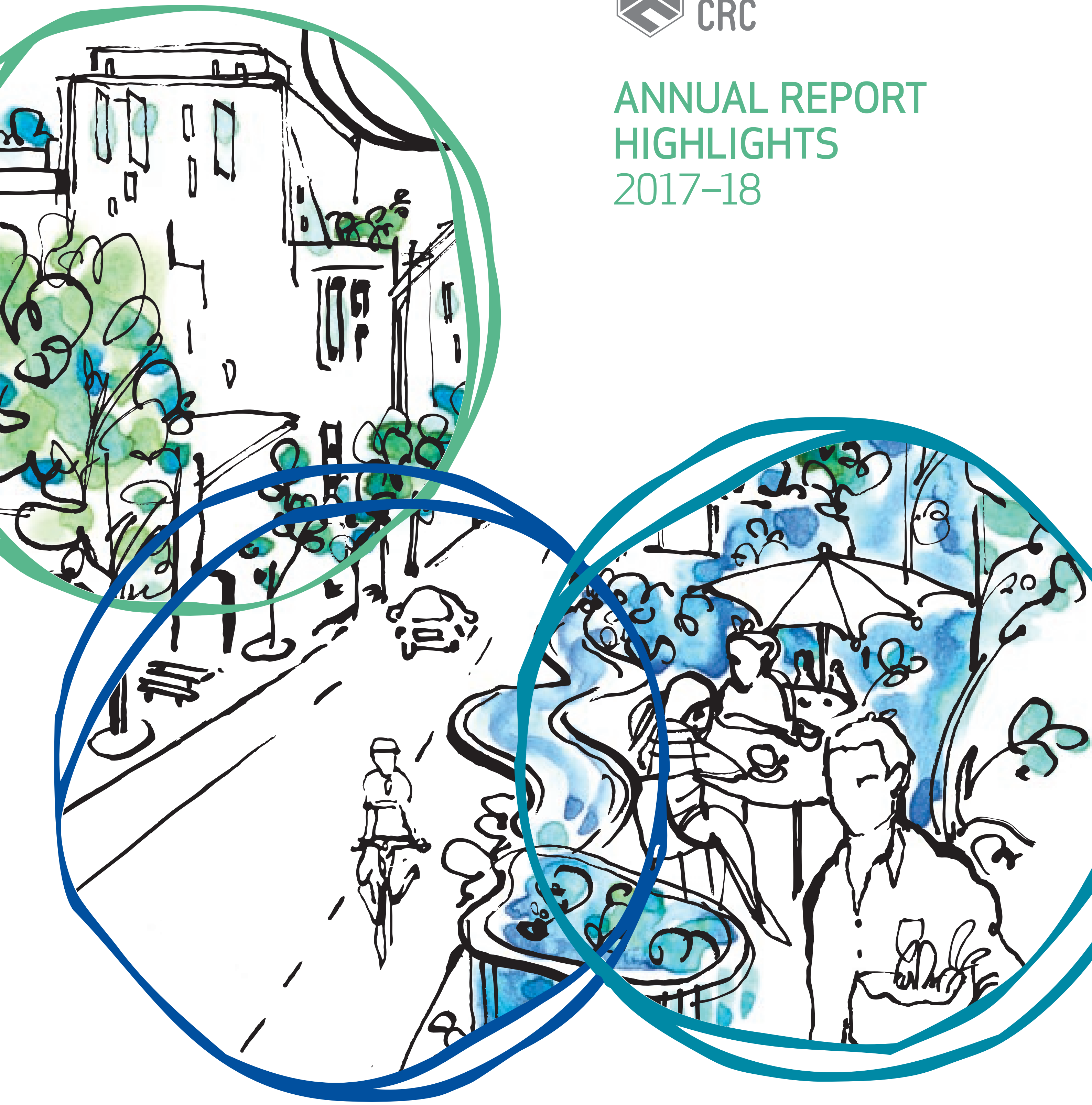
LOW CARBON LIVING CRC

ANNUAL REPORT HIGHLIGHTS
2017–18



Australian Government
Department of Industry, Innovation and Science

Business
Cooperative Research Centres Program

LOW CARBON LIVING CRC

2017/18 PARTICIPANTS

CONTENTS

James Cook University, The Science Place, Townsville QLD, designed by CRCLCL participant HASSELL.

Photo: Andrew Rankin

OUR OBJECTIVES

The Cooperative Research Centre for Low Carbon Living (CRCLCL) is a national research and innovation hub with a vital mission: to drive Australia's built environment sector towards a globally competitive low carbon future.

We support outstanding research that is designed to meet the needs of end users, including manufacturers of building materials and products; architects, planners and developers; home owners and communities; and government and regulatory organisations.

We are a highly collaborative organisation and engage with a wide variety of industry and government partners whose contribution to our mission is invaluable. We have strong links with Australia's premier universities and an outstanding cohort of student researchers whose work is guided by an elite team of senior researchers in the low carbon built environment sector.

We have two primary goals:

- Contribute to a cumulative reduction in carbon emissions of 10 megatonnes by 2020
- Enable a projected economic benefit to Australia of over $684 million by 2027

Our research aims to deliver:

- A more efficient and productive built environment sector
- Engaged communities that take action to reduce carbon emissions in their homes, suburbs and cities
- A high quality evidence base for low carbon planning and policy
- Large-scale national capability, growth and development
- Tools, technologies, strategies and research that will ensure the built environment sector remains globally competitive.

The CRCLCL has now completed the sixth year of its seven-year term and many of our research projects have already contributed to the development of next-generation, low carbon materials and technologies, and are guiding government towards resilient, sustainable cities of the future. We hope you will enjoy reading more about our achievements in the following pages.

MESSAGE FROM THE CHAIR

This penultimate year of the CRCLCL has been an extremely important one as we turn our attention to the utilisation of our projects and to securing the legacy of the Centre through the ongoing work of our six research Nodes based across Australia.

The CRCLCL represents the largest collaboration of low carbon research conducted in the nation and for that reason, as we enter our final year, our legacy arrangements are critical to ensuring that our exemplary research and impact continue to resonate in Australia's low carbon built environment sector.

"We are supporting an unprecedented number of higher degree research students across the country – the largest commitment to low carbon research capability undertaken in Australia."

I'm pleased to report that one of our major legacy items, the CRCLCL Knowledge Hub, launched its online presence in 2018. The website will provide a permanent home for CRCLCL research, offering a one-stop-shop for government and industry to access best practice knowledge and academic publications well beyond the completion of the CRCLCL.

Another essential part of the CRCLCL legacy is our commitment to leave a stronger research capability. To this end, we are supporting an unprecedented number of higher degree research students across the country – the largest commitment to low carbon research capability undertaken in Australia. To further support all our researchers, the CRCLCL recently developed a High Intensity Impact Training module to help researchers test, validate and pitch their research to an industry audience, ensuring greater uptake and utilisation of our work. To date, the module has been delivered across all our Nodes and the feedback from our researchers has been extremely positive.

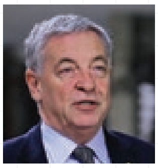
Despite moving into our final year, CRCLCL research continues to gain momentum with the Board approving 26 new projects in the last 12 months across diverse areas including applications of geopolymer concrete, energy efficient swimming pools, better ventilation for schools, inner-urban travel, community battery storage, building code reform, and the optimal measurement of emissions intensity.

In terms of governance, over the past year we have both farewelled and welcomed members of the CRCLCL Board. Warwick Dawson, Director of Knowledge Exchange in UNSW's Division of Enterprise, joined the CRCLCL Board in February as Research Sector Director replacing Dr Kevin Cullen who was in the position for five years. We sincerely thank Kevin for his service.

We also warmly congratulate Board member Professor Ken Maher who received an Order of Australia in the Queen's Birthday 2018 Honours List acknowledging his distinguished service to architecture and landscape design, particularly through urban infrastructure projects, and to environmental sustainability in planning. We are privileged to have had Ken on our Board since the CRCLCL's inception.

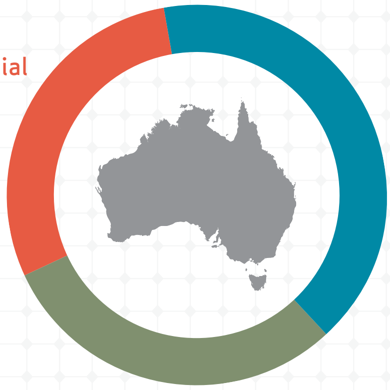
As the CRCLCL moves closer to its completion in June 2019, I feel confident that our research will continue to influence government, industry and the broader community through our world-leading products, tools and services.

Finally, I would like to thank our CEO Professor Deo Prasad and Board members, our dedicated researchers, students, government and industry partners and the HQ team for their commitment to this unique collaboration.



The Hon Robert Hill AC
Chair, Board of Directors

2018 SNAPSHOT



29% Commercial revenues

41% Energy & carbon reductions

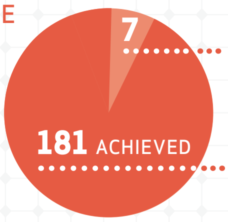
30% Other benefits

$684m
expected benefit to Australian economy by 2027

120+
APPROVED PROJECTS
52 COMPLETED
77 ACTIVE

BUILDINGS
COMMUNITIES
PRECINCTS

188 TOTAL MILESTONES DUE TO DATE



to be met in FY7

includes 47 utilisation milestones

8 IMPACT PATHWAYS

16 LIVING LABORATORIES

44 PARTICIPANTS
19 Industry
15 Government
10 Research

161 PUBLICATIONS
7 Books/chapters
59 Journal articles
69 Conference papers
26 End-user reports

ENABLING SIGNIFICANT CARBON REDUCTIONS

10Mt target by 2020 = the annual greenhouse gas emissions from 2.1 million passenger vehicles*

67Mt target by 2027 = the annual emissions from 14.3 million passenger vehicles*

*Source: USA EPA Greenhouse Gas Equivalencies Calculator

ONCE IN A GENERATION

CAPACITY BUILDING FOR THE BUILT ENVIRONMENT SECTOR

PREPARING INDUSTRY-READY GRADUATES

FORECAST INVESTMENT
$8m
in student scholarships over life of CRCLCL

HDRs ENROLLED
104
67 ONGOING
27 COMPLETED
10 DISCONTINUED

6
NODES OF EXCELLENCE

Knowledge Hub

Curtin University
Swinburne University
University of Melbourne
University of South Australia
University of Wollongong
UNSW Sydney

KNOWLEDGE HUB launched in 2018

James Cook University, The Science Place, Townsville QLD, designed by CRCLCL participant HASSELL.

Photo: Andrew Rankin

MESSAGE FROM THE CEO

Six years ago, the CRCLCL opened its doors with a deep commitment to help the built environment sector reduce its carbon footprint while enabling it to become globally competitive through multi-disciplinary collaborative research that delivers world-leading innovations. At the time, we were faced with many challenges including a disparate sector with little appetite for research and innovation.

Thankfully, much has changed in recent years and now both the sector and industry have evolved to realise the critical need for carbon reduction at all levels of the built environment. Not only that, the sector has become the largest employer in Australia, making our work even more important as we strive to keep our cities, and the industry that supports them, environmentally competitive into the future.

