* This paper will provide an overview of the work within the Research Project, and focus on the first steps in establishing the Digital Heritage Research Centre at Unitec.

**Keywords:** Digital technology; heritage; architectural education; Digital Heritage Research Centre

## Made to order: incrementally formed cladding systems

Richard Burnham<sup>1</sup>

<sup>1</sup> *University of Tasmania, Hobart, Australia*  
*Richard.Burnham@utas.edu.au*

**Abstract:** Two ‘live’ community projects – designed and fabricated in a Masters of Architecture unit – integrate incrementally formed aluminium components into building systems. Incremental Sheet Forming (ISF) deforms sheet material into three-dimensional forms through pressure imparted by a robot-held tool. Form and patterning are derived from numerically controlled toolpaths. The projects, a cocktail bar and a gateway structure, investigate multiple research and educational objectives. Parameters of the forming process – geometry and patterning, wall angle and thickness, surface preparation and material properties – are assessed through prototyping. The potential for the mass-customisation of unique components with ISF constitutes a significant advantage over alternative metal forming techniques. The projects leveraged two approaches to mass-customisation; one by parametrically adjusting geometrical forms and the other by adopting a ‘jigsaw’ approach, where each component is a unique part of a larger pattern-making exercise. Forming jigs became an integral part of prototyping, iterated in parallel with the evolution of the component and fixing regime. The ISF formed components contribute to the structural performance of the gateway by bracing the cells of a waffle structure while providing a structurally independent rainscreen in the cocktail bar. The paper describes previous ISF experiences, learning acquired during prototyping, workflow, and the performance of the assembled components.

**Keywords:** Incremental forming; cladding; education; digital fabrication.

## Modelling optimal residential tree arrangement to curb energy demands under present and future climate conditions

Mina Rouhollahi<sup>1</sup> and John Boland<sup>2</sup>

<sup>1,2</sup> *UniSA STEM, University of South Australia, Adelaide, Australia*

Mina.rouhollahi@mymail.unisa.edu.au<sup>1</sup>, John.Boland@unisa.edu.au<sup>2</sup>,  
0000-0001-5011-7483<sup>1</sup>, 0000-0003-1132-7589<sup>2</sup>

**Abstract:** Australian Local Government Areas (LGA) failure to compensate their 30% urban tree canopy benchmark depletion: leading to hotter treeless medium density suburbs. This paper presents an Optimal Residential Tree arrangement (ORTa) concept for technical policy guideline updates, as an effective pioneer energy-efficient approach. ORTa is a multi-criteria sustainability framework promoting tree inclusion, deep soil management, soft landscape volume, biodiversity, long-term energy and water conservations and enhanced resident wellbeing. This study has three phases: first phase integrates current urban development and scattered open site assessment; the second phase analyses long-term climate-building response, utilising Fourier series solar dependency data, resulting in accurate air and surface temperature predictions. The third phase adds evapotranspiration to AccuRate software, integrating field-work data, to calculate crucial tree allocation parameters, validating bi-seasonal optimisation criteria. We then evaluate Adelaide and Perth ORTa variations, with a 2050+ climate forecast. Adelaide's longer winters and higher wind velocity affect energy reduction results, with Perth showing double annual conservation. ORTa encourages governments, and accreditation bodies, to value tree microclimate modification strengths and provide stakeholders with education, inspiration and support. CSIRO 2050+ climate projections, strengthen our hypothesis, demonstrating ORTa's 80% climate retention. ORTa policy inclusion will transform research and future tree canopy cover and net-zero strategies.

**Keywords:** Nature-based solution, Optimal residential tree arrangement, Energy efficiency, Resilient neighbourhood.

## Net zero cities: Precinct by precinct

Peter Newman<sup>1</sup> and Dominique Hes<sup>2</sup>

<sup>1</sup>*Curtin University, Perth, Australia*  
*p.newman@curtin.edu.au, 0000-0002-8668-2764<sup>1</sup>*

<sup>2</sup>*City of Melbourne, Melbourne, Australia;*  
*dominiquehes27@gmail.com*

**Abstract:** A net zero city can be developed precinct by precinct through focussing on precincts around electric mid-tier transit along main road corridors. These are outlined through steps that enable broader design goals to be fulfilled as well as showing how technological innovation fits into precincts.

