LOW CARBON LIVING CRC

FACTSHEETS and GUIDE NOTES

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THERMAL MODELLING: IMPROVING YOUR HOME'S HEATING AND COOLING EFFICIENCY

PROJECT FACTSHEET

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KEY POINTS

- **Improving home energy use is one of the most cost-effective ways to reduce carbon emissions.**
- **We have created and validated thermal model of CSR's sustainable demonstration house which, drawing upon a suite of monitoring devices and local weather data, predicts the energy required to heat and cool your house.**
- **Our model and data are available to assist you improve the efficiency of your existing or future home.**

THE OPPORTUNITY / CHALLENGE

In Australia, the building sector accounts for 20% of annual energy consumption and 23% of greenhouse gas emissions (GHG)[1]. The main reason for this is the growing demand of detached homes equipped with energy-intensive air-conditioning systems[2].

Increasing the energy efficiency of residential buildings has been recognised as one of the fastest and most cost-effective methods to reduce emissions (IPCC 2007, IEA 2008, McKinsey 2008).

A recent study estimated that over 3.3 million houses will need to be built by the end of 2030 to accommodate Australia's rapid economic growth[2]. Therefore, it is crucial that a smarter design of detached housing is developed that meets demand yet provides greater energy efficiency[5].

OUR RESEARCH

In 2012, CSR Building Products established an 8-Star energy-efficient house (CSR House) to improve industry and consumer knowledge on the energy efficiency and liveability benefits of the detached-house design and its building materials[5].

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To maximise knowledge generation, we monitored and measured CSR House and produced a thermal model of the building which we validated using this data.

Our model predicts the energy required to heat and cool a house using specific heating and cooling appliances, based upon a range of inputs:

- Data from 140 individual sensors within CSR House collected over a one-year period, including thermostat settings, temperature and humidity, and site weather.
- Blower door testing to determine the house's air tightness.
- Thermal imaging across the seasons to assess thermal performance and how it changes over a year.

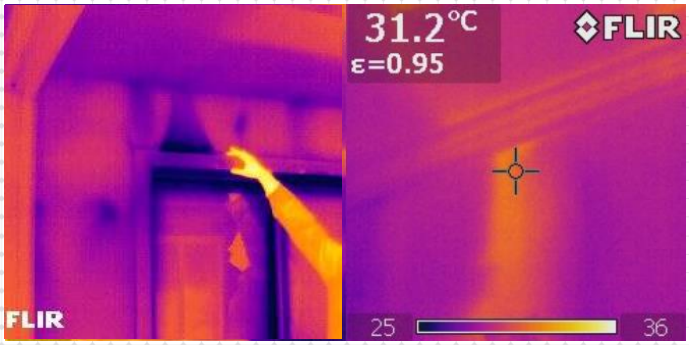

Fig. Thermal imaging shows air infiltration

We undertook a comparison of the total energy consumption estimated by our model simulation with the actual energy consumed by CSR House. This informed model revisions to enhance technical performance. We also performed a cost analysis using the collected cost data to examine the energy savings and cumulative costs of the house.

Fig. CSR House

RESEARCH OUTCOMES

Our project has produced the fundamental scientific and economic evidence regarding the potential and viability of low energy houses for Australian conditions. This research helps pave the way for the next generation of software tools that will allow for rapid optimization of building designs in terms of their energy/carbon performance and their cost.

CSR House is a unique experimental facility that has provided a wealth of valuable data on the performance of energy-efficient buildings. It has allowed us to validate the thermal model we have developed which in turn has enabled us to:

- Explore changes to the CSR House design, which can further push low carbon performance.
- Gather data supporting assessments on the cost of carbon reduction for such high performing homes.
- Measure the most efficient design in terms of thermal performance and the building envelope, and determine whether this is technically feasible and cost effective.
- Accelerate uptake of low energy housing by providing the scientific and economic evidence behind the energy and thermal performance of an 8-star energy-efficient home, which in turn can lower GHG emissions.
- Better understand the energy movements and uncontrolled energy losses in the building envelope.
- Explore high performance houses in differing climate zones across Australia.

Fig. Our thermal camera proved effective at identifying insulation imperfection and led us to discover that two insulation batts were missing.

PROJECT TEAM

- Ray Thompson (Key stakeholder), CSR Building Products
- Jesse Clark (Building Scientist), CSR Building Products
- Prof. Wasim Saman (project leader and joint supervisor of PhD candidate), University of South Australia.
- Assoc. Prof. Alistair Sproul (joint supervisor), University of NSW.
- Zichao Meng, PhD student

PROJECT REPORTS

To access the project data, project reports and PhD thesis, please contact us.

FURTHER INFORMATION

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MINIMISING YOUR POOL'S ENERGY CONSUMPTION

GUIDE NOTE

LOW CARBON LIVING CRC

KEY POINTS

- **Pool pumps are the second biggest user of electricity in Australian homes after hot water systems.**
- **Pool pump motors are often more powerful and run longer and much faster than required.**
- **Significant dollar and carbon savings can be achieved by adjusting the pump's speed and run times to achieve maximum efficiency – by installing a controller or a variable speed and energy efficient pump.**
- **There is no negative impact on water quality, keeping your pool pristine.**

THE CHALLENGE

Pools can be a major contributor to energy consumption. The challenge is to reduce the energy demands of the pumping systems for the pool's filtration, chlorination and solar heating without compromising water quality or the pool's thermal performance.

THE OPPORTUNITY

Heating and cleaning pools is energy intensive and the cost of energy is increasing. For example, in July 2017 three major energy retailers in Australia increased the prices for electricity and gas by ~20%[1].