Many of the projects featured in this our final CRCLCL Annual Highlights Report are a testament to our commitment to lowering carbon emissions in the built environment. They include: *Climate Clever*, the education program that is being rolled out nationally after a successful pilot program in Perth schools; *Low Carbon Living Australia*, which has helped 80 tourism businesses lower their carbon emissions; the world-first geopolymer barricades that are protecting NSW Ports; and *Built to Perform*, the report that has proven that changes to the National Construction Code can improve energy efficiency in Australian buildings by up to 56 per cent (pages 22-23). We also highlight the trajectory of our Urban Heat Mitigation projects which have culminated in an authoritative new body of Australian research on the critical subject of how to cool our cities (pages 24-25).

We have a dedicated CRCLCL team and this year we farewelled two of our Node Leaders as they reached retirement. I sincerely thank Professor Wasim Saman (University of South Australia) and Professor Peter Newman (Curtin University) for their expertise and leadership in overseeing the smooth running of two of our six research Nodes. I'm pleased to announce Professor Christopher Saint, Dean of Research and Innovation Information Technology Engineering and the Environment, as our new University of South Australia Node Leader and Professor Greg Morrison, Director of the Sustainability Policy Institute as Curtin University's new Node Leader. We value the experience they bring to the CRCLCL.

Looking back at the trajectory of the CRCLCL, I'm extremely proud of how far we've come. We started with 27 projects in our first year; this has now grown to more than 100 projects that are delivering real impact to the built environment. We began six years ago with only two Living Labs and now have 16 homes and precincts across Australia where residents, industry and researchers are working collaboratively to test low carbon living technologies.

> "Now both the built environment sector and industry have evolved to realise the critical need for carbon reduction at all levels of the built environment."

We have also surpassed our expectations regarding higher degree research student enrolments; we currently have 67 ongoing students, 27 completed and have comfortably exceeded our target of 88 enrolments when we began in 2012. This new generation of Australian researchers will not only understand technical and design challenges but how to work effectively with industries and commercial partners to ensure that great ideas are translated into better cities.

We hope you enjoy reading this showcase of CRCLCL research in this our last Annual Highlights Report.

Scientia Professor Deo Prasad AO
Chief Executive Officer

PROGRAM 1

Integrated Building Systems

Developing new low carbon embodied products and services, and finding ways to communicate best practice design through rating tools, standards and display homes.

1 Harnessing the Australian sun

2 Lowering the embodied carbon in buildings

3 Mainstreaming low carbon buildings

PROGRAM 2

Low Carbon Precincts

Creating planning techniques and data for delivering low carbon developments at a precinct level. Communicating best practice in sustainable city planning through exemplar precinct developments and tools.

4 Designing integrated low carbon precincts

PROGRAM 3

Engaged Communities

Capturing a new community appetite for low carbon living. Through research, communicating to business and government the vision of a prosperous, liveable and sustainable society.

5 Evidence base for low carbon living policy

6 Enhancing community engagement

RESEARCH ACTIVITIES

The CRCLCL's research projects are organised under three Programs:

PRECINCTS

BUILDINGS

COMMUNITIES

comprising 8 IMPACT PATHWAYS

Together these set out a strategy for achieving a low carbon, economically viable built environment.

The following pages showcase the progress of a sample of these projects.

7 Living laboratories as low carbon lifestyle narratives

8 Enhance education and capacity building

Josh's House (CRCLCL Living Laboratory) and surrounding houses, Perth WA
Photo: Acorn Photography.

IMPACT PATHWAY 1

HARNESSING THE AUSTRALIAN SUN

The CRCLCL aims to make active solar products the default choice for roofing in Australia. The energy potential of the sunlight landing on our rooftops is vast and could be used to heat, power and even cool entire cities. Impact Pathway 1 is helping to move Australia towards this exciting, low carbon possibility.

RESEARCH HIGHLIGHTS

3-IN-1 ROOFTOP SOLAR: POWER, HEATING AND COOLING

This unique rooftop solar project transforms the sun's energy into electricity, heating and cooling to provide year-round comfort, regardless of the season. The breakthrough three-in-one technology integrates a photovoltaic module, a solar thermal collector and a desiccant heating and cooling system to create the new BlueScope PVT roofing technology. Unlike standard rooftop PV units that only generate electricity, this co-generation apparatus also efficiently harnesses and utilises heat from the roof to maintain comfortable indoor temperatures and ventilation. In 2017-18, all the components in a prototype system were installed on a rooftop at UNSW, enabling additional testing ahead of planned commercialisation.

The system's key innovation is its capacity to function effectively across a range of temperatures. The project was completed in mid-2018, with finalised PhD theses expected by the end of the year.

RP1015: Combining a building integrated PVT system with a low temperature desiccant cooler to drive affordable solar cooling

GETTING THE MOST OUT OF RESIDENTIAL SOLAR

Smart monitoring, forecasting and management of residential rooftop solar systems can maximise their benefits. Working with Solar Analytics, Australia's largest independent solar monitoring company, this CRCLCL project aims to optimise energy efficiency by using intelligent algorithms that assess local loads, weather and energy generation. The result is the automated delivery of analyses of electricity production and consumption. In 2017-18, researchers focused on interactive applications to predict solar irradiance and residential demand for individual households. The forecasts are valuable for the management of power grids but also to help households get the most out of their PV systems. Smart algorithms for diverting residential solar PV energy to hot water systems and batteries were also developed and implemented in association with PhD research. The project is expected to be completed before the end of 2018.

RP1023: Forecasting and home energy analysis in residential energy management solutions

PARTICIPANTS

- AECOM
- BlueScope
- CSIRO
- CSR
- GWA
- Multiplex
- NSW Office of Environment and Heritage
- Solar Analytics
- UNSW Sydney
- University of South Australia

Tyree Energy Technology Building, UNSW Sydney NSW, constructed by CRCLCL partner Multiplex.

Photo: Courtesy of UNSW

LOWERING THE EMBODIED CARBON IN BUILDINGS

Conventional building materials embody significant quantities of energy and carbon. CRCLCL researchers are developing new, more environmentally friendly building materials as well as innovative processes to propel them into mainstream use.

University of Queensland Advanced Engineering Building, Brisbane QLD, designed by CRCLCL participant HASSELL.
Photo: Scott Burrows

PARTICIPANTS

- AECOM
- Ametalin
- Ash Development Association of Australia
- Australasian Slag Association
- BlueScope
- Independent Cement and Lime
- Multiplex
- NSW Ports
- Standards Australia
- Swinburne University of Technology
- Sydney Water
- UNSW Sydney
- University of Wollongong

INDUSTRIAL INNOVATION: PUTTING LOW CARBON CONCRETE TO WORK

By utilising industrial waste as a resource, geopolymer concrete promises to reduce construction emissions by up to 80 per cent when compared with conventional Portland cement. However, to reap the environmental and commercial benefits, real-world testing and guides for the specification, production and use of geopolymer concrete are essential. In 2017-18, CRCLCL researchers conducted large-scale testing of the product and a comprehensive geopolymer concrete handbook is being finalised. In partnership with the Port Kembla Authority, high-density geopolymer test bollards were successfully incorporated into coastal defence structures. Results were reported and an Australian provisional patent (number 2017903845) was secured. As conventional concrete is responsible for up to 8 per cent of global CO_2 emissions, geopolymer concrete – which incorporates problematic fly ash waste – offers considerable promise for reducing the carbon footprint of construction.

RP1020: Reducing barriers for commercial adaptation of construction materials with low embodied carbon

CUTTING EMBODIED CARBON AT THE DRAWING BOARD

The building sector routinely seeks to minimise costs and optimise the construction process even when plans are still on the drawing board. Using a similar approach, this project aims to reduce embodied carbon in the built environment by identifying potential carbon savings before construction begins. Using the industry-standard practice of 'value engineering' this project adds embodied carbon to costs and 'constructability' to deliver a new triple bottom line. Working with data provided by partner Multiplex, CRCLCL researchers published a new report in 2017-18 that identified savings of 1.26 per cent in embodied carbon and 0.72 per cent in materials costs. Demonstrating that greener buildings can be cheaper is significant; Australia's built environment accounts for almost 25 per cent of emissions and is the nation's third largest sector.
The project will be completed in early 2019.

RP1034: Carbon Value Engineering: Integrating carbon and cost reduction strategies in building design

THE VALUE OF KEEPING A COOL ROOF

Standard roof temperatures can exceed 80°C on hot days. By contrast, 'cool roofs' that use materials and colour that reflect the sun's heat can reduce interior temperatures, improve the efficiency of air conditioning and solar panels and, at large scale, can combat the urban 'heat island' effect. However, the benefits appear to be underestimated. This project will deliver a comprehensive set of cool roof design and cost-benefit calculation resources, based on typical large-footprint Australian buildings, including three examples in Shellharbour and Nowra on the NSW south coast and Wetherill Park in Sydney's west (providing a total roof area of more than 160,000m^2). This includes rigorous evidence-based assessments of the impact of cool roof products on the thermal performance of buildings. In 2017-18, extensive measurement and computational modelling was undertaken for sites in Nowra and Wetherill Park, followed by cost-benefit analyses and greenhouse gas abatement estimations.
A final report is due before the end of 2018.

RP1037: Driving increased utilisation of cool roofs on large-footprint buildings

IMPACT PATHWAY 3

MAINSTREAMING LOW CARBON BUILDINGS

CRCLCL researchers are gathering, analysing and promoting evidence that demonstrates the merits of low carbon products, materials and designs. Their findings aim to instil confidence in low carbon buildings and drive up demand for them. The work within this impact pathway also supports smart policy and decision-making, and facilitates accurate comparisons between low carbon and traditional products, materials and designs.

RESEARCH HIGHLIGHTS

SAVING ENERGY BY FINE-TUNING HVAC SYSTEMS

With heating, ventilation and air conditioning (HVAC) accounting for up to half the energy consumption of Australia's commercial buildings, the rapid identification and diagnosis of faults is a potentially important energy and emissions saving measure. Automatic fault detection and diagnostic (FDD) tools are emerging on the market; however, the numerous commercial products and different delivery models are confusing and their comparative value poorly understood. This CRCLCL project has delivered a rigorous and systematic independent evaluation of the potential costs and benefits of emerging automated FDD tools through comprehensive real-world demonstrations. Researchers determined their efficacy across a range of commercial building types and HVAC systems. The project was completed in 2017-18, with the delivery of comprehensive field testing results across four major case studies and feedback to participating industry partners.

RP1026: Evaluation of next-generation automated fault detection and diagnostic tools

A MODULAR FUTURE FOR MEDIUM-RISE BUILDINGS

Modular building systems can reduce construction times and costs while virtually eliminating construction waste. These combined advantages promise to slash the carbon footprint of the construction sector, a major global emitter. However, effective modular building systems depend on robust connections for assembly and can be limited by transport challenges and other technical issues, such lateral load resistance. This project is developing an innovative, repeatable steel-based framing solution for medium-density construction, based on the maximum transportable unit size of 16m x 4.5m x 3m. In 2017-18, three concepts for joins were developed

for rigorous testing. The positive industry response has led to the extension of the project to 2019 to allow more time for the dissemination of ideas and results.