**Keywords:** NetZero, precincts, planning, transport.

## Optimizing conditioning systems in the perimeter zones of office buildings

Hung Q. Do<sup>1</sup>, Mark B. Luther<sup>2</sup>, Jane Matthews<sup>3</sup> and Igor Martek<sup>4</sup>

<sup>1, 2, 3, 4</sup> *School of Architecture and Built Environment, Deakin University, Geelong, Australia*  
{qhdo<sup>1</sup>, mark.luther<sup>2</sup>, jane.matthews<sup>3</sup>, igor.martek<sup>4</sup>}@deakin.edu.au , 0000-0002-9677-7636<sup>2</sup>, 0000-0003-3367-9278<sup>3</sup>, 0000-0001-6573-1291<sup>4</sup>

**Abstract:** Despite recent advances in thermal comfort research and conditioning technology, providing thermal comfort in office buildings still faces several difficulties resulting in discomfort, reduced occupant efficiency, and increased energy use. This problem is most acute in perimeter zones, which are highly valued, because of the high level of visual comfort, but also are strongly influenced by the external environment. While many envelope solutions have been proposed, little consideration has been given to innovative energy-efficient conditioning systems for perimeter zones. This research seeks to determine the requirements for conditioning systems in perimeter zones.

A pragmatic review of the conditioning characteristics of perimeter zones and their existing conditioning systems in Australian office buildings is discussed. The excessive application of glazing alongside intense and constantly changing solar gains are the main contributing factors to the difficulties in providing thermal comfort in perimeter zones. An evaluation of three commonly used conditioning systems namely, Variable Air Volume (VAV), Under Floor Air Distribution (UFAD), and Chilled Beam (CB), is considered alongside the newly proposed capillary radiant systems. Criteria such as energy consumption, thermal comfort, control–response, and other operational aspects of the four systems, are investigated and evaluated revealing their strengths and limitations. Considering the comparison among various conditioning systems, several parameters are identified, being: 1) capability to achieve comfort, 2) energy efficiency, 3) fast response time, 4) ease of installation and aesthetics, and 5) effective cooling capacity. Empirical testing of the proposed responsive radiant conditioning system is indicated as the next research step, with preliminary testing outcomes also provided.

**Keywords:** thermal comfort; radiant conditioning system; energy efficiency; perimeter zones.

## Parametric solar shading for sensitive internal environments: a workflow

Elzine Braasch<sup>1</sup>

<sup>1</sup>*Norman Disney Young, Wellington, New Zealand  
e.braasch@ndy.com*

**Abstract:** Building performance simulation tools provide a unique opportunity to evaluate solar architectural principles during the most influential early stages of the design process. Solar shade devices are typically designed with the intent to reduce solar penetration where possible, improving thermal performance and visual comfort for occupants within the indoor environment. In the case of patient wards, where the presence of direct sunlight is seen to contribute to the recovery of the patient, careful consideration is required to optimise a building's façade such that appropriate natural light is provided but not at the expense of high cooling demand and energy consumption. This study examines the use of parametric modelling as a data-driven design approach to providing façade solutions that balance sunlight entry with optimal thermal and visual comfort for new hospital buildings. A parametric model workflow to design external shades in conjunction with patient ward layouts and overall design methodology is developed. The approach demonstrates the applicability of data-driven design for micro-environments which require specific attention to solar design where conflicting priorities exist.

**Keywords:** Parametric; Solar; Hospital; workflow.

## Passive prefab: how can existing prefab systems be adapted to meet Passive House requirements?

Hannah Parker<sup>1</sup> and Guy Marriage<sup>2</sup>

<sup>1, 2</sup> *Victoria University of Wellington, Wellington, New Zealand*  
{*hannah.parker*<sup>1</sup>, *guy.marriage*<sup>2</sup>}@vuw.ac.nz

**Abstract:** New Zealand housing faces a health and affordability crisis. Our existing housing stock is cold, draughty, and prone to dampness and mould. New houses are being built far below similar climate standards worldwide, and recent New Zealand Building Code Clause H1 amendments do not increase our standards to those comparable climate standards. In addition, current building practices are prone to delays, cost increases, and defects. Given these issues, this paper asks how Passive House standards can be applied to existing prefabrication systems to provide healthy and affordable housing? The research implemented an action research methodology incorporating the adaptation of an existing prefabrication system to Passive House standards. Various existing prefabrication methods were evaluated and the most applicable to the research was selected for further development. The prefabrication system selected was refined through a series of prototypes utilising the plan-design-test-evaluate action research cycle to incorporate lessons from each earlier test. The exploration into increasing an existing prefabrication system to Passive House standard provides a high-performance housing solution utilising current technologies. The panelised system is easily transportable to most sites and is simple to erect, maximising the number of projects which could use it. When constructed, the system meets the rigorous Passive House standards around New Zealand without large-scale changes in the design phase reducing design time and complexity. This research can show that by adapting current successful systems to Passive House standards, the health and affordability of housing can be increased throughout New Zealand.