One in every ten Australian homes has a pool, but it may come as a surprise to many householders to know that their pool pump is the second biggest user of electricity after their hot water system, contributing significantly to their power bills. Likewise, on a commercial scale, heating and filtering public pool facilities are expensive for councils and businesses. There is also a considerable cost for the environment, with pools responsible for around half a percent of Australia's total annual greenhouse gas emissions, or about three megatonnes of carbon, each year.

The good news is that this presents a huge opportunity to reduce peak demand on the electricity network and contribute to sustainability targets while achieving real dollar savings - and it's easier and cheaper to do than you might think.

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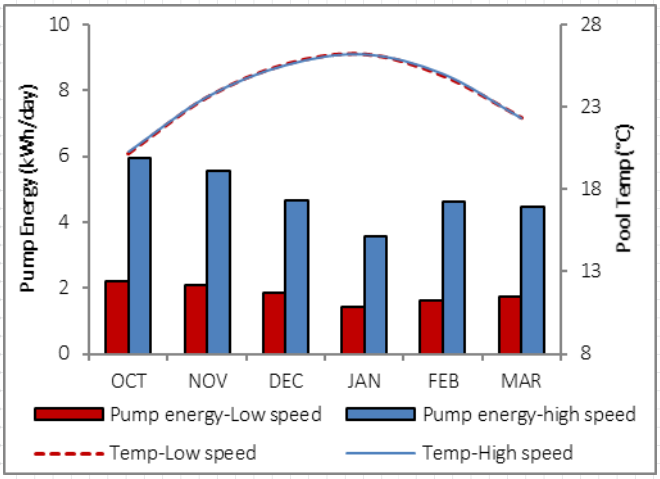
OUR RESEARCH

Our research looked at a typical residential pool heating system and the impact of running an 8 star variable speed pump (Viron eVo P280) at different intensities. We also investigated the impacts of running the pump at low speed on the solar pool heating system, pool chlorinator, pool cleaner, and pool water quality.

Pool heating

We now have robust evidence to establish that by operating a three-speed pump at low speed and adjusting the throttle valve properly, residential pool owners can see a 250% increase in the amount of heat produced by their pool heating system, for every unit of energy consumed. This leads to energy and **cost savings of around 60%** in comparison to the 'business as usual' operation of a solar pool heating system using a typical single speed pump (Fig. 1).

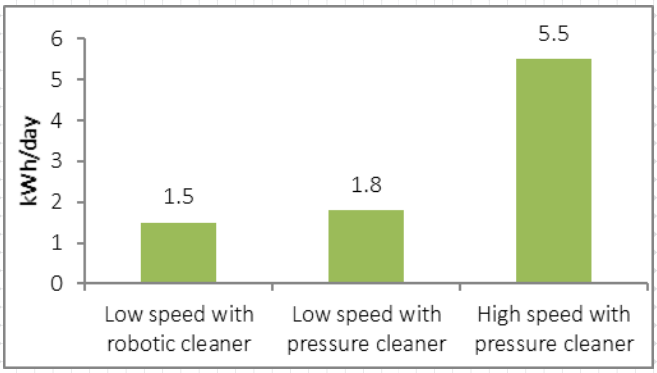
[1] Electricity price rises locked in from July 1, 2017: http://www.news.com.au/finance/small-business/electricity-price-rises-locked-in-from-july-1-2017/news-story/0bad2dcddc1a3040c4abbf07d25cb7fc



Pool filtration

As for pool filtration systems, we concluded that retrofitting a variable speed pump and a robotic cleaner can achieve **savings of over 70%** on electricity bills (Fig. 2).

Overall, for heating and filtration, these relatively minor upgrades translate to real dollar savings of nearly 70%, and pool owners can still enjoy acceptable pool thermal conditions and excellent water quality.



VALUE PROPOSITION

- **Savings:** Save up to 60% for solar pool heating, and 70% for the pool filtration system in comparison to the business as usual case. Further reductions in energy usage can be achieved with the installation of robotic (as opposed to pressure) pool cleaners.
- **Quality**: See no reduction in pool water quality, and significantly improved water quality with the use of robotic pool cleaners.
- **Simplicity:** Installing a variable or multi-speed pump is as easy as engaging your local qualified technician, who should be able to complete the job within a couple of hours. Once installed, the pumps are 'set and forget' – they don't require specialist knowledge. No manual work is required to clean the pool except to sweep the steps or collect the debris on pool surface if a robotic pool cleaner is used.
- **Compatibility:** Variable or multi-speed pumps are compatible with all pools.
- **Affordability:** Upgrade costs are low relative to gains. A typical single speed pool pump costs in the order of $775, while the variable speed pump used in the study was just $1150 and cost around $300 to install. Typical robotic cleaners cost around $1500, with no installation cost.
- **Leadership:** Positively influence the behaviour of friends and neighbours by demonstrating the benefits of having an energy efficient pool.
- **Impact:** Reduce CO_2 emissions and peak electricity demand.

Two types of pool cleaners - pressure cleaner and robotic cleaner

Run your pool filtration system off a PV?

If you own a pool and have a solar photovoltaic system on your roof then the great news is that you may run the pool filtration system off the PV. On a sunny day, you can run your efficient pool filtering system using solar electricity from your own roof while still having sufficient PV output left for other appliances. What's more important is that, even on a cloudy day a typical solar PV system can still supply the majority of the electricity required to keep your pool clean!