RP1031: Low carbon medium-rise modular structures using innovative connections

DRIVING THE UPTAKE OF HIGH-PERFORMANCE HVAC SYSTEMS

Big energy savings can be achieved by installing high-performance heating, ventilation and air conditioning (HVAC) systems in commercial buildings, with associated reductions in emissions. However, more information is needed to drive the widespread uptake of high-performance HVAC, to improve best practice and to inform building codes. This project is investigating the minimum energy requirements of the National Construction Code (NCC), best practice of HVAC designs in Australian commercial buildings, and the five largest energy consuming components of a high-performance commercial HVAC system. Initial research in 2017 resulted in a submission to the NCC-2019 review of Section J of the code. Further results will be reported in late 2018, including findings on the interpretation of code provisions and building performance.

RP1033: Mainstreaming high-performance commercial building HVAC

PARTICIPANTS

AECOM
Ausgrid
BlueScope
City of Sydney
CSIRO
CSR
Curtin University
HASSELL
Multiplex
NSW Department of Planning and Infrastructure
NSW Office of Environment and Heritage
Randwick City Council
Renewal SA
Swinburne University of Technology
Sydney Water
University of Melbourne
UNSW Sydney
University of South Australia
Victorian Building Authority

DESIGNING INTEGRATED LOW CARBON PRECINCTS

CRCLCL research is contributing to the design of entire low carbon neighbourhoods, including individual buildings, transport, infrastructure, land use and waste management. This Pathway recognises both the environmental benefits of low carbon precincts and their potential to promote human wellbeing. It is also focused on the development of tools for precinct design and assessment that will make it easier for industry and government to make low carbon choices.

FORECASTING CARBON IMPACTS OF URBAN DEVELOPMENTS

This CRCLCL project has developed a new tool that integrates demand for energy, transport, waste and water (ETWW) with carbon impacts to enable accurate forecasting of the carbon footprint of urban developments. This unique approach allows for interactions between the different ETWW demand domains and considers population changes, socio-economic variables and changes in household behaviour. As such, the tool enables carbon impacts of new development or redevelopments in urban precincts to be effectively and efficiently forecast, aiding decision-making and emissions calculations. Results were initially presented at a CRCLCL-hosted symposium attended by domain researchers, project leaders and industry representatives. In 2017-2018, the project was presented to the CUPUM 2018 (International Conference on Computers in Urban Planning), including its modelling approach, forecasting methodologies, carbon impacts and industry perspectives.

RP2002: Integrated ETWW demand forecasting and scenario planning for precincts

FEELING THE HEAT IN OUR CITIES

A new cross-disciplinary understanding of the causes of urban heat island (UHI) effects is delivering new planning and design solutions. Heatwaves are Australia's most deadly natural hazard and the main driver of spikes in peak electricity demand. This CRCLCL project investigated UHIs in Sydney, Melbourne and Adelaide and found that residents with pre-existing health conditions or living in rental accommodation and/or energy poverty were the most vulnerable. By contrast, cooling features like canopies, water features and shadow coverage, as well as building insulation and reflective surfaces, improved people's heat resilience. With the research component completed in 2017-18, findings at the metropolitan, precinct and building level were shared widely via publications, utilisation and dissemination activities, seminars, presentations and media appearances. Associated PhDs were due to be completed in late 2018.

RP2005: Urban micro climates: Comparative study of major contributors to the Urban Heat Island (UHI) effect in three Australian cities (Syd, Melb, Adelaide)

TRACKING CARBON EMISSIONS IN BUILDING MATERIALS

CRCLCL researchers have developed new software tools and databases to track the embodied carbon and emissions of building materials over their life cycle, from processing to distribution to use. A new database of Australia-specific embodied carbon emissions for construction materials, including concrete, steel and timber, informed the development of a new Embodied Carbon Explorer (ECE) tool, delivered in 2017-2018. The ECE tool was deployed on the Industrial Ecology Lab (a Nectar Virtual Laboratory) along with its sister tool, the PCA (Precinct Carbon Assessment), developed in Matlab. In the utilisation stage, the tools were aligned with the National Carbon Offset Standard for Precincts (NCOS-P) and presented to industry partners. The planned move of the PCA online in 2019 will enhance the project's accessibility and impact.

RP2007: Integrated Carbon Metrics: A multi-scale life cycle approach to assessing, mapping and tracking carbon outcomes for the built environment

A NEW TOOL TO CUT EMISSIONS FROM WATER RECYCLING

Effective water recycling is important for safeguarding public health and the environment but is costly in terms of energy and emissions. This project has developed a new Benchmarking Energy and Carbon (BEC) tool, tailored to Australian conditions, that will enable the wastewater industry to optimise processing to reduce emissions and energy use. Previously, the industry relied on German benchmarking

PARTICIPANTS

AECOM
Aurecon
Ausgrid
Better Building Partnership
BlueScope
BuildingSMART
City of Melbourne
City of Sydney
CSIRO
Curtin University
Dept Environment Water & Natural Resources SA
Dept of Environment SA
Dept of Industry NSW
Dept of Infrastructure and Transport NSW
Dept of Water and Natural Resources SA
HASSELL
Housing Industry Assoc.
Multiplex
NSW Office of Environment and Heritage
Renewal SA
SA Water
Sustainability Victoria
Swinburne University of Technology
Sydney TAFE
Sydney Water
University of Melbourne
UNSW Sydney
University of South Australia
Urban Growth NSW
Urban Renewal Authority
UTS
Victorian Building Authority

methodology untested in the local context. CRCLCL researchers critically reviewed the German methodology and used Australian wastewater treatment operations case studies, and a water industry data set, to inform its adaptation for Australian plants. The resulting new suite of wastewater treatment energy benchmarks and KPIs were integrated into the new BEC tool in 2018. By mid-2018, trialling and testing with industry partners was underway.

RP2017u1: Energy benchmarking for efficient, low carbon water recycling operations

USING FOOD WASTE TO GROW MORE FOOD

A third of food produced worldwide goes to waste and much of it ends up in landfills, generating huge volumes of damaging greenhouse gases (particularly methane). Composting to turn waste food into soil conditioners for agricultural food production is a potential solution but what systems work best remains unclear. This CRCLCL project is investigating different composting options, ranging from on-site home-based systems, to larger scale community and commercial schemes. A distributed model for reducing greenhouse gases by diverting food waste away from landfill is under development and researchers are scrutinising the environmental, health, social and economic co-benefits. In 2017-18, they installed additional on-site home composting apparatus and undertook a wide range of outreach and communication activities, including media releases and events.

RP2019: CO_2 Reduction and Food Production from Household and Commercial Food Waste: Composting for Different Urban Forms

GREENING INNER CITY TRANSPORT OPTIONS

What's standing in the way of active and public transport options for Australian cities? CRCLCL researchers are investigating ways to shift travel habits towards more sustainable transport modes and developing a framework to support effective investments in greener urban transport systems.

In 2017-18, they developed a database, carbon calculator and mobile apps for use in active transport surveys (bike, walking etc). In association with the South Australian Government's Carbon Neutral Adelaide plan, the researchers are now engaged in an extension project, RP2021e1, to study the use of shared transport services. By determining what role share bikes, cars, Uber-type services and 'eco-cabbies' play in reducing urban transport emissions, this project will contribute to Adelaide's broader goal to become carbon neutral. Literature reviews, interviews and surveys were completed in 2017-18 and a final report is due in late 2018.

RP2021 and 2021e1: Greening Suburban Travel and Carbon Neutral Adelaide – Greening Inner-Urban Travel

IMPACT PATHWAY 5

EVIDENCE BASE FOR LOW CARBON LIVING POLICY

The CRCLCL aims to provide evidence to show the high social, environmental and financial benefits of carbon mitigation policy for Australia and encourage government and community uptake.

RESEARCH HIGHLIGHTS

PARTICIPANTS

ASBEC
CSIRO
Curtin University
Department of Industry
Energy Action
Green Building Council Australia
HASSELL
Multiplex
NSW Office of Environment and Heritage
PCA
Strategy Policy Research
Swinburne University of Technology
Sydney Water
University of Melbourne
UNSW Sydney
University of Wollongong

UNPACKING CONSUMER CHOICES TO DRIVE ENERGY EFFICIENCY

What influences households to embrace energy-efficient technologies or behaviours? This complex question has been incorporated into a new model that will help policymakers and industries drive energy efficiency in the residential sector, responsible for around nine per cent of emissions. The project identified the main factors that drive or frustrate the adoption of energy-efficient products or practices including the imitation of peers, the limitations of budgets and media messages. It also considered 'decision points' that offered opportunities to influence consumer behaviour. For example, recruiting plumbers to promote solar hot water was an effective way to engage householders deciding on a new hot water system. The project was completed in mid-2018 with a final report and the delivery of a novel Agent-Based Modelling (ABM) tool aligned to industry platforms.

RP3028: A 'virtual market' for analysing the uptake of energy efficiency measures in the residential sector

THE HOW AND WHY OF WATER-EFFICIENT CONSUMER CHOICES

The two biggest uncertainties in estimating future demand for water are customer behaviour and the adoption of water-efficient appliances. This CRCLCL project looked at the many factors that influence consumer decisions to take up water-conserving products and services and how and why they select particular appliances and fixtures, like washing machines and taps. Researchers developed a model that predicts the actions of different segments of the community and explores the future adoption of water-efficient technologies in homes and businesses. As most of the energy used in the urban water cycle goes to heating water, reducing overall water usage is a good way to reduce emissions. Using behavioural science and Agent-Based Modelling, research was completed in 2017-18 and the resulting model presented to partner Sydney Water.

RP3035: Sydney Water Diffusion Modelling project

POTENTIAL WIN-WIN FOR COMMUNITY AND PUBLIC HOUSING

Retrofitting community and public housing with energy-saving technologies and features represents a major opportunity to simultaneously reduce household emissions and protect economically vulnerable tenants from hefty energy bills. In 2017-18, researchers established 'living labs' to monitor 21 homes retrofitted with heat pump hot water systems, draught sealing, reverse cycle air conditioning and rooftop solar PV in Parramatta, Bathurst, Orange and Narrabri. Analysis of the data streams is ongoing, with the aim to develop an evidence-based business case for retrofitting public housing stock based on low carbon benchmarks. This is a promising option as community and public housing is usually centrally managed and is regularly upgraded and maintained, providing opportunities for energy-efficient retrofits to be incorporated into maintenance practices and budgets.

RP3044: Mainstreaming low carbon retrofits in social and community housing

IMPACT PATHWAY 6

ENHANCING COMMUNITY ENGAGEMENT

The CRCLCL supports collaboration between developers and communities that stimulates demand for low carbon infrastructure and services. Our researchers are developing community engagement and consultation processes to facilitate rich dialogue about community aspirations for low carbon living. Councils, property developers and utility companies will be able to use these processes to improve developments and enable faster approvals.