**Keywords:** Prefabrication; Passive House; healthy housing; affordable housing.

## Physical environment as a factor in schools' performance and efficiency: A review of previous research

Paulo Vaz-Serra<sup>1</sup>, Neeraj Dangol<sup>2</sup>, Raghu Dharmapuri Tirumala<sup>3</sup> and Piyush Tiwari<sup>4</sup>

<sup>1, 2, 3, 4</sup> Faculty of Architecture Building and Planning, University of Melbourne, Australia  
{p.vazserra<sup>1</sup>, neeraj.dangol<sup>2</sup>, dtvraghu<sup>3</sup>, piyush.tiwari<sup>4</sup>}@unimelb.edu.au  
0000-0001-5286-0801<sup>1</sup>, 0000-0003-4179-3716<sup>2</sup>, 0000-0002-6614-0167<sup>3</sup>, 0000-0002-3195-2843<sup>4</sup>

**Abstract:** The physical environment can considerably influence the efficiency and functionalities of facilities and spaces. Some recent studies examining schools' efficiency consider several factors such as human capital, parents' socioeconomic background, perceptions of teachers and parents towards schools, and financial status. However, very few studies have investigated the influences of schools' physical environment and facilities on their efficiency and students' academic performance. This research aims to review the recent studies on factors influencing schools' efficiency and student academic performance, and the importance accorded to physical environment. The research database, Scopus, is searched using combinations of relevant keywords and various studies that identify the influencing factors. A preliminary analysis of most of these studies indicates that the physical environment's influence on school performance appears peripheral. However, it was identified that physical environment, facilities, and services influence students' academic performance directly and indirectly. One of the limitations highlighted was that many of the studies, which include the physical environment factors in examining schools' efficiency, were based on a single country. The studies were mainly focused on the USA, and only a handful was based on Australia and the rest of the world. This paper identifies the need for more such studies that can contribute to bridging the knowledge on the efficiency drivers of the schools. A better understanding of the drivers for better school performance is needed to lead to an efficient allocation of funding, particularly for public schools in Australia.

**Keywords:** Efficiency, Literature Review, Performance, Schools, Students.

## Post-Pandemic Study Spaces: Post Occupancy Evaluation of BREEAM Excellence Rated University Building

Ozlem Duran<sup>1</sup> and Jing Zhao<sup>2</sup>

*University of Lincoln, Lincoln, U.K*  
*jingzhao@lincoln.ac.uk, 0000-0002-0497-4932*

**Abstract:** This paper presents preliminary findings from a Post Occupancy Evaluation research of a BREEAM excellence-rated university building, to understand the experience of the students using university study spaces under a post-pandemic teaching and learning context. The research uses a combined qualitative and quantitative method and focuses on occupancy patterns, thermal comfort, air quality, noise and lighting level of the study spaces within the building, as well as the students' preferences and experiences of the study spaces. The research collected over 200 questionnaire survey data from students who use the study areas, as well as monitored environmental data and observation data over 5 working days prior to the exam period. The study also compares the field research with the predicted performance simulation model data made before the pandemic, to understand the difference the pandemic has made to the designed usage and environmental comfort of the building. The result suggests that the post-pandemic occupancy level is significantly different from the pre-pandemic design assumptions and environmental control strategies need to be re-evaluated to provide optimum thermal comfort. Furthermore, the result raises questions in relation to overheating predictions in the performance simulation model, suggesting a need to re-evaluate overheating calculation criteria in educational buildings.