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THE CRCLCL HOME COMFORT INDEX: SUPPORTING ENERGY EFFICIENT WELL-BEING

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **Mandatory building codes and sustainability rating tools are limited in their support for energy efficient building upgrades because they do not capture the potential home comfort and health benefits that such upgrades can bring.**
- **To address this situation, we developed a Comfort Index tool to quantify the effects of energy- and carbon-saving construction methods on home comfort.**
- **The Home Comfort Tool can be accessed here: https://comforttool.csr.com.au**

THE OPPORTUNITY / CHALLENGE

A House Energy Rating is an index which represents the thermal performance of residential homes, that is, how well a building naturally heats and cools. Currently in Australia, under the Building Code of Australia (BCA) all new homes must meet a minimum standard of 6 Stars under the Nationwide House Energy Rating Scheme (NatHERS).

Worldwide, mandatory building codes are considered the most effective way of achieving higher levels of energy saving, and therefore, a good way to reduce carbon dioxide emissions.

Despite soaring energy prices, there is a low appetite for energy efficiency upgrades above 7 Stars. However, research has shown that an energy efficient home is a very comfortable home, and if homeowners were able to experience the improved thermal amenity, acoustics, air quality and other benefits of homes >7 stars, we believe they would be more likely to invest in them.

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A significant barrier has been the lack of a robust way to measure the increased comfort levels associated with energy- and carbon-saving building products. This makes it difficult for designers, builders and homeowners to make decisions based on whether these products should be integrated into a design.

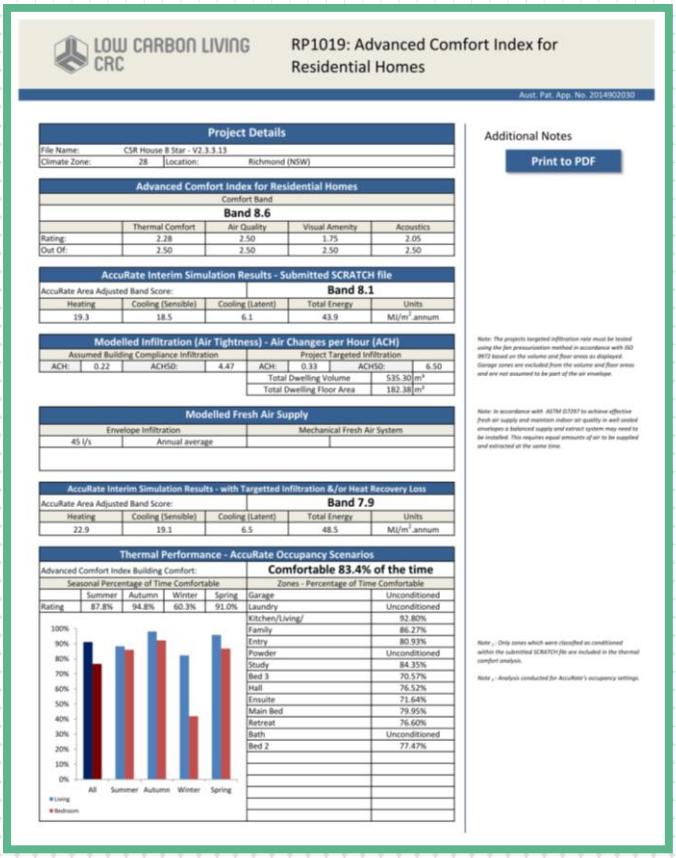
OUR RESEARCH

In conjunction with CSR Building Products (CSR), we developed an advanced Comfort Index tool underpinned by a sophisticated algorithm which can quantify the intangible benefits of energy- and carbon- efficient homes. The tool acts as a guide to the relative

comfort levels of low-carbon homes in order to inform the decision making process.

The steps we took in developing the tool included:

- A detailed international literature review.
- Development of an index algorithm.
- Development of input and output parameters for the tool.
- Creation of an online platform for the tool.
- A trial of the tool from a technical accuracy perspective.
- Marketing of the tool to the building industry (through CSR) and incorporating consumer feedback into the Comfort Index.



RESEARCH OUTCOMES

Our Comfort Index tool:

- Quantifies the comfort and health benefits of energy efficient homes – the comfort index – at the building scale.
- Bridges the gap between minimum building codes for energy efficiency and higher levels of energy efficiency and comfort in house design and quality of construction.
- Provides a user-friendly, interactive method to guide builders and consumers on the levels of comfort and health they can expect from certain energy efficient building upgrades.

The tool provides builders and consumers with well-informed information on the comfort and health benefits associated with energy efficiency upgrades. This tool also supplements increases in energy efficiency regulations, while at the same time, offering an alternative selling point to the traditional energy efficiency payback schemes.

We estimate that our Comfort Index has the potential to increase building energy efficiency by around 50MJ/m^2/home across all 150,000 new homes built in Australia each year.

The index will be marketed through CSR, the largest supplier of energy efficient building products to the Australian market. As such, CSR can influence more builders nationally than any other industry player. CSR will provide continued industry feedback to the Project Team to support improvements to the tool.

Our Comfort Index tool has been showcased in a publication by the Australian Institute for Refrigeration Air Conditioning and Heating (AIRAH)[1] – Australia's most progressive heating, ventilation, air conditioning, and refrigeration professional organisation.