OLDER SUBURBS GO LOW CARBON

Authorities in Australia's capital cities plan to regenerate established suburbs to deliver liveable, medium-density low carbon precincts. By redeveloping ageing suburbs in 'smart' ways and infilling available land, housing density and affordability can be increased while carbon emissions are reduced. This CRCLCL project will deliver new processes, standards and certification procedures, based on state-of-the-art design and assessment tools. They will support community groups to work with local governments, state agencies and property developers, to co-design sustainable medium-density housing precincts. Developed in collaboration with the CRC for Spatial Information (now FrontierSI), the new procedures and protocols aim to build trust, reduce conflict and increase incentives for low carbon urban regeneration and densification. In 2017-18, researchers worked closely with two local councils in Victoria and forged links with an additional council in NSW.

RP3034: Community co-design of low carbon precincts for urban regeneration in established suburbs

PARTICIPANTS

- Blue Mountains World Heritage Institute
- BMCC
- BMLOT
- City of Fremantle
- CRC Spatial Information
- CSIRO
- Curtin University
- Gridstone
- NSW Office of Environment and Heritage
- Swinburne University of Technology
- Sydney Institute of TAFE
- University of Melbourne
- UNSW Sydney
- University of South Australia

IMPACT PATHWAY 7

LIVING LABORATORIES AS LOW CARBON LIFESTYLE NARRATIVES

The CRCLCL has helped to establish 16 Living Laboratories around Australia. They are 'learn by doing' community developments – ranging from individual homes to entire precincts to groups of people – through which the CRCLCL, its researchers and partners can integrate, test and evaluate low carbon living solutions. Living Laboratories also promote engagement with the public and help to generate demand for low carbon solutions.

RESEARCH HIGHLIGHTS

TAKING ZERO EMISSIONS HOMES TO THE MASS MARKET

This CRCLCL project seeks to amplify the success of Josh's House, a living lab based in Perth's port suburb Fremantle, by showcasing the technology, affordability and liveability of a High Performance (HP) Zero Emissions Home (ZEH). To help drive the adoption of this model for mass commercial development, new case study sites were established in Townsville, Canberra and Melbourne in 2017-18. The project is assessing potential cost barriers to uptake and consumer interest as well as informing developers and the construction industry of market potential. As residential homes are a major contributor to emissions, particularly through their daily operations, HP-ZEH homes show great promise. A solar power upgrade to the original Josh's House Living Lab was also undertaken as part of an electric vehicle home trial and the first video in the *The Builders Journey* video series completed.

RP3009: High Performance Housing: LL monitoring, evaluating and communicating (Josh's House)

ARE WE READY FOR LOW CARBON LIVING?

To support the adoption of low carbon options, how end users make decisions must be better understood. This project has delivered a new Low Carbon Readiness Index, a reliable and practical indicator of people's psychological readiness to transition to low carbon living alternatives, based on the social psychology of behavioural change. The index can predict a person's willingness to choose low carbon alternatives and has been developed for use across CRCLCL projects and for annual national assessments. In 2017-18, researchers completed reporting on the index and published findings and recommendations to inform regulatory and other interventions to drive low carbon solutions.

RP3012: Environmental attitudes: low carbon behavioural practice

LOW CARBON LIVING PAYS OFF FOR ADELAIDE

The Adelaide Living Laboratory project has demonstrated that low carbon living is a great value proposition for both governments and householders. Drawing on data and insights from three key Adelaide low carbon developments at Tonsley, Lochiel Park and Bowden, researchers found zero carbon housing in local areas was overwhelmingly positive. The benefits for the South Australian community were calculated at $2.42 in economic gain for every $1 invested in low carbon homes. Homes in Lochiel Park Green Village, for example, use less than a third of the energy required by a conventional home due to energy efficient lighting and appliances, solar water heaters and rooftop PV.

RP3017: Adelaide Living Laboratory Hub– Lochiel Park, Bowden and Tonsley

GETTING THE WORD OUT ABOUT LOW CARBON HOME RENOVATIONS

This project aims to deliver media and communications strategies to promote low carbon renovating to a mass market, shifting away from current perceptions of 'green building' as a niche market. Researchers designed, developed and assessed new strategies including designs for a website that offers renovators tools to imagine various low carbon options by planning renovations online. With a popular renovation culture backed by TV competitions and widespread mainstream and social media interest, the decarbonisation of Australia's eight million houses through low carbon renovations could significantly reduce national emissions. By identifying innovative ways to reach renovators via the media, the project aims to help make low carbon renovating the norm.

RP3021: Media and communication strategies to achieve carbon reduction through renovation of Australia's existing housing

PARTICIPANTS

AGL
Australian Windows Association
Blue Mountains World Heritage Institute
BlueScope
BMCC
BMLOT
City of Fremantle
Clean Energy Council
CSIRO
CSR
Curtin University
Dept Environment Water & Natural Resources SA
Energy Efficiency Council
Fletcher Insulation
Gridstone
Housing Industry Association
Josh Byrne & Associates
Knauf Insulation
LandCorp
Low Energy Supplies & Services Pty Ltd
Masters Builders Association
NSW Office of Environment and Heritage
Renewal SA
Stockland

Bowden CRCLCL Living Laboratory, Adelaide SA

Photo: Renewal SA

White Gum Valley CRCLCL Living Laboratory, Perth WA, residential home with rooftop PV

Photo: Courtesy JBA © VAMMedia

SUBURBIA'S FUTURE: GREEN, MEDIUM DENSITY, SOLAR POWERED

The White Gum Valley (WGV) Living Lab has tracked a low carbon infill residential development in Fremantle in Western Australia from its inception to evaluate the impact of key features such as solar-focused design, W materials, water sensitive design and shared solar power generation. The 2.2ha WGV medium-density mixed housing precinct, developed by the West Australian Government agency LandCorp, aims to demonstrate the cost-effectiveness and liveability of green developments. The monitoring of WGV continued in 2017-18 alongside work on a database, a visualisation platform and a seventh *Density by Design* video. WGV residents will be able to trade solar energy with each other directly, one of the first examples of peer-to-peer energy trading in the residential space. The project will deliver a new evidence base to drive the mainstream development of low carbon precincts.

RP3033: Mainstreaming Low Carbon Housing Precincts – the White Gum Valley Living Lab

THE POWER-SHARING ECONOMY: COMMUNITY BATTERIES FOR ROOFTOP PV

This CRCLCL project takes the White Gum Valley low carbon precinct model to the wider community of Fremantle, enabling the development and testing of community-level battery storage utilising a solar power sharing model. In 2017-18, design planning for the first stage of Beyond WGV commenced as part of the redevelopment of Fremantle and a new subdivision proposal was submitted to LandCorp for approval. Planned innovations in energy and water systems, supported by the RENeW Nexus Smart Cities project, offer new opportunities to deliver community battery storage by capturing value from reduced head works, diversified load balancing and economies of scale. The project will assess these innovations at the district scale, to provide a much-needed new evidence base to inform agencies and politicians considering new energy generation and management models.

RP3043: Beyond White Gum Valley: Community Battery Storage

ENHANCED EDUCATION AND CAPACITY BUILDING

The CRCLCL's mission relies on the creativity and energy of superlative researchers and we are proud to support students undertaking higher degrees by research. Based at our partner universities across the country, our students will graduate with valuable skills that will help create a globally competitive and environmentally sustainable built environment.

PARTICIPANTS

- AECOM
- BuildSMART
- CSIRO
- Curtin University
- Master Builders Australia
- Multiplex
- Strategy Policy Research
- Swinburne University of Technology
- Sydney Coastal Councils
- TAFE NSW
- University of Melbourne
- UNSW Sydney
- UrbanGrowth NSW
- Victorian Building Authority

ADRIANA SANCHEZ
PhD candidate, UNSW

"Urban resilience is the way cities cope with and plan for challenges that may threaten their population and infrastructure, such as climate change.

"My research aims to understand how urban resilience policy, particularly around climate change and other long-term challenges, can be developed and implemented at the metropolitan level in an effective and efficient manner and I have been developing a framework to compare and learn from international efforts.

"My research points to the importance of understanding the local opportunities and challenges – the political, fiscal and governance constraints – that may affect public and private organisations' ability to deliver resilience action over long periods of time. The research was published earlier this year in *Palgrave Communications – Nature*.

"I got involved with this project because I'm passionate about policy and believe that cities can drive global change. The thing that excites me most about this project is that every city is different but we can still learn from their experiences and use that knowledge to develop better policy."

NP4005: Urban Sustainable Resilience: A policy framework

BARAN YILDIZ
PhD candidate, UNSW

"Residential demand makes up almost one quarter of total energy use and is responsible for significant quantities of greenhouse gas emissions. In addition, electricity in Australia is some of the most expensive in the world. Therefore, we have both economic and environmental motivations to manage our household energy consumption well.

"We also live in the age of the Internet of Things, surrounded by smart gadgets and applications. Smart home energy management systems are slowly finding their place in our households where they can optimise the operation of our appliances and help us utilise solar power and batteries effectively. Ultimately, they can transform our homes into energy-smart dwellings.

"My research, which is being undertaken with [performance management software company] Solar Analytics, endeavours to understand the day-to-day consumption patterns of households and the underlying factors that affect habitual human behaviours. I am also investigating the most effective methods to forecast household electricity loads by using machine learning models.

"The results have shown that the information gained from my research can expand the capabilities of home energy management systems, and help to improve the potential savings and reduce the associated emissions. I am excited to see the deployment of my research in a real-world product that will help to combat climate change."

RP1023: Forecasting and home energy analysis in residential energy management solutions

MEET SOME OF OUR STUDENTS

CATHERINE KAIN

PhD candidate,
University of Melbourne

"We have the technical know-how to create sustainable, low carbon housing but we need property developers on board to ensure its uptake on a broad scale.

"My research investigates the developer's priorities in building apartments. Using the profit principle of providing value to customers, I ask 'can the developer integrate greater energy efficiency into their apartment developments and use this for competitive advantage'?

"I want to know what the developer thinks about energy efficiency; for instance, do they view the building code requirements as a maximum or minimum standard, and can they incorporate greater energy efficiency in their branding?

"We know that property buyers mainly look for location, features and layout, but could purchasers be persuaded to consider how the apartment feels; the comfortable temperature without turning on air conditioning, and how much money they could save on energy bills?

"The research points to an opportunity for developers to take a strategic look at the 'package deal', including energy efficiency for a competitive edge.

"Ultimately, I would like to see developers recognise a market advantage in incorporating energy efficiency in creative branding without waiting for building policy to enforce change."

RP3017: Adelaide Living Laboratories

JANE LOVEDAY

PhD candidate,
Curtin University

"With 55 per cent of the world's population now living in urban areas, urban heat is a growing global challenge. Air and surface temperatures are increasing due to both climate change and loss of vegetation.

"In Australia, private residential land occupies more than half of urban areas, so my research was prompted by the possibility of reducing urban heat by choosing better types of residential landscaping materials. This involved modifying a low-cost temperature sensor to assess the heating and cooling properties of individual landscape elements typically used in Perth backyards.