**Keywords:** University buildings, Post-occupancy evaluation, thermal comfort, occupant behaviour.

## Regenerative Design Performance assessment: a critical review

Fernando Pavez<sup>1</sup>, Duncan Maxwell<sup>2</sup> and Victor Bunster<sup>3</sup>

<sup>1, 2, 3</sup> *Building 4.0 CRC, Caulfield East, Victoria, Australia; and*  
<sup>1, 2, 3</sup> *Monash University, Melbourne, Australia. {fernando.pavezsouper<sup>1</sup>, duncan.maxwell<sup>2</sup>, victor.bunster<sup>3</sup>}@monash.edu*  
0000-0003-2145-2631<sup>1</sup>, 0000-0002-9039-1441<sup>2</sup>, 0000-0002-7665-4567<sup>3</sup>

**Abstract:** The global sustainability movement has developed a variety of new design and building methodologies. Regenerative Design (RD) focuses on understanding the dynamic relationship between people, a place and ecosystems. By weaving together the natural and social systems, RD maximises humans' and nature's creativeness and abundance. Projects are not seen as an end product but rather as the beginning of a process that will continue to evolve long after completion. RD approaches to building are receiving increased attention in industry and academia. In this context, developing a clear shared understanding and evaluating the practical implications of this new approach remains an open issue. This critical review attempts to fill this gap by reviewing the concept, its aims, the existence of any performance measurement criteria, design methods and the expected outcomes of the RD approach to design and building. A summary process workflow diagram and an Assessment Methodology (AM) for evaluating RD project progress are proposed. The AM is presented as a series of questions to be answered qualitatively and quantitatively to aid track progress through time. Both diagram and AM may become valuable tools for further discussion about the methodological implications of RD project delivery for the architecture profession and for upgrading architectural education accordingly.

**Keywords:** Regenerative; circular; design; sustainability.

## Retrofit strategies influencing thermal performance in weatherboard-clad dwellings constructed before 2003 in a cool temperate climate

Jack Tan<sup>1</sup>, Phillipa Watson<sup>2</sup> and Mark Dewsbury<sup>3</sup>

<sup>1, 2, 3</sup> *University of Tasmania, Launceston, Australia*  
*jack.tan@utas.edu.au*

**Abstract:** This paper explores simulation-based envelope performance improvements for typical low-quality dwellings in southern Australia. Australia has over 7.6 million detached private dwellings 2005-2006 data reported there were 6.3 million detached dwellings by 2005. Most of these were built prior to the 2003 national energy efficiency regulations. Pre-2003 dwellings are a significant concern as a high proportion of them have poor-quality building envelopes which are likely energy inefficient, costly to heat or cool and unhealthy to live in. Retrofitting them to provide better indoor environments is crucial for long-term sustainability goal. This paper describes a stage of PhD research that is investigating energy, thermal comfort, and health related indoor environmental qualities. Using the energy modelling tool AccuRate, this paper assesses external envelope improvement actions that can improve both energy efficiency and indoor environmental quality. Over 800 simulations were conducted exploring options to achieve a 6 Star NatHERS result. This paper finds that many pre-2003 houses likely have a house energy star rating below 1.5 Stars and that feasible retrofits can improve energy efficiency up to 6 stars. This paper contributes to further understanding envelope retrofit strategies and provides recommendations towards improved energy efficiency outcomes for existing dwellings.

**Keywords:** Retrofitting existing housing, energy efficiency, thermal comfort, NatHERS.

## Smart Cities with no brain: A case for urban design studies utilising open-source platforms

Yang Ye<sup>1</sup>

<sup>1</sup> *School of Architecture, Harbin Institute of Technology, Harbin, China*

<sup>1</sup> *Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, Harbin, China  
yeyang@hit.edu.cn , 0000-0003-2642-0436*

**Abstract:** Urban space quality is the core research target of the Chinese urbanisation project. This is a positional paper, using a brief historical perspective of the progress of Chinese urban design, and a current problematic in Chinese smart-city platforms to foreground future studies in urban quality using open-source platforms and technology. Traditional research and design methods are mostly based on field surveys and analogue design projection. Open-source platforms such as street view images have the characteristics of wide coverage, high accuracy of human-scale street information, and low data collection costs, and can provide some new research ideas for the evaluation of urban space walkability. This paper first reviews the development process of urban quality initiatives in the Chinese, and proposes the prospects for future research.