PROJECT TEAM

- Jesse Clarke (Project Coordinator), CSR Building Products
- Assoc. Prof. Alistair Sproul (Project Leader), University of NSW
- Dr. Jessie Copper (Key Researcher), University of NSW
- Anir Upadhyay (Assistant Researcher), University of NSW

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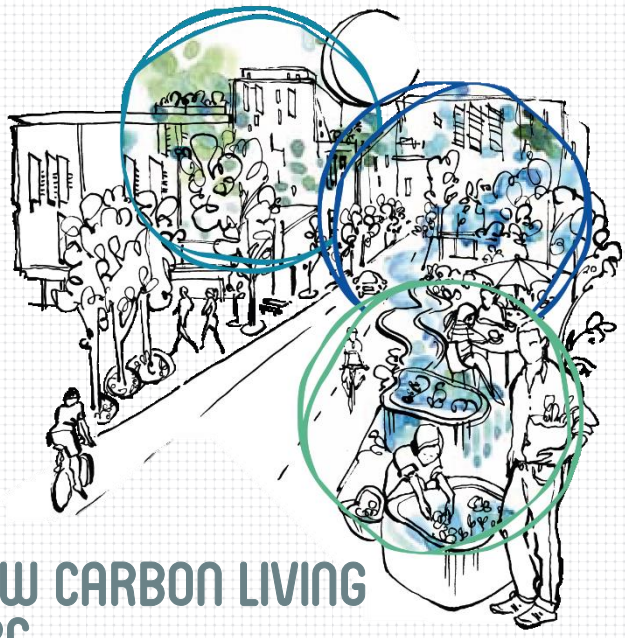
REFERENCES

1. Australian Institute of Refrigeration Air Conditioning and Heating (AIRAH). (2016). *Improving Australia Housing Envelope Integrity*. Melbourne, Vic.

HOME ComfortTool

BUILDING COMMUNITY RESILIENCE: COASTAL PROTECTION USING HIGH DENSITY LOW CARBON CONCRETE



DEMONSTRATION PROJECT

LOW CARBON LIVING CRC

KEY POINTS

- **The manufacture of Portland cement in Australia produces eight million tonnes of CO_2 per year.**
- **Australia generates 14 million tonnes of fly ash (from coal fired power generation) and 3 million tonnes of slag (from steel manufacture) as industrial by-products.**
- **Significant CO_2 reductions and economic benefit can be achieved by substituting Portland cement with slag and fly ash to make geopolymer concrete.**
- **The high density of geopolymer is ideal for coastal defences, and can provide major material and cost reductions.**

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THE CHALLENGE & OPPORTUNITY

The manufacture of one tonne of concrete produces nearly an equal weight of CO_2 emissions, and it is estimated that the manufacture of Portland cement in Australia produces eight million tonnes of carbon emissions per year.

At the same time, Australia generates 14 million tonnes of fly ash (from coal fired power generation) and 3 million tonnes of slag (from steel manufacture) as industrial by-products. Rather than being sent to landfill, these 'waste products' can be used in the manufacture of geopolymer concrete (GPC), replacing a significant amount of Portland cement.

GPC has many superior qualities, including higher tensile strength and improved resistance to chemical deterioration in the marine environment. However there have been many challenges in making fresh GPC behave like traditional concrete, such as ease of pumping, long setting time, and curing requirements.

WHY USE GEOPOLYMER CONCRETE?

One of the unique properties of GPC is its high density. This is especially important for maritime applications. Coastal structures are often exposed to heavy seas and require very large armour units (typically 8-60 tonnes in NSW) to remain stable. While rock is often the preferred material due to its low cost, it can be difficult to source quality rock of sufficient size, so concrete units are required.

Density is important in the stability of coastal armour units because stability increases with the density cubed, so small increases in density have a significant benefit. This has dramatic implications for both new structures and the maintenance of existing ones.

OUR RESEARCH

We are working with the maritime and concrete industries to perfect GPC for use in coastal construction applications.

NSW Ports have recognised the potential value of GPC in maritime structures, and are hosting a field trial of GPC armour units in a breakwater at Port Kembla. A small batch of 18-tonne Hanbar units made from high density GPC have been cast and placed on the northern breakwater. These units will be monitored for stability and integrity, and will provide a valuable benchmark for the future use of geopolymer concrete.

Batching the concrete requires a unique supply chain, and has needed the most progressive minds in the concrete industry to succeed. It has involved the supply of specialist materials from Australian Steel Mill Services, the Australasian (iron and steel) Slag Association and ICL Construction. Batching has been performed by MKD Machinery in a specialised mobile batching rig that allows the concrete to be made to tight tolerances on site.

VALUE PROPOSITION OF OUR RESEARCH

- **Lower carbon footprint** for the construction industry
- **Diverting industrial waste from landfill**
- More **resilient coastal communities through better infrastructure**
- **Simpler and more efficient repairs and adaptive measures** for breakwaters and seawalls

This project is a collaboration between research and two distinct industry sectors to bring novel technologies to market. It has required vision and financial contribution from NSW Ports and the CRCLCL, cutting edge research from UNSW on a construction driven timeframe, world class knowledge of marine infrastructure, and time, materials and industry leading know-how from concrete and material suppliers.