"I have ranked these elements according to their heating potential, providing some guidance as to which elements are better for certain locations. For example, 'cool' pavements such as white concrete do not absorb very much solar radiation. This is great for keeping surface temperatures low because it reflects most of the visible light. However, if located close to a house, it will heat up the surface of walls, thus adding to urban heat.

"Ultimately, I would like to see policy developed to promote cooler backyards for urban heat reduction and for the benefits this would provide, not only to human health, but to the health of nature within our urban areas."

RP3009: High Performance Housing: Monitoring, evaluating and communicating the journey

WILLIAM CRAFT

PhD candidate, UNSW

"The United Nations predicts that most of the buildings we will live and work in in 2050 have already been built so retrofitting our existing building stock is crucial to our sustainable future. We need to move beyond seeing building retrofits solely as a technical challenge to improve efficiency and instead view them as opportunities with potential to add positive social and ecological benefits to both their inhabitants and the surrounding environment.

"My thesis has developed a holistic and proactive framework for sustainable building retrofits. It explores how a building can potentially interact with and add value to its surroundings. My thesis involved the development of a place-based, collaborative retrofit process and a set of key principles to provide direction for designers to integrate regenerative design concepts into the building retrofit process.

"I have been awarded a Master of the Built Environment and am now undertaking a PhD which will expand on this research to explore how regenerative design concepts can be applied to the redevelopment of our existing neighbourhoods.

"I believe this area of research is important as we need to go beyond net-zero approaches to find ways to realign the way we design, build and think with the living world around us."

NP4003: Towards 'Proactive' Retrofitting: Developing a regenerative framework for building retrofits

TAKING RESEARCH TO REALITY

From schools and buildings, to tourism and ports, CRCLCL research is helping to lower carbon emissions in all aspects of urban life.

The CRCLCL's Low Carbon Living – Australia project has helped 80 Blue Mountains businesses significantly reduce their carbon footprint and led to a partnership with Eco Tourism Australia and a national rollout starting with the NSW Southern Highlands.

"Blue Mountains residents and businesses are focused on lowering carbon emissions because the area is experiencing major problems from climate change; more extreme and frequent bush fires are impacting on the region, tourists and residents so we needed to take action," said CRC LCL project leader and Blue Mountains resident, Associate Professor John Merson.

Low Carbon Living – Australia supports businesses to calculate their emissions online and lower their carbon footprint by reducing energy, waste and water. While residents and visitors can help reduce their own carbon footprint by supporting local businesses who are reducing theirs.

Scenic World, Australia's most visited privately owned tourist attraction has been part of the project since it began. Attracting one million visitors each year, the business has greatly minimised its carbon footprint by installing solar panels and feeding energy back into the grid through its cable car and scenic railway rides.

"The Blue Mountains CRC LCL program really got in and did a deep measure of Scenic World's carbon footprint which helped us identify and focus our business strategy so that we could work towards really minimising our environmental impact," said Anthea Hammon, project partner and Scenic World's Managing Director.

The CRC for Low Carbon Living has funded research that proves energy standards in Australia's National Construction Code must be urgently upgraded if new buildings are to be fit for a zero carbon future.

Built to Perform, prepared by the Australian Sustainable Built Environment Council (ASBEC) and ClimateWorks Australia, shows that setting stronger energy standards for new buildings in the Code could, between now and 2030, reduce energy bills by up to $27 billion, cut energy network costs by up to $7 billion and deliver 78 million tonnes of cumulative emissions savings.

The report points to a host of simple measures – double-glazed windows, better insulation and air tightness, outdoor shading and more efficient air conditioners, hot water systems and lighting – that could drive down emissions and costs.

"All of the buildings being built today will still be operating in 2050, so Australia's Building Code needs to be zero carbon ready," said CRCLCL Project Leader and ASBEC Executive Director Suzanne Toumbourou.

The outputs of the report and the modelling completed by the CRC are due to be considered by the COAG Energy Efficiency Council in December.

Scenic World Managing Director Anthea Hammon with Project Leader John Merson at Scenic World, Blue Mountains NSW.

Photo: MediaKoo

Dr Vanessa Rauland with a teacher and students from Neerigen Brook Primary School, Armadale WA. Photo: Sam Proctor

> The contribution of the CRC to the Built to Perform report has been critical to providing the evidence base the Government needs to implement a building trajectory of its own for 2050.
>
> **Francesca Muskovic,** Policy Manager – Sustainability and Regulatory Affairs, Property Council of Australia

The CRCLCL's ClimateClever Program is helping to shape the next low carbon generation by teaching Australian school students how to measure and reduce their school's carbon footprint.

The ClimateClever Initiative is a low carbon, educational program underpinned by an innovative App that has already saved Perth schools almost $38,000 collectively on utility bills.

CRCLCL Project Leader Dr Vanessa Rauland said there are no current benchmarks and few rigorous, data-driven programs targeting how to measure energy and water consumption and carbon emissions in Australian schools.

Horizon Power recently partnered with ClimateClever to subsidise schools in Broome to join the program.

"We all want more control over our energy usage and electricity bills and this program also motivates students to implement similar initiatives at home," said Horizon Power Retail and Community Manager, Jodie Lynch.

The program is now being rolled out nationally after the success of its two-year pilot program in Western Australia involving 8,729 students across 15 schools. The project resulted in 83 tonnes of carbon emissions being saved along with significant energy and water savings.

"There's a lot of wastage occurring in schools through inefficiencies that could easily be prevented. Considering the constant budget cuts facing schools, there's a huge opportunity for financial savings both for schools and education departments," said Dr Rauland.

In a world-first project with NSW Ports, the CRCLCL has incorporated waste from coal-fired power stations into low carbon geopolymer concrete armour to protect the coastline at Port Kembla from extreme weather events. Aimed at validating the use of a special high-density geopolymer concrete in marine environments, the 17-tonne Hanbar Geopolymer units will be monitored for stability and integrity, providing a valuable benchmark for the future use of this unique material.

Steel furnace slag (SFS) geopolymer concrete is denser than traditional concrete and the holistic solution emits 50 per cent less carbon making it suitable for extreme environments like ports.

Batching the concrete requires a unique supply chain and has involved the supply of specialist materials from Australian Steel Mill Services, Wagners, and Independent Cement & Lime. Batching was performed using a conventional commercial plant, Cleary Brothers, allowing the concrete to be made near the site, to tight tolerances.

"In only three years we've taken a product that didn't exist before, developed it in the lab, upscaled it and turned it into a commercially viable product – none of that would have been possible without the CRCLCL's support," said CRCLCL Project Leader Professor Stephen Foster.

The greater project, undertaken with Standards Australia, is working towards the publication of comprehensive guides for engineers on the specification, production and use of geopolymer concrete.

The project is supported by CRCLCL partners Ash Development Association of Australia and Australasian (iron & steel) Slag Association.

> The CRCLCL is an important enabler to help our association build a wall of knowledge around new materials so that we can move towards developing industry standards.
>
> **Project partner Craig Heidrich,** Managing Director, HBM Group

L-R: Peter Engelen, General Manager Planning and Infrastructure, NSW Ports; Ben Modra, UNSW Water Research Laboratory; and CRCLCL Project Leader Professor Stephen Foster, Port Botany NSW. Photo: MediaKoo

COOLING OUR CITIES

Since its launch in 2012, the CRCLCL has worked closely with industry and government to generate an authoritative body of research to help keep Australian cities cool.

The new evidence-based decision support tools, optimal development models and planning recommendations are equipping policymakers and planners to drive positive changes to cityscapes based on Australian conditions.

Professor John Boland, from the University of South Australia, led the CRCLCL's first urban heat island (UHI) research to identify cost-effective strategies to mitigate localised heat effects in Adelaide, Sydney and Melbourne. While some 400 cities worldwide experience urban heat stress, Australian cities face unique challenges including the influence of inland deserts on city weather patterns and variable climate change impacts. Professor Boland's team focused on creating heat resilience in urban environments to enable the continued enjoyment and health benefits of outdoor spaces.

Aspects of this research were used in Australia's first *Guide to Urban Cooling Strategies* authored by Associate Professor Paul Osmond, Director of the Sustainable Built Environment program at UNSW. The CRCLCL's most popular publication to date, the guide details options for Australia's different climate zones and is aimed at built environment professionals and regulatory agencies. Associate Professor Osmond believed the guide's popularity revealed the "pent-up demand" from industries and governments around the world for user-friendly, evidence-based advice. After its publication, the global C40 Cities Climate Leadership Group approached him to present a webinar with the City of Tel Aviv, where authorities are trying to improve outdoor thermal comfort.

"Working with multiple industry partners through the CRC structure was both valuable and essential. The cooling strategies guide is a good example. The initiative actually came from our industry partners who said the research is great, but now we need something to help us apply the findings in the real world," Associate Professor Osmond said.

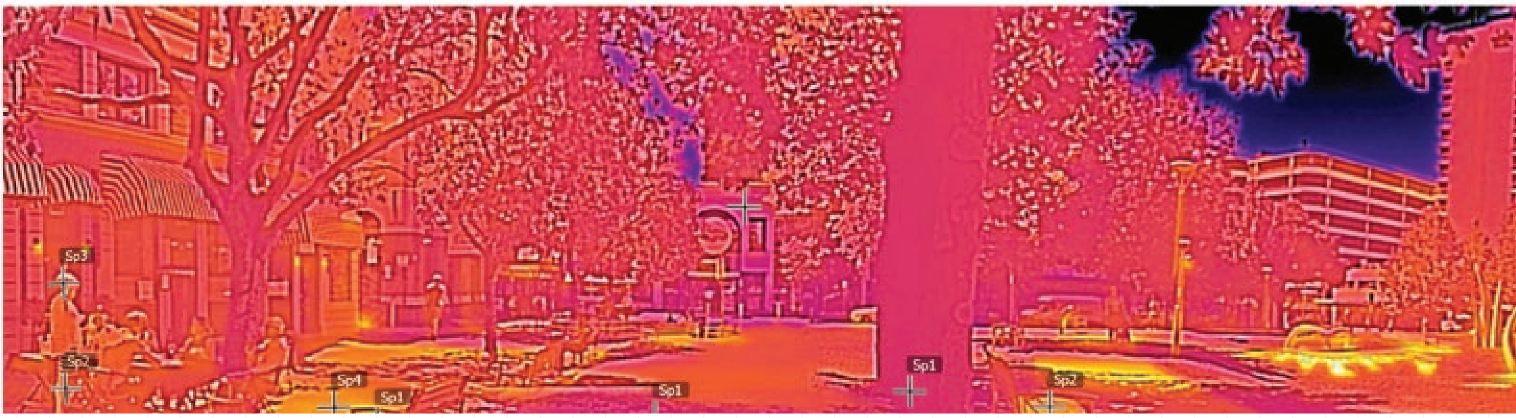
Mat Santamouris, Professor of High Performance Architecture at UNSW, has continued the CRCLCL's work in the field by testing potential UHI solutions in Western Sydney, where temperatures are often 6 to 10°C higher than in the city's east, driving a doubling in consumption of electricity for cooling and a three-fold increase in heat-related deaths. Professor Santamouris' team investigated eight areas in Sydney's west including Parramatta and Penrith, where a record maximum temperature of 47.3°C was recorded in early 2018. Collaborating with Sydney Water, the team found that by integrating water-based technologies like fountains with 'cool' materials and vegetation, local temperatures could be reduced by between 2.5 and 2.8°C, with further work aiming for a 4°C reduction. Resulting use of cooling energy fell 35 per cent and peak electricity demand by 5 per cent.