**Keywords:** Urban design paradigms; Data based urban design; Smart city platforms;

## Study on the influence of subway entrance space layout on indoor air quality

Wei Wang<sup>1</sup>, Lei Zhang<sup>2</sup>, Sihan Xia<sup>3</sup> and Mengmeng Da<sup>4</sup>

<sup>1, 2, 4</sup> *School of Architecture and Urban Planning, Anhui Jianzhu University, Hefei 230601, Anhui, China; vivi.gan@126.com<sup>1</sup>, koalei@126.com<sup>2</sup>, 893453817@qq.com<sup>4</sup>, 0000-0002-6411-6104<sup>1</sup>, 0000-0002-8704-7981<sup>2</sup>, 0000-0002-6822-6837<sup>4</sup>*

<sup>1</sup> *Key Laboratory of Built Environment and Health, Anhui Jianzhu University, Hefei 230601, Anhui, China*

<sup>3</sup> *School of Architecture, Harbin Institute of Technology, Harbin, China  
xsh\_25@126.com, 0000-0002-6206-2376<sup>3</sup>*

**Abstract:** With the increasing area covered and the number of people served by subways due to rapid urbanization, air quality in subway stations on the health of passengers and staff has received increasing attention from society and scholars. In previous studies, the removal and control of underground pollutants have mainly focused on the indoor air conditioning and ventilation of metro stations rather than on optimizing architectural design. Therefore, this study focuses on the effect of subway entrance space layout on indoor particulate matter distribution. Our research selected three morphological indicators, namely, entrance direction, roof shape, and entrance height/width ratio, as the influencing factors. Indoor pollution in the form of subway entrances in different places was simulated after actual monitoring and verification. The results show that (1) the particle interception rate of the lateral entrance is twice as high as that of the forwarding entrance; (2) when the entrance height-width ratio is less than 1:1, the larger the entrance width is, the better the overall air quality of the subway station; (3) the abatement effect of roof morphology on the indoor particulate matter is ranked as sloping roof > flat roof > no roof. In general, the spatial morphology design can influence the entry of particulate matter into the metro station and reduce the direct infusion of outdoor pollutants through air convection and return flow.

**Keyword:** Metro stations; underground pollutants; CFD; spatial form; optimization strategy.

## The role of education in the circular built environment: Analysis of Australian educational programs impact on construction and demolition waste management

Salman Shooshtarian<sup>1</sup>, Savindi Caldera<sup>2</sup>, Tim Ryley<sup>3</sup>, Tayyab Maqsood<sup>4</sup>, Atiq Zaman<sup>5</sup> and Peter SP Wong<sup>6</sup>

<sup>1,4,6</sup>*RMIT University, Melbourne, Australia*

{salman.shooshtarian<sup>1</sup>, tayyab.maqsood<sup>4</sup>, peterspwong<sup>6</sup>}@rmit.edu.au,  
0000-0002-6991-8931<sup>1</sup>, 0000-0001-7166-8110<sup>4</sup>, 0000-0002-8429-2551<sup>6</sup>

<sup>2,3</sup>*Griffith University, Brisbane, Australia*

{s.caldera<sup>2</sup>, t.ryley<sup>3</sup>}@griffith.edu.au, 0000-0002-1263-2924<sup>2</sup>, 0000-0003-0878-5546<sup>3</sup>

<sup>5</sup>*Curtin University, Perth, Australia*

atiq.zaman@curtin.edu.au, 0000-0001-8985-0383<sup>6</sup>

**Abstract:** Resource circularity has become a necessity in the built environment sector. A significant amount of construction and demolition (C&D) waste is generated worldwide. This waste results from poor resource efficiency in the sector. Australia is among the lowest-ranked countries in the Organisation for Economic Co-operation and Development (OECD) regarding the sector's resource efficiency. A circular economy and resource efficiency can be achieved primarily through education, enforcement, and encouragement in the sector. Of these three elements, education is the focus of this paper. Education can generate attitudinal and behavioural change among stakeholders to move towards effective waste management (WM). This study aims to determine whether current Australian educational programs have successfully achieved circular economy objectives and improved resource efficiency. This paper provides an insightful overview of the programs and proposes a framework to evaluate the effectiveness of educational programs in a circular built environment. Lastly, it recommends a few practical suggestions to improve their effectiveness in the built environment sector.

**Keywords:** Construction and demolition waste, circular economy, behavioural change, Australia, training.

## The walking tourist: How do the perceptions of tourists and locals compare?

Swarnali Dihingia<sup>1</sup>, Morten Gjerde<sup>2</sup> and Brenda Vale<sup>3</sup>

<sup>1,3</sup> *Victoria University of Wellington, Wellington, New Zealand  
(swarnali.dihingia, brenda.vale)@vuw.ac.nz<sup>1</sup>*

<sup>2</sup> *Norwegian University of Science and Technology, Trondheim, Norway  
morten.gjerde@ntnu.no<sup>2</sup>*