PROJECT TEAM

The following organisations and companies contribute to our project:

- NSW Ports
- UNSW Centre for Infrastructure Engineering and Safety
- UNSW Water Research Laboratory
- Australian Steel Mill Services
- Australasian (iron & steel) Slag Association
- ICL Construction
- MKD Machinery Australia

PROJECT REPORTS

This project applies the learnings from our project RP1020. That project has a broad suite of publications which are listed in our project catalogue and available on our website: lowcarbonlivingcrc.com.au

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A FRAMEWORK FOR PROCURING OFFSITE RENEWABLE ENERGY

PROJECT FACTSHEET

KEY POINTS

- **Commercial electricity users now have a number of innovative options for sourcing their renewable energy supplies from other asset owners.**
- **The Australian market for offsite renewable energy procurement is immature but growing rapidly.**
- **We have developed a framework that characterises the market for, and supports consumers when making decisions about, the procurement of offsite renewable energy.**

THE OPPORTUNITY / CHALLENGE

Electricity consumers across the globe want more control and choice over the power they purchase. In Australia, GreenPower and 'behind the meter' renewable energy options are being supplemented by electricity procured from renewable energy facilities located at other sites. Internationally, this practice has seen major technology companies including Google, Amazon, Facebook, and Microsoft procure large volumes of energy from newly constructed offsite renewable energy facilities.
Offsite renewable energy procurement, either through Power Purchase Agreements (PPAs) or facility ownership can:

- Offer Australian consumers another avenue for both managing electricity costs and achieving sustainability goals.
- Enable the renewable energy industry to diversify its new investment sources.
- Assist Australia in meeting its renewable energy target and climate goals.

However, there are a range of barriers to the development of a new market for offsite renewable energy procurement in Australia, including:

- End user skills and knowledge.
- The limited availability of public information.
- An underdeveloped market for services and products.

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OUR RESEARCH

We investigated the offsite renewable energy market to provide practical and academic insights to assist its development. We addressed a set of forward-looking questions including:

- What might an Australian market for offsite renewable energy look like?
- Who would participate in this market?
- What are the preferences and views of potential market participants?
- How should these participants approach their interaction with such a market?

We investigated the potential for end-users to become a driving force underpinning new utility-scale renewable energy facilities in the Australian electricity market.
These questions were answered through an exploratory, descriptive and explanatory approach to:

- Describing how consumers can procure offsite source-specific renewable energy.
- Understanding why consumers may wish to procure source-specific offsite renewable energy.

- Characterising who potentially makes up the market for offsite renewable energy procurement.
- Appreciating what factors enable and inhibit the effective provision of offsite renewable energy by market actors.

We conducted an industry survey, looked at case studies of implemented deals, and held workshops with market participants to develop a practical framework that can support decision-making regarding the structure of offsite renewable energy contracts.

VALUE PROPOSITION

The results of our study provide actionable insights for consumers through a decision-support framework, full details of which are set out in our report available on the CRCLCL website. The framework sets out the options available when structuring an offsite renewable energy procurement, with seven key decisions required. It can help reduce transaction costs and contribute to overall market development by guiding and informing both end-users and other market participants.

DECISION TYPE	OPTIONS AVAILABLE		
Economic structure	Buy	Own	
Project type	New	Existing	
Form of renewable energy procured	Green	Black	Bundled
Deal type	Exclusive	Aggregated	
Counterparty	Retailer	End-user	
Procurement approach	Physical	Virtual	
LGC treatment	Sell	Surrender	Combination

At an academic level, this study characterises the broader market environment that will arise from the interaction between end-users, electricity retailers, and renewable energy project developers. This will help inform governments designing policies and programs to support offsite renewable energy procurement, and renewable energy in general.

HOW YOU CAN BENEFIT

The offsite renewable energy procurement framework will be valuable for organisations designing a procurement strategy that:

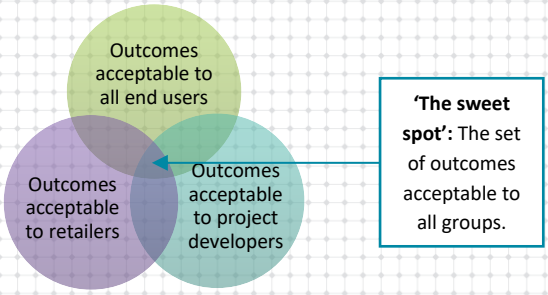
- Reduces electricity costs.
- Establishes ownership or a contractual procurement agreement.
- Overcomes barriers to the installation of 'behind the meter' renewable energy.

LESSONS

The future Australian electricity industry will offer a wider range of electricity procurement options to meet end-user needs and preferences.

Australia is facing electricity cost pressures and the need to meet environmental objectives, and is likely to replicate the US experience, resulting in the dramatic growth of offsite renewable energy procurement by corporations and institutions, who are already very interested in this avenue.

There are, however, a set of market risks that need to be managed effectively to achieve desirable outcomes. Australian electricity users require a set of standardised market product and service offerings to effectively manage these risks, and governments and NGOs can provide public information to enhance the development these.



NEXT STEPS

Our research identified a set of areas for future work including:

- The accounting treatment of PPAs for the procurement of offsite renewable energy.
- Development of methods and tools for end-users to manage the price/volume risk in matching intermittent supply with variable generation.
- Optimising offsite renewable energy technology choice for end users.
- Policy design for the provision of information supporting end user decision-making.

PROJECT PARTNERS

- University of New South Wales (UNSW)
- AGL
- AECOM
- Multiplex

PROJECT REPORTS

Mitchell, E. and Mills, G. 2017. Facilitating end user deployment of off-site renewable generation. CRCLCL

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AN INTEGRATED DEMAND AND CARBON FORECASTING TOOL FOR ENERGY, TRANSPORT, WASTE AND WATER

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **Estimating and managing demand for energy, transport, waste and water services are critical components of sustainable urban development.**
- **We have produced a tool that can both forecast the demands of these services as well as their carbon impact as they interact and vary according to the number of buildings, their structure and use, as well as the number of residents.**

CRC for Low Carbon Living

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With a focus on collaborative innovation, the CRCLCL brings together property, planning, engineering and policy organisations with leading Australian researchers. It develops new social, technological and policy tools for facilitating the development of low carbon products and services to reduce greenhouse gas emissions in the built environment. For more information visit www.lowcarbonlivingcrc.com.au/

THE OPPORTUNITY

Energy, transport, waste and water (ETWW) services are significant contributors to carbon emissions. By assessing the ETWW needs of a building or precinct, we can forecast their associated carbon footprint and implement measures to reduce it.