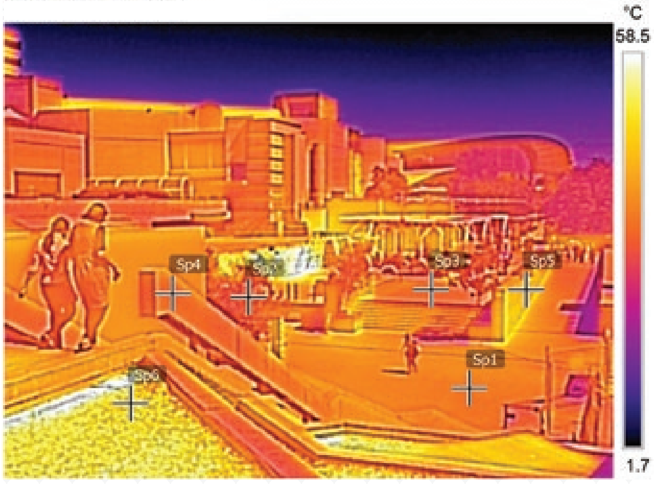
The resulting *Cooling Western Sydney* report is now informing the redevelopment of Parramatta's CBD. The city's new main street is likely to include materials that reflect heat rather than absorb it, strategically placed water features and misting, shading and trees, and smart paving that can generate electricity via integrated photovoltaic cells or even by harnessing the kinetic energy of pedestrians.

Professor Santamouris is also collaborating with the Greater Sydney Commission to predict UHI conditions around the site of the new Western Sydney Airport and development hub, so that evidence-based cooling measures can be incorporated into its design from the outset.

Meanwhile, the CRCLCL is delivering a unique online support tool to help mitigate UHI effects by connecting policymakers, developers and planners to the best evidence-based analysis and solutions. The tool identifies heat risks within new plans and cross-references them to local climatic conditions.

Thermal imaging of Hindmarsh Square, Adelaide. Images: Courtesy of Dr Ehsan Sharifi.

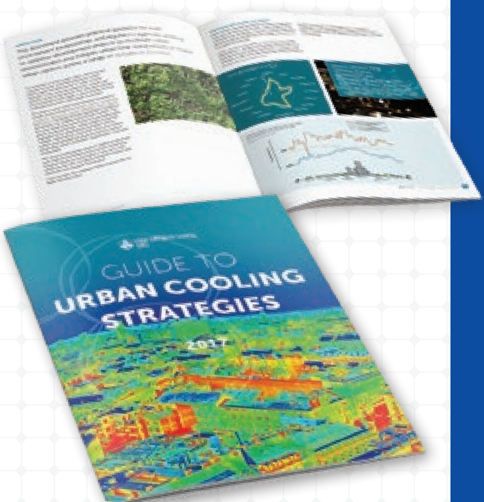


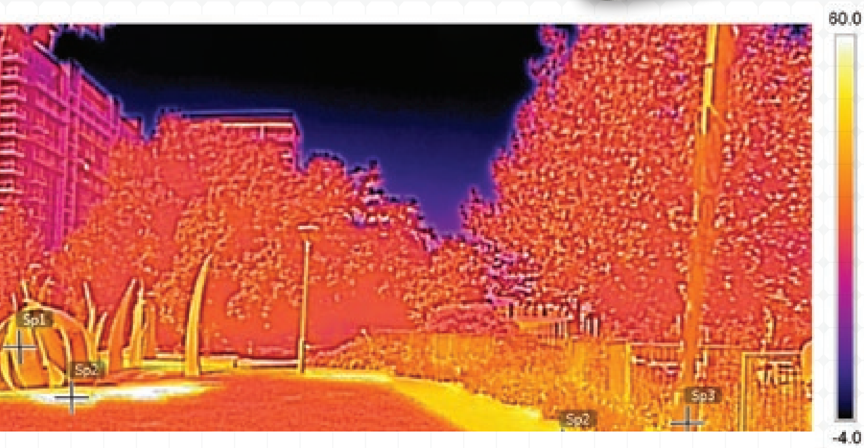


The resulting scenario analysis can then be used to model a range of mitigating options at both the building and precinct scale, using 3D visualisation technologies and heat mapping.

Developer, UNSW Associate Professor Lan Ding, said the tool was "an important bridge" between research and its practical application. Sixteen industry and government partners, including major developers Landcom and Stockland, are involved in the project – evidence that building and regulatory professionals are keen to work with universities to improve outcomes.

Ding, Santamouris and Osmond are now combining their expertise to develop a Continuing Professional Development course, Managing Urban Heat, that will be available online from 2019. The course will facilitate the transfer of knowledge to planners, designers and landscapers, using interactive case studies developed in real-world conditions with CRCLCL partners.





What do our PhDs think?

"If we want to cool our cities, we need to understand that every building has a different heat 'footprint'," says UNSW PhD candidate, **Jonathan Fox**.

Fox's research in Sydney focuses on how different building facades affect outdoor microclimates. While much research has focused on the heat effects of urban precincts, few studies have drilled down to the level of individual buildings and how they impact on their surroundings.

An architect turned academic, Fox is using precise weather observations at a building's location to evaluate the performance of external materials and surfaces, like reflective facades. The result is a unique, predictive model of the heat impact of different materials under specific conditions.

Building performance is also the focus of **Gertrud Hatvani-Kovacs**' PhD research at the University of South Australia.

An architect and engineer, Hatvani-Kovacs is investigating ways to offset a building's heat gain. She has recommended that Australia's energy efficiency star-rating scheme for homes be modified to consider separate cooling and heating loads, not just total energy demand. She's also warned against the excessive use of air conditioning which generates waste heat further increasing outdoor temperatures. The research has informed the forthcoming National Construction Code 2019.

Dr Ehsan Sharifi believes planners need a better understanding of how to build heat resilience into outdoor spaces at the precinct level. Dr Sharifi, who completed his PhD at the University of South Australia, studied the use of public spaces in Sydney, Melbourne and Adelaide and found people were willing to remain outdoors, but only until temperatures reached 22 to 34°C, then they started moving into air-conditioned spaces. The findings have given planners the necessary parameters to maintain open public spaces.

While trees and green spaces cool cities and create valuable social and health benefits, planners need policy incentives to move beyond entrenched ideas, according to **Dr Judy Bush**, a postdoctoral research fellow at the University of Melbourne. Dr Bush's PhD research looked at sustainability transitions theories to help planners retain and maximise green space in cities. Initiatives included: 'greening' under-utilised roads and areas around high pedestrian activity. Private landholders could also be encouraged to plant gardens and create green walls and green roofs.

SPREADING THE WORD

Communication keeps the sense of community alive among researchers while inspiring participants and building new industry relationships. This year the CRCLCL's communications activities increased significantly in line with the 2017-2019 Communications Strategy, which focuses on the utilisation of the Centre's research and overall legacy.

IN THE MEDIA

The Centre and its research continued to attract strong media interest over the past year. The distribution of media releases and opinion pieces resulted in 55 media mentions, including significant coverage in *The Sydney Morning Herald*, *The Daily Telegraph*, *Herald Sun* and *Architecture and Design*. CRCLCL researchers also took part in radio interviews with ABC local radio, Radio National and RTR FM. In August, CRCLCL Chair Robert Hill, Professor Chris Ryan and Professor Mark Stevenson were interviewed about 'cities of the future' for an episode of ABC RN's popular *The Science Show*. Centre CEO Professor Deo Prasad authored four opinion pieces for the industry analysis news site *Sourceable*, increasing his following to more than 203k readers since he began regularly contributing in 2016. The publication of Australia's first *Guide to Urban Cooling Strategies* and the launch of the *Cooling Western Sydney* report in partnership with Sydney Water also resulted in extensive media coverage.

The prime platform for distributing research is the Centre's website, which is a focus of the communication strategy and acts as a springboard to promote the CRCLCL's work across other online and social media including LinkedIn and Twitter. This year the number of visitors to the CRCLCL website increased by 33 per cent compared to the previous reporting period, with a total of 13,981 visitors using the website during that timeframe.

> "The number of visitors to the CRCLCL website increased by 33 per cent compared to the previous reporting period."

COLLABORATION

The CRCLCL Participants Annual Forum provided researchers and collaborators with the opportunity to connect and hear about the utilisation and uptake of CRCLCL research. The Forum was held at the Melbourne Town Hall on 22 and 23 November 2017, with 170 people in attendance over both days. A Forum highlight was the Industry Breakfast which focused on driving innovation in the built environment sector. The breakfast was hosted in partnership with the Australian Sustainable Built Environment Council, a major built environment stakeholder, and the Energy Efficiency Council.

The Forum's international keynote speaker Peter Madden OBE, Director of UK company Ecovivid and Professor of Practice in Future Cities at Cardiff University, helped promote the event with an interview on ABC Radio Melbourne. Also delivering engaging keynote addresses were the Lord Mayor of Melbourne Robert Doyle AC and Dr Kate Wilson, Executive Director of Science at the NSW Office of Environment and Heritage.

Below: **Annual Participants Forum 2017, Melbourne VIC**

Right: **CRCLCL HQ filming in the Blue Mountains NSW.**
Photo: MediaKoo

Clockwise from right: **CEO, Prof. Deo Prasad attends GABC Annual Assembly in Dubai United Arab Emirates; Dr Jemma Green with Sir Richard Branson, Necker Island British Virgin Islands** Photo: Courtesy of Jemma Green; **The Hon Gabrielle Upton speaking at the launch of the OEH Node at UNSW Sydney, NSW.** Photo: Rob Largent

OUTREACH

Over the year, the CRCLCL hosted or took part in more than 50 events locally and internationally. In October, the Centre co-hosted the launch of the Energy Efficiency Decision Making Node with the Office of Environment and Heritage. Held at UNSW, the event was attended by the NSW Minister for the Environment, Heritage and Local Government, the Hon Gabrielle Upton. The result of a competitive bid, the Node and its research will focus on energy efficiency investment decisions, efficient products and energy-saving actions.

As part of the CRCLCL's commitment to international engagement, the CEO attended the Global Alliance of Building and Construction's (GABC) Annual Assembly in Dubai in February. The CRCLCL is the GABC's only Australian member and the Annual Assembly, hosted by the United Arab Emirates government, provides a valuable opportunity to meet with representatives from 50 countries who share the same commitment to low carbon built environments. Professor Prasad also took part in a preparatory meeting for the UN Habitat's World Urban Forum at the United Nations and Social Commission for Asia and the Pacific and attended the World Urban Forum, the world's premier conference on urban issues, in Kuala Lumpur. The CEO also delivered a presentation on low carbon cities in Shanghai at the Asia Pacific Leadership Programme on Environment for Sustainable Development hosted by Tongji University, one of the CRCLCL's international participants.