**Abstract:** Walking is known to be a healthy and sustainable way of moving about the city, particularly in comparison with motorised forms of transport. For these and other reasons, there is a growing interest amongst urban planners and policy makers in enhancing conditions for walkers. Growing the number of people walking makes sense from the perspectives of public health, reducing pollution and greenhouse gas emissions and social sustainability. This also applies to people visiting a city; tourists are increasingly walking to get to know the places they visit from the footpath. However, there is little known about their experiences. This research addresses the question of how visitors perceive and evaluate the city they are visiting when they walk. Comparisons are made with the experience of local residents. The paper examines the relatively overlooked domain of tourist walkability and investigates the extent to which accessibility and topography may influence walking experiences. Data was gathered from a Walk Diary in which respondents evaluated the environment along a single walk. Responses were received through convenience sampling from 132 people in two New Zealand cities: Christchurch and Wellington. The Walk Diary provided an effective way of capturing differences between locals and tourists when they walk. Insights from this study will be particularly useful to those tasked with enhancing people's urban walking experience.

**Keywords:** walking; tourists; accessibility; walking experience.

## Thermal performance of student-built naturally ventilated remote accommodation in Fish River, NT

David Kroll<sup>1</sup>, Joti Weijers-Coghlan<sup>2</sup> and Arianna Brambilla<sup>3</sup>

<sup>1</sup> *University of Adelaide, Adelaide, Australia*

*david.kroll@adelaide.edu.au, 0000-0003-3447-0775*<sup>1</sup>,

<sup>2</sup> *University of South Australia, Adelaide, Australia*

*joti.weijers-coghlan@unisa.edu.au, 0000-0003-0047-0136*<sup>2</sup>,

<sup>3</sup> *University of Sydney, Sydney, Australia*

*Arianna.brambilla@sydney.edu.au, 0000-0002-8494-7861*<sup>2</sup>

**Abstract:** Remote accommodation in tropical Australia is often characterised by poor thermal performance and enormous energy costs when mechanical cooling systems are installed. Fish River Station, located in the Northern Territory, features a series of bala balas; tent-like structures to host aboriginal rangers working on-site, offering only a roof to shed beds from the rain and no additional features to provide thermal comfort. This paper is part of the Fish River project, a 3-year-long student design-build project to retrofit two of the bala balas to improve living conditions for the rangers. This paper reports on the thermal performance of one of the comprehensively retrofitted bala balas, enhanced with roof insulation and other upgrades to reduce radiant heat and improve overall thermal comfort inside. The retrofitted bala bala and an original, unmodified bala bala were monitored simultaneously (temperature/humidity/radiant heat). The authors expected to find significant improvements in thermal comfort due to the upgrades. The data shows that the upgrades resulted in overall improvements in indoor comfort. However, they also caused a thermal lag and heat retention at nighttime and during the early morning hours. The study shows that the effectiveness of roof insulation needs to be considered carefully depending on the local climate and how the accommodation is used.

**Keywords:** building performance, thermal comfort, natural ventilation, indoor environmental quality.

## Tools to assess internal surface mould growth: dynamic vs static

Griffin Cherrill<sup>1</sup>, Michael Donn<sup>2</sup>, Nigel Isaacs<sup>3</sup> and Stephen McNeil<sup>4</sup>

<sup>1, 2, 3</sup>*School of Architecture, Victoria University of Wellington, Wellington, New Zealand*  
{griffin.cherrill<sup>1</sup>, michael.donn<sup>2</sup>, nigel.isaacs<sup>3</sup>}@vuw.ac.nz, 0000-0001-6890-6843<sup>1</sup>, 0000-0002-4716-4286<sup>2</sup>, 0000-0002-1348-4644<sup>3</sup>

<sup>4</sup>*Building Research Association of New Zealand (BRANZ), Judgeford, New Zealand*  
steve.mcneil<sup>4</sup>@branz.co.nz

**Abstract:** The paper reports on research to identify a reliable tool to take account of thermal bridging. This will allow designers to evaluate the performance of timber-framed construction and the potential for internal surface mould growth. The Isothermal Planes method required by New Zealand Building Code Clause E3/AS1 to avoid internal moisture is too simplistic, therefore a more reliable tool is required. This paper compares the results from the static (moment in time) tool THERM and the dynamic tool WUFI 2D. Internal conditions were estimated by following Appendix A.1 of ISO 13788:2012 and calculated using a calibrated whole building simulation, WUFI Plus. The Temperature Factor and VTT Mould Growth Index were used to interpret the results from the static and dynamic tools, respectively. When ISO 13788:2012 is used to estimate the internal conditions, the risk of mould growth concluded from the static and dynamic tools is inconsistent with the measured data. The reason is that ISO 13788:2012 assumes internal relative humidity (RH) does not exceed 70% RH, yet mould growth commences at 80%. When internal conditions from the calibrated whole building simulation were used in WUFI 2D, the risk of mould growth was consistent with the measured data. Although using a dynamic tool over a static tool is preferred to simulate over time and account for the changing external climate, the results also highlight the importance of applying correct internal conditions, especially when assessing risk.