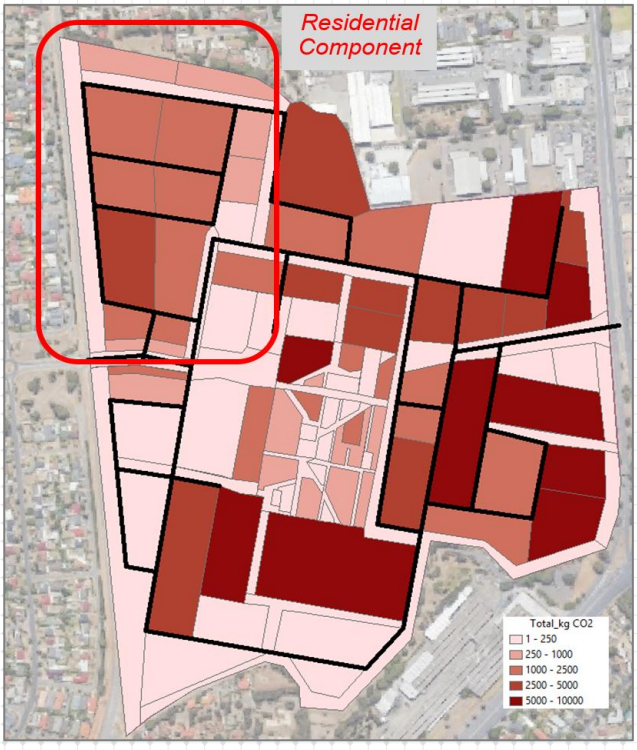
Driven by industry planning needs, we developed a unique integrated toolset that can assess the sustainability of buildings and precincts.

OUR RESEARCH

We have developed an integrated tool that forecasts ETWW demands and the associated carbon impacts at the building level. This estimate can be adjusted according to various scenarios and development plans.

Our model is unique in that it was developed by combining existing state-of-the-art models with a number of newly developed models.

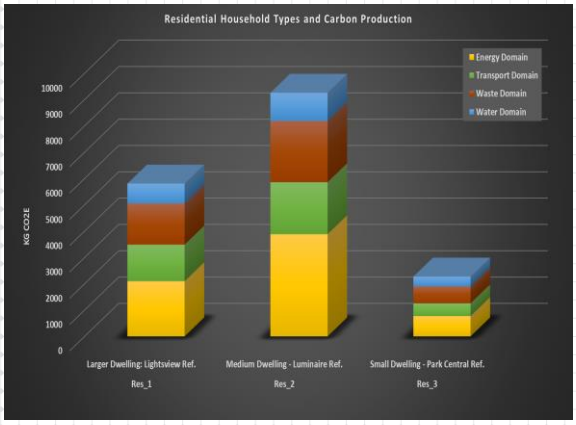
Research and development of the tool focused on residential precincts in a multi-purpose precinct context. This enabled us to create a tool that assesses the overall impacts of both existing and new developments.



OUTCOMES

Our demand estimation model can forecast ETWW demands and associated carbon impacts as they interact and vary according to the building structures, occupant numbers and types of activities within a precinct. This is a unique approach to demand estimation as the tool allows for:

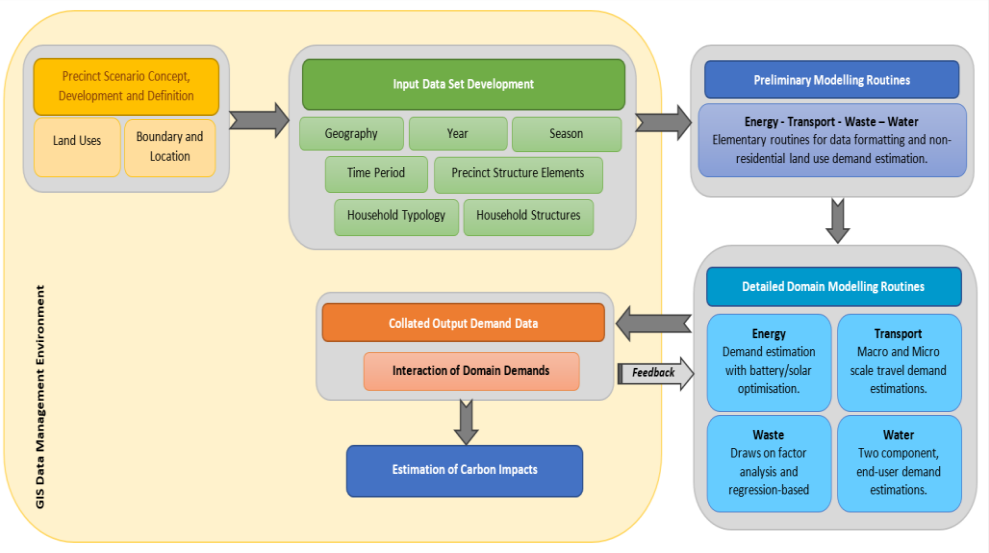
- Highly accurate estimates of the main ETWW demands and associated carbon impacts at both the household and precinct level.
- Analysis of a variety of forecast scenarios.
- Adjustments to the forecast demands in response to population changes, socioeconomic variables and household behaviour.
- Calculations of a range of influences, including solar energy generation and battery storage, water recycling and rainwater use, alternative transport fuels (e.g. electric vehicles), and recycling and waste transport efforts.
- Estimation of the effects of climate change using projected temperature and precipitation, and through climate-related changes to seasonal demands and local water supplies.
- Interactions with external facilities, such as transport networks, off-site waste disposal, water supply locations and grid-based energy supplies.
- Spatial presentation of results within Geographic Information System (GIS).