CRCLCL PhD graduate Dr Jemma Green achieved international success when her peer-to-peer renewable energy trading platform, Power Ledger, won Sir Richard Branson's Extreme Tech Challenge in October. Dr Green also recently partnered with United States-based clean energy not-for-profit, Helpanswers, a collaboration that will lead to hundreds of clean energy trading projects across the US. Power Ledger also announced its partnership with the Asia-Pacific's leading renewable energy company BCPG in Thailand earlier this year.

Back in Australia, the CRCLCL hosted four National Forums on the topics: cooling cities; future cities; transition to low carbon living; and expanding local renewable electricity to households, precincts and communities. The Forums are designed to showcase research projects and outcomes and identify utilisation and collaboration pathways with senior government and industry stakeholders.

The past year's communication, collaboration and outreach activities have been extremely successful and the Centre looks forward to its final year of operation to yield even more impressive results.

OUR PEOPLE

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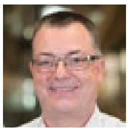

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Business Manager and Company Secretary

Christine Lee
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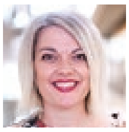

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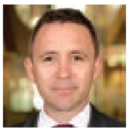

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Stewart Wallace
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Education Leader

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Assoc. Prof. Alistair Sproul
Program Leader, Integrated Building Systems

Prof. Peter Newton
Program Leader, Low Carbon Precincts

Dr Stephen White
Program Leader, Engaged Communities

Prof. Greg Morrison
Node Leader, Curtin University

Dr Lan Ding
Node Leader, UNSW Sydney

Prof. Christopher Saint
Node Leader, University of South Australia

Prof. Peter Graham
Node Leader, Swinburne University of Technology

Prof. Chris Ryan
Node Leader, University of Melbourne

Prof. Paul Cooper
Node Leader, University of Wollongong

FINANCIAL OVERVIEW

The CRC for Low Carbon Living continued to maintain a healthy financial position in the 2017-18 reporting period, carrying forward unspent funds to use in its utilisation-focused research in year seven (final year). The financial statements for the CRC for Low Carbon Living Ltd have been independently audited by HLB Mann Judd (NSW) Pty Ltd and submitted to ASIC, ACNC and the Commonwealth CRC Programme. The Auditor's report contained no adverse, qualified or other matters of emphasis. Copies of the Annual Financial Report for the period ended 30 June 2018 are available on request.

RESOURCES RECEIVED

TOTAL CASH AND IN-KIND CONTRIBUTIONS BY PARTNERS & GOVERNMENT IN 2017-18 (FY6)

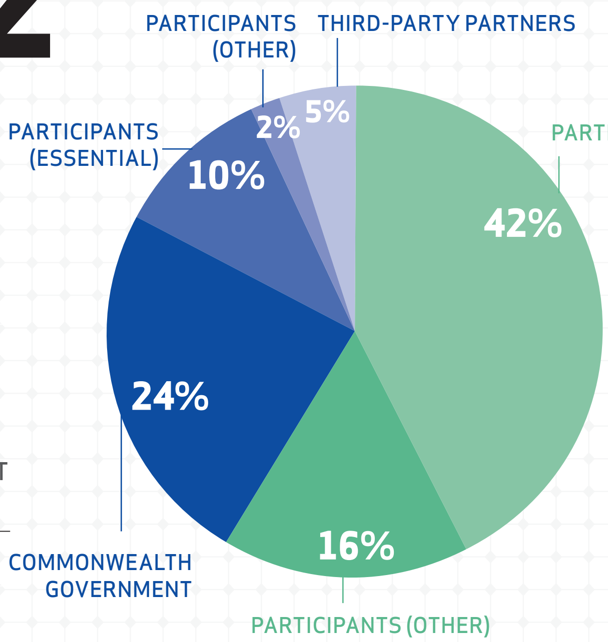
$19.42 MILLION

CASH

FROM TWO SOURCES:

1. CRC PARTICIPANTS (ESSENTIAL, OTHER & THIRD-PARTY PARTNERS) ($3.38M)
2. COMMONWEALTH GOVERNMENT ($4.75M)

TOTAL: $8.13 MILLION



IN-KIND

Includes time provided by participant employees (equivalent to 36.6 full-time researchers valued at $10.26m) and other non-staff resources such as facilities, equipment and materials ($1.02m).

TOTAL: $11.28 MILLION

RESOURCES APPLIED

RESOURCES APPLIED ACROSS THE THREE RESEARCH PROGRAM AREAS IN 2017-2018 (FY6)

$20.61 MILLION

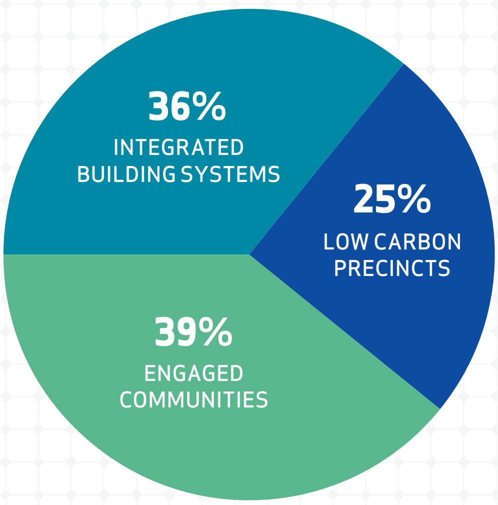
IN-KIND APPLIED $11.28m

CASH APPLIED $9.33m

This includes proportions of expenditure on:

- Governance and administration $1.86m (20%)
- Education (scholarships) $1.48m (16%)
- Research – Staff $4.23m (45%)
  – Non-staff $1.76m (19%)

No capital purchases made.



YEAR 6 PROJECTS 1 July 2017 – 30 June 2018

	NO.	IMPACT PATHWAY	PROJECT TITLE	PROJECT PARTICIPANTS
PROGRAM 1 – INTEGRATED BUILDING SYSTEMS	RP1001	1. Harnessing Australian Sun	Air handling solutions, integration approaches and building design considerations for Photovoltaic Thermal (PV-T) roofing.	BlueScope; UNSW; UniSA
	RP1009	3. Mainstream low carbon buildings	Closing the Loop on Evidence-based Low Carbon Design of non-residential buildings	UNSW; UniMelb; Curtin; UniSA; Brookfield; HASSELL; AECOM
	RP1010	3. Mainstream low carbon buildings	Monitoring and modelling the CSR Low Energy House	CSR; UniSA; UNSW
	RP1014	3. Mainstream low carbon buildings	Impact of energy efficient pool pumps on peak demand, energy costs and carbon reduction	UNSW; Ausgrid
	RP1014u1	3. Mainstream low carbon buildings	Energy efficient swimming pools – engagement and utilisation	UNSW; Randwick City Council
	RP1015	1. Harnessing Australian Sun	Combining a building integrated PVT system with a low temperature desiccant cooler to drive affordable solar cooling	UNSW; Bluescope; CSIRO; GWA Group
	RP1017	3. Mainstream low carbon buildings	Validating and improving the BASIX energy assessment tool for low carbon dwellings	UNSW; NSW OEH; NSW Planning & Infrastructure; Dept of Industry; City of Sydney
	RP1017e1	3. Mainstream low carbon buildings	Validating and improving the BASIX energy assessment tool for low carbon dwellings – Ph 2	UNSW, NSW OEH
	RP1020	2. Low carbon materials	Reducing Barriers for Commercial Adaptation of Construction Materials with Low-Embodied-Carbon	Australasian Slag Association (ASA); Ash Development Association of Australia (ADAA); AECOM; Sydney Water; UNSW; Swinburne; Standards Australia
	RP1020u1	2. Low carbon materials	Demonstrating use of Geopolymer Concrete for high density coastal protection units	Australasian Slag Association (ASA); AECOM; UNSW; Ash Development Association of Australia (ADAA); NSW Ports; Independent Cement and Lime Pty Ltd (ICL); Australian Steel Mill Services Pty Ltd (ASMS)
	RP1021	3. Mainstream low carbon buildings	Reframing Building Regulation: The role of Building Regulation as a Policy Instrument for the Transition to Low Carbon Built Environment	Curtin
	RP1022u1	2. Low carbon materials	Prototyping, testing, optimising and demonstrating the industrial scale production of composite engineered stone from reclaimed glass	UNSW; NewSouth Innovations Pty (Nsi)
	RP1023	1. Harnessing Australian Sun	Forecasting and home energy analysis in residential energy management solutions (Algorithms)	UNSW; Solar Analytics (Suntech)
	RP1024	3. Mainstream low carbon buildings	Facilitating the transition to low carbon housing (NatHERs)	UniSA; CSIRO; CSR
	RP1026	3. Mainstream low carbon buildings	Evaluation of next-generation automated fault detection and diagnostic tools for commercial building energy efficiency	CSIRO; City of Sydney (CoS)
	RP1031	3. Mainstream low carbon buildings	Dev/Optimise LC medium-rise modular structures using innovative connections	Swinburne; Brookfield; UniMelb; VBA; AECOM; BlueScope
	RP1033	3. Mainstream low carbon buildings	Mainstreaming High Performance Commercial Building HVAC	AECOM; CSIRO; UNSW
	RP1034	2. Low carbon materials	Carbon Value Engineering	UNSW; Brookfield
	RP1037	2. Low carbon materials	Driving Increased Utilisation of Cool Roofs on Large-Footprint Buildings	BlueScope; UoW; UNSW
	RP1040	2. Low carbon materials	Advanced hybrid ventilation systems for schools	UNSW
PROGRAM 2 – LOW CARBON PRECINCTS	MR2204	4. Integrated low carbon precincts	FY7: Book documenting Best Practice Approaches to the Design of Zero Carbon Low Consumption Communities published.	Swinburne
	MR2306	4. Integrated low carbon precincts	FY7: manual describing the use and application of the integrated tool set published.	Swinburne
	RP2005	4. Integrated low carbon precincts	Urban Micro Climates: Comparative study of major contributions to the Urban Heat Island effect in three Australian cities (Sydney, Melbourne, Adelaide).	UniSA; UNSW; UniMelb; City of Sydney (CoS); Urban Renewal Authority (RTA); Govt of SA Dept of Environment; Water and Natural Resources (DEWNR); BlueScope; HASSELL; CSIRO
	RP2007	4. Integrated low carbon precincts	Integrated Carbon Metrics (ICM) – a multi-scale life cycle approach to assessing, mapping and tracking carbon outcomes for the Built Environment	UNSW; UniMelb; UniSA; AECOM; Aurecon; Sydney Water; BlueScope
	RP2007u1	4. Integrated low carbon precincts	Integrated Carbon Metrics (ICM) – Tool alignment with National Carbon Offset Standard for Precincts	UNSW; UniSA
	RP2008	4. Integrated low carbon precincts	Beneficial reuse of solids from Wastewater Treatment Operations	UNSW; UniSA; Sydney Water; SA Water
	RP2010	7. Living laboratories	Informing and Trialling the inclusion of Low Carbon requirements in State Government Built Environment Sector Tenders	Curtin; Swinburne; UrbanGrowth NSW
	RP2011e1	4. Integrated low carbon precincts	PIM - Stage 2 project extension	UNSW; Brookfield; BuildingSmart; AECOM; Aurecon
	RP2017	4. Integrated low carbon precincts	Energy benchmarking for efficient, low carbon water recycling operations	UniSA; SA Water; Sydney Water; UNSW
	RP2017u1	4. Integrated low carbon precincts	Operationalising Australian energy benchmarking for efficient, low carbon wastewater treatment	UniSA; UNSW
	RP2019	4. Integrated low carbon precincts	Carbon reductions from composting food waste for food production – fitting recycling models to urban forms	Swinburne; UniSA; City of Melbourne; Sustainability Victoria; Renewal SA
	RP2021	4. Integrated low carbon precincts	Greening Suburban Travel	UniSA; Swinburne; UniMelb; CSIRO
	RP2021e1	4. Integrated low carbon precincts	Carbon Neutral Adelaide – Greening Inner-Urban Travel	UniSA; Swinburne
	RP2023	4. Integrated low carbon precincts	Microclimate and UHI Mitigation Decision-Support Tool	UNSW
	RP2024	4. Integrated low carbon precincts	Guideline for Urban Cooling Strategies	UNSW
	RP2028	4. Integrated low carbon precincts	Co-benefits Calculator development & trial	UNSW
	RP2006	7. Living laboratories	Action research to examine and demonstrate how to mainstream low-cost and low carbon housing in Western Australia. FredZED	Curtin; City of Fremantle; WA Housing Authority; The Next Practice
PROGRAM 3	RP3007	6. Community engagement	Opportunities and challenges for the development and implementation of community-scale renewable energy projects	UNSW; UniSA
	RP3008	5. Evidence base for LCL Policy	Visions & Pathways 2040	UniMelb; UNSW; CSIRO; Swinburne
	RP3009	7. Living laboratories	High Performance Housing: LL monitoring, evaluating & Communicating (Josh's House)	Curtin; UniSA; Josh Byrne & Associates (JBA)