**Keywords:** Simulation; mould; static; dynamic.

# Towards a Post-Occupancy Evaluation linking occupant behaviour and energy consumption to mitigate the energy performance gap in residential retrofitted buildings: a literature review

Luis E. Medrano-Gómez<sup>1</sup>, Paola Boarin<sup>2</sup> and Alessandro Premier<sup>3</sup>

*<sup>1, 2, 3</sup> The University of Auckland, Auckland, New Zealand  
{lmed585<sup>1</sup>, p.boarin<sup>2</sup>, alessandro.premier<sup>3</sup>}@auckland.ac.nz*

**Abstract:** Building retrofit has become a leading sustainable action in the built environment and is expected to deliver the most energy savings by 2050. However, an Energy Performance Gap (EPG) has been identified in literature and practice related to occupant behaviour. Although links between EPG and occupant behaviour are being increasingly investigated, a lack of mixed-method studies in the field and technocentric approaches have not delivered the expected energy savings. Post-Occupancy Evaluations (POE) have proven to evaluate performance effectively, thus providing critical information to face the EPG. However, unravelling the impact of physical parameters and occupant behaviour on energy consumption requires new perspectives integrating contextual, societal and physical elements. Although current POE practice and recertification schemes consider occupant behaviour, it is evaluated simplistically and subjectively, resulting in a lack of assessment of Occupant-Building Interactions (OBI). This paper reviewed previous studies on EPG in retrofitted buildings, occupant behaviour and energy consumption, POE and rating systems, OBI, and socio-technical approaches to identify gaps in knowledge and opportunities for an innovative POE framework assessing behaviours leading to EPGs in retrofitted residential buildings. It was found that despite an increasing interest in the impact of occupant behaviours on energy consumption in buildings, there is a critical need for research assessing energy-related behaviours, magnitudes, and resulting energy savings from behavioural interventions.

**Keywords:** Energy performance gap; occupant behaviour; post-occupancy evaluation; retrofit.

## Urban dwellers' view on hazards and disasters; and, the COVID-19 pandemic: implications for resilient urban housing in the post-pandemic period

Minerva Rosel<sup>1</sup> and Isidoro Malaque III<sup>2</sup>

<sup>1,2</sup>*University of the Philippines Mindanao, Davao City, Philippines*  
{*mcrosel1*<sup>1</sup>, *irmalaqueiii*<sup>2</sup>}@up.edu.ph

**Abstract:** This paper aims to assess the housing needs and conditions of the city population, particularly in the central business district (CBD), as a pre-requisite for design intervention towards urban resiliency and enhanced quality of life. In the southern part of the Philippines, a comprehensive study was conducted in Davao City on urban dwellers' view towards hazards and disasters, through a survey covering more than 1,000 respondents from the CBD's daytime population, that was carried out in the latter half of 2019 prior to the community quarantine restrictions due to COVID-19 pandemic. Study shows that most city dwellers belong to the working population who prefer co-living arrangements, whether transient or permanent. This implies a need for new design parameters in urban housing design, as an alternative to conventional configurations. Furthermore, learning from the current pandemic, utmost consideration for health protocols in shared spaces must also be considered. With the onset of the pandemic, the real estate industry saw a shift in market preferences, particularly in high-density housing. Considering other urban hazards and disasters concerning the city dwellers as identified in the comprehensive study, new design insights and parameters are hoped for resilient infrastructure and housing developments in the post-pandemic period.

**Keywords:** Mindanao urbanization; mass housing; urban resilience; resilient cities.

## Visual environments for people living with dementia: a review of building performance criteria

Jane Waterhouse<sup>1</sup>, Alessandro Premier<sup>2</sup> and Paola Boarin<sup>3</sup>

<sup>1, 2, 3</sup> *Future Cities Research Hub, The University of Auckland, Auckland, New Zealand*  
*{j.waterhouse<sup>1</sup>, alessandro.premier<sup>2</sup>, p.boarin<sup>3</sup>}@auckland.ac.nz,*  
*0000-0002-6131-6354<sup>1</sup>, 0000-0002-2565-9923<sup>2</sup>, 0000-0003-3252-5699<sup>3</sup>*

**Abstract:** Globally, there is an increased incidence of dementia correlated with aging populations and growing efforts toward diagnosis. This effort is accompanied by a movement to create more therapeutic built environments for people living with dementia to help promote a better quality of life. Due to the complex implications and consequences of this population's visual and cognitive impairments, the visual environment can be hugely impactful. This paper provides a review of the literature on the relationship between lighting and health for the population living with dementia. The review provides insights into the current approaches for designing indoor visual environments to improve the health of people living with dementia and examines the level of evidence underlying these recommended approaches. Literature review results showed that appropriate visual environments could help alleviate the dementia-related decline in visual perception and spatial ability, as well as sleep, mood, and behaviour disturbances. However, the existing evidence does not yet provide conclusive building performance metrics and thresholds for designing appropriate visual environments for people living with dementia. Accordingly, the review indicates the future research priorities towards improving building performance for design and research into visual environments for people living with dementia in healthcare and residential settings.

**Keywords:** Dementia, Health and Wellbeing, Visual Environment, Building Performance.

## What can academic research do for city-building practitioners?

Fanni Melles<sup>1</sup>, Jeni Paay<sup>2</sup> and Ian Woodcock<sup>3</sup>

<sup>1,2</sup> *Swinburne University of Technology, Melbourne, Australia*  
{fmelles@swin.edu.au<sup>1</sup>, 0000-0001-6664-1183<sup>1</sup>}

<sup>3</sup> *The University of Sydney, Sydney, Australia*

**Abstract:** Cities are where we need to begin solving global and local urban challenges by changing how we approach urban management, planning and design. Academic research, like the smart city field, currently focuses more on informing urban policy-makers than city-building practitioners such as architects, urban planners and designers, and engineers. These professions directly affect urban fabric, systems and behaviour through their practice. However, there is a disconnect between academic theories on achieving urban sustainability and city-building practices. In this article, we analyse 43 semi-structured interviews with practitioners based in Melbourne, Australia, to understand their perceptions about academic research related to the future of cities and its relevance for and relationships with practice. According to the participants, academic research rarely connects with practice, and research outcomes do not reach practitioners as they are not in an easily accessible form. The interviewees felt that academic research discounts the value of practical knowledge. These practitioners advocated for more innovative research and risk-taking in academic research with adequate proof and translation, making findings more applicable to practice. They praised collaboration across disciplines and stakeholders. Insights from this research indicate the need for pathways for translating academic research findings into practical advice for city-building practitioners.

**Keywords:** academic research; practical implementation; city-building practitioners.

## Zeroing in: A community-based approach to the design of public space for zero-carbon living

Susan J. Wake<sup>1</sup> and Pippa Sommerville<sup>2</sup>

<sup>1,2</sup> *Unitec Institute of Technology, Auckland, New Zealand*

<sup>1</sup>*swake@unitec.ac.nz, 0000-0002-1837-7581*

<sup>2</sup>*sommerville.pippa2@gmail.com*

**Abstract:** This paper addresses our need to shift to a net-zero (zero-carbon) lifestyle. It begins by considering how public space can contribute to this and what other cities are doing about it. A case is then made for a community-based participatory approach, as it will empower people within the process of climate change mitigation. The results from participant surveys in the study area of Rānui, an outer suburb of Auckland, were followed by consultation workshops with community members. These were incorporated into a research-by-design process that has identified some key ways this community would like to see public space adapt in pursuit of a net-zero lifestyle. This research presents a holistic, integrated approach to emissions reduction which is meaningful and relevant for communities, and puts landscape architecture at the centre of the solution.

**Keywords:** zero emissions; net-zero, community participation; public space design







PROUDLY SPONSORED BY



**Curtin University**

THE **SCHOOL OF DESIGN &**  
THE **BUILT ENVIRONMENT**



The **ARCHITECTURAL  
SCIENCE ASSOCIATION  
(ANZAScA)**



Government of Western Australia  
Department of Finance  
Office of the Government Architect



**CIAT**



Department of Planning,  
Lands and Heritage



Western  
Australian  
Planning  
Commission