HOW YOU CAN BENEFIT

Our tool is highly useful in urban development because it helps planning agencies and infrastructure providers, operators and developers to both project and deliver sufficient and sustainable ETWW services to urban precincts.

Our tool can be used to estimate the carbon impact of various household structure types; the effectiveness of carbon-friendly technologies; and the effects of climate change. The tool also allows practitioners to investigate 'what-if' type scenarios, which is useful in policymaking and planning for future urban development.



PROJECT TEAM

Supervisors, leadership team and researchers: Em. Prof. Michael AP Taylor, Prof. Rocco Zito, Dr. Nicholas Holyoak, Prof. John Boland, Prof Peter Newton

Research team: Mr Steven Percy (PhD candidate), Dr. Michalis Hadjikakou, Mr He (PhD candidates) and Dr. Ivan Iankov;

Partner organisations: AECOM, CSIRO, SA Water South Australian Government's Department of Environment, Water and Natural Resources, South Australian Government's Department of Planning, Transport and Infrastructure, South Australian Urban Renewal Authority (RenewalSA), Sydney Water, The University of New South Wales and The University of South Australia.

FURTHER INFORMATION

For more information about this project, please contact:

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Taylor, M.A.P. Holyoak, N., Zito, R., Percy, S. , Hadjikakou, M. Iankov, I. and He H. (2017) Energy, Transport, Waste and Water Demand Forecasting and Scenario Planning for Precincts: Final Report, CRCLCL.

Holyoak, N., Taylor, M.A.P, Hadjikakou, M. and Percy, S. (2017) *An Integrated Demand and Carbon Impact Forecasting Approach for Residential Precincts*, In CUPUM 2017: Planning Support Science for Smarter Urban Futures, Springer, pp. 295-315

INTEGRATED CARBON METRICS - A MULTI-SCALE LIFECYCLE APPROACH FOR THE BUILT ENVIRONMENT

PROJECT OVERVIEW

LOW CARBON LIVING CRC

KEY POINTS

- **'Embodied' carbon in the built environment contributes an additional 18 per cent towards Australia's overall emissions**
- **We are developing a suite of carbon accounting tools that provide a complete picture of the carbon lifecycle, at the building, precinct and city level.**
- **The tools can inform more effective planning strategies to reduce carbon.**

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THE OPPORTUNITY

Buildings produce a significant amount of carbon in their day-to-day use, with operational emissions from the built environment contributing an estimated 20 per cent towards Australia's annual national total. Carbon mitigation strategies and standards developed by industry and government generally focus on these 'direct emissions'.

Another important part of the picture is the carbon emissions created during other stages of a building's life, such as in the production of materials and in construction. This 'embodied' carbon contributes an additional 18 per cent towards Australia's overall emissions, making it an important focus for new research and an enormous opportunity to boost built environment carbon reductions.

OUR RESEARCH

Our Integrated Carbon Metrics (ICM) project is building knowledge about both the direct and indirect carbon emissions in the building process, to better inform those making decisions about our future built environment.

Our research team is developing carbon accounting tools that can be scaled to the building, precinct or city level, to provide a holistic picture of the carbon lifecycle in the Australian built environment.

In particular, our project is developing:

- A database of information about the carbon embodied in different construction materials used in Australia.
- A carbon flow analysis tool, which can track emissions along production and supply chains and show in detail how different industries contribute to carbon emissions.
- A 3D Precinct Information Modelling tool, which can calculate and visualise carbon emissions during the planning of precincts.
- A precinct lifecycle energy modelling tool, based on low carbon scenarios.
- A framework to help link lifecycle assessment and costing for buildings.
- City Carbon Footprinting, to provide a picture of the embodied carbon emission flows in and out of cities.

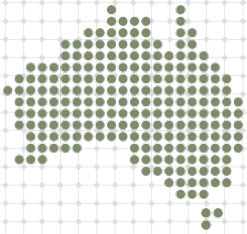
VALUE PROPOSITION

These decision support tools are intuitive, scalable and can be used in combination with existing carbon assessment tools. They will assist building designers, manufacturers, planners and developers in the future planning of our buildings, precincts and cities. By arming them with comprehensive information about how carbon is created over a building's lifecycle, the ICM project can inform more effective planning and mitigation strategies to reduce carbon, helping to meet national targets.

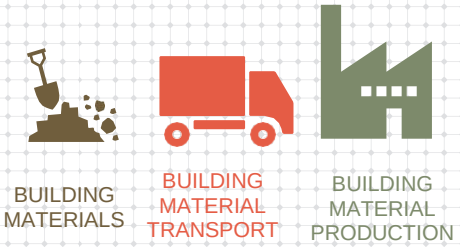
What's more, they will be open source and publicly available, meaning they can be continually updated with new information by the people using them and working across the sector.

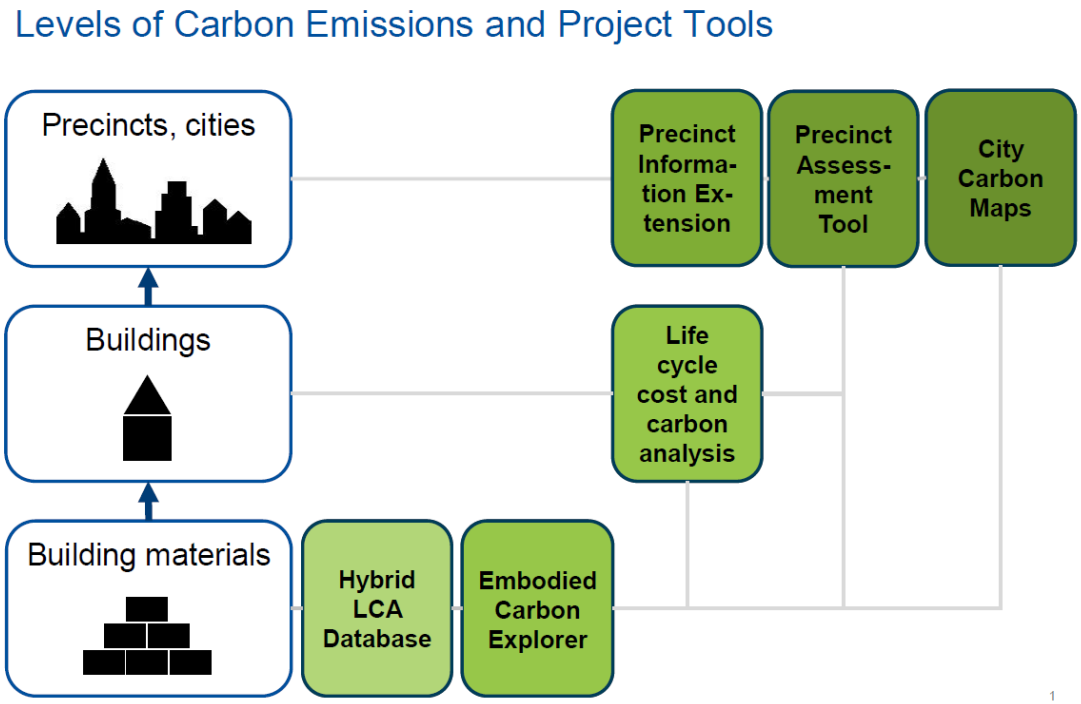
PROJECT PARTNERS

- University of Melbourne
- University of New South Wales
- University of South Australia
- AECOM
- Aurecon
- BlueScope
- Sydney Water



18% of Australia's embodied carbon emissions are from:





FURTHER INFORMATION

Built environment professionals and project teams can trial and tailor our tools.

To access them, or for more information about this project, please contact:

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HOW SUSTAINABLE IS YOUR GREEN INFRASTRUCTURE?

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **Green Infrastructure (GI) improves the sustainability of urban landscapes and helps to remedy the adverse impacts of accelerating urbanisation.**
- **The ability to assess and regulate the sustainability performance of the built and natural environments, based on measurable criteria at a variety of scales, is critical to sustainable development.**
- **We developed an indicator-based model with 16 key indicators to measure the sustainability performance of existing and proposed GI.**

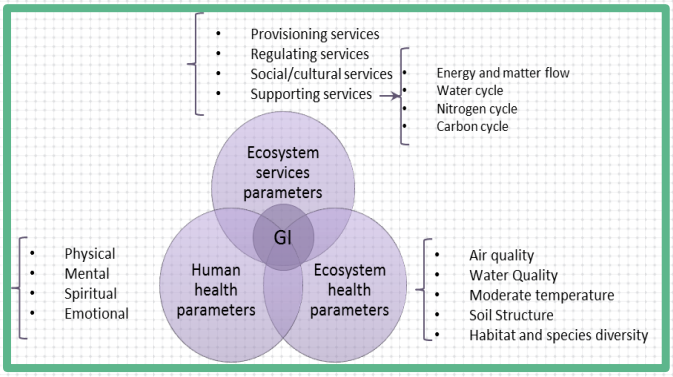

Fig. Conceptual Framework of the GI performance assessment model where GI links people, nature and the built environment.

OPPORTUNITY

GI or living infrastructure is an interconnected network of natural, semi-natural and engineered components such as gardens, green corridors, waterways and green walls and roofs. These components provide ecosystem services and thus support our well-being.

Global challenges associated with accelerating urbanisation, human-driven land alteration and climate change have increased the demand for tools that monitor and assess the sustainability of the natural and built environments.

GI has been identified as a nature-based and cost-effective sustainability solution for promoting more sustainable urban development and restoring degraded ecosystems.

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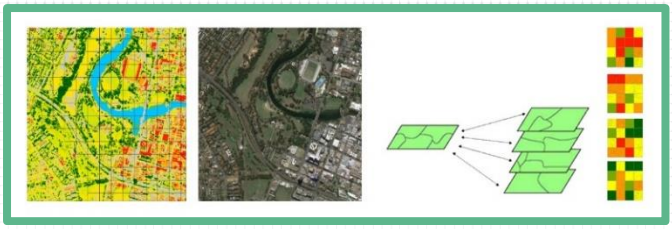
A range of models that assess the sustainability performance of GI have been developed, although to date there is no consensus on a model that is comprehensive and integrative across all types and aspects of GI and ecosystem services.

OUR RESEARCH

We have developed a single, integrated and comprehensive GI evaluation model that can assess the multiple key benefits of GI, and how each of these factors contribute to reaching project sustainability