	NO.	IMPACT PATHWAY	PROJECT TITLE	PROJECT PARTICIPANTS
PROGRAM 3 – ENGAGED COMMUNITIES	RP3009e1	7. Living laboratories	High Performance Housing: LL monitoring, evaluating & Communicating (Josh's House)	Curtin; UniSA; Josh Byrne & Associates (JBA)
	RP3010u2	6. Community engagement	Low Carbon Living – Blue mountains; Program transfer to the Southern Highlands of NSW	Blue Mountains World Heritage Institute (BMWHI)
	RP3010u3	6. Community engagement	Low Carbon Living – Blue mountains; Program national rollout additional regions	UNSW
	RP3011	7. Living laboratories	Community Carbon Reduction & Wellbeing Enhancement	Curtin
	RP3012	7. Living laboratories	Transformation to Low Carbon Living: Social Psychology of Low Carbon Behavioural Practice	UniMelb; CSIRO; Swinburne
	RP3015	8. Education and capacity building	Increasing knowledge and motivating collaborative action on Low Carbon Living through team-based and game-based mobile learning	Swinburne; UniMelb; Vic Building Authority (VBA); (Master Builders Associates (MBA); Sydney Coastal Councils; BuildSmart
	RP3017	7. Living laboratories	Adelaide Living Laboratory Hub – Lochiel Park, Bowden and Tonsley	Renewal SA; UniSA; Govt of SA Dept of Environment; Water and Natural Resources (DEWNR)
	RP3020e1	6. Community engagement	Influencing Change through Low Carbon Schools community program	Curtin
	RP3020u1	6. Community engagement	Mainstreaming Low Carbon, High Performance Schools and classrooms	Curtin
	RP3021	7. Living laboratories	Media and communication strategies to achieve carbon reduction through renovation of Australia's existing housing	Swinburne; BlueScope; CSR; HIA; Masters Builders; Sustainability Victoria
	RP3023	6. Community engagement	The contribution of community-owned renewable energy to regional development and resilience in the face of climate change	UNSW; NSW OEH
	RP3025	8. Education and capacity building	Sydney TAFE Carbon Reduction Website	TAFE NSW – Sydney Institute
	RP3028	5. Evidence base for LCL Policy	A "virtual market" for analysing residential housing policy interventions	CSIRO; Swinburne; NSW OEH
	RP3029e1	6. Community engagement	Project extension: Driving a National Social Media Conversation on Energy Efficient Housing – Stage 2	CSIRO; NSW OEH
	RP3031	5. Evidence base for LCL Policy	Information, Risk and Retrofit: Enabling Energy/Carbon Disclosure at the Building Retrofit Investor – User interface	Brookfield; UniMelb; Swinburne; UNSW
	RP3033	7. Living laboratories	Mainstreaming Low Carbon Housing Precincts – the WGV Living Lab	Curtin; Fremantle Council; Josh Byrne & Associates (JBA); LandCorp
	RP3034	6. Community engagement	Community co-design of LC precincts for urban regeneration in established suburbs	UNSW; Swinburne; NSW OEH; CRC Spatial Information
	RP3035	5. Evidence base for LCL Policy	Sydney Water Diffusion Modelling project	CSIRO, Sydney Water
	RP3039	8. Education and capacity building	Liveability Real Estate framework training and professional development	CSIRO
	RP3043	7. Living laboratories	Beyond WGV: Community Battery Storage	Curtin; Fremantle Council; Landcorp
	RP3044	5. Evidence base for LCL Policy	Mainstreaming Low Carbon Retrofits in Social and Community Housing	UoW; NSW OEH
	RP3045	7. Living laboratories	Living Labs Coordinator	UNSW, OEH
	RP3049	7. Living laboratories	Housing Construction Roadmap	CSIRO; NSW OEH; GBCA
SPECIAL PROJECTS	SP0006	8. Education and capacity building	Measuring economic, environmental & social value in LC Built Env.	Brookfield; UNSW
	SP0008	8. Education and capacity building	CRCLCL Knowledge Hub	Swinburne
	SP0008e1	8. Education and capacity building	Developing a methodology for Systematic Review and Establishing Synthesis Methodology in Built Environment	UNSW
	SP0008e2	8. Education and capacity building	Knowledge Hub 'animation' (dynamic interface)	Swinburne
	SP0012	4. Integrated low carbon precincts	Strategic Study On The Cooling Potential And Impact Of Water Based And Other Urban Climate Mitigation Technologies In Western Sydney	Sydney Water; UNSW
	SP0014	4. Integrated low carbon precincts	ARENA Project (G00855): Student Paula Hansen: Increasing uptake of Solar PV in strata residential developments	Curtin
	SP0016	5. Evidence base for LCL Policy	ASBEC Trajectory Project	CSIRO; UoW; Energy Action; ASBEC
	SP0017p0	5. Evidence base for LCL Policy	NSW OEH Energy Efficiency Decision Making (EEDM) NODE – OEH Funding	NSW OEH
	SP0017p1	5. Evidence base for LCL Policy	EEDM in the NSW Social Housing Sector	UNSW; CSIRO; UoW; NSW OEH
	SP0017p2	5. Evidence base for LCL Policy	EEDM in the NSW Transport Sector	UNSW; CSIRO; UoW; NSW OEH
	SP0017p3	5. Evidence base for LCL Policy	EEDM – BASIX (inc UoW extension)	UNSW; OEH
	SP0018	5. Evidence base for LCL Policy	Policy Scenario Utilisation milestone activities (inc $150k CSIRO cash contribn)	CSIRO
	SP0019p1	4. Integrated low carbon precincts	Low Carbon Guide – Precincts	Curtin
	SP0019p2	8. Education and capacity building	Guide to Low Carbon Commercial Buildings – new build	UNSW; AECOM
	SP0019p3	8. Education and capacity building	Guide to Low Carbon Commercial Buildings – retrofit	UNSW
	SP0019p4	4. Integrated low carbon precincts	Low Carbon Guide to Residential Buildings – new build	Curtin
	SP0019p5	8. Education and capacity building	Low Carbon Guide to Residential Buildings – retrofit	UNSW; UoW
	SP0019p6	6. Community engagement	Low Carbon Guide for Households/Occupants	UniSA
	SP0019p7	4. Integrated low carbon precincts	Low Carbon Guide for SMEs	Swinburne
	SP0020p1	5. Evidence base for LCL Policy	Government Procurement for Sustainability Outcomes	Strategy Policy Research (SPR)
	SP0021	5. Evidence base for LCL Policy	Emissions Intensity Metrics	Strategy Policy Research (SPR)

PARTICIPANTS INDEX

	IMPACT PATHWAY							
	1	2	3	4	5	6	7	8
AECOM Australia Pty Ltd		■	■	■				■
Amalgamated Metal Industries Pty Ltd (Ametalin)								
Ash Development Association of Australia		■						
Aurecon Australia Pty Ltd				■				
Australasian Slag Association		■						
Australian Window Association Inc								
BCI Media Group Pty Ltd								
BlueScope Steel Limited	■	■	■	■			■	
BuildingSMART Australasia Incorporated				■				
Centre for Liveability Real Estate								
City of Fremantle							■	
City of Melbourne				■				
Commonwealth Department of Industry (previously Commonwealth Dept of Climate Change and Energy Efficiency)			■					
Commonwealth Department of Infrastructure & Regional Development								
Concordia University, Canada (Smart Net-zero Energy Buildings Research Network)								
Consult Australia								
CSIRO	■		■	■	■	■	■	■
CSR			■				■	
Curtin University of Technology			■	■		■	■	
Green Building Council of Australia			■					
HASSELL Ltd			■	■				
Housing Industry Association Limited							■	
KTH, Royal Institute of Technology, Sweden								
Master Builders Australia Limited							■	■
Multiplex Australasia Pty Limited		■	■	■	■			■
NSW Department of Planning & Infrastructure			■					
NSW Office of Environment & Heritage			■		■	■		
Renewal SA (Urban Renewal Authority)				■			■	
SA Government – Department of State Development								
South Australia Water Corporation				■				
Standards Australia Limited		■						
Swinburne University of Technology		■	■	■	■	■	■	■
Sydney Coastal Councils Group Inc.								■
Sydney Water Corporation		■		■	■			
TAFE NSW – Sydney Institute								■
The Australian Institute of Architects								■
The Council of the City of Sydney				■	■			
The Infrastructure Sustainability Council of Australia								
Tongji University, China								
United Nations Environment Programme (UNEP)								
University of Melbourne			■	■	■		■	■
University of New South Wales	■	■	■	■	■	■		■
University of South Australia	■		■	■		■	■	
University of Wollongong		■			■			■
Urban Growth NSW (Landcom)							■	
Victorian Building Authority (Building Commission)			■					■

LOW CARBON LIVING CRC

CRC for Low Carbon Living Ltd
ABN: 59 156 259 193

Room 202-207, Level 2
Tyree Energy Technologies Building
UNSW Sydney NSW 2052 Australia

www.lowcarbonlivingcrc.com.au
info@lowcarbonlivingcrc.com.au
P: +61 2 9385 5402
F: +61 2 9385 5530

Australian Government
Department of Industry, Innovation and Science

Business
Cooperative Research Centres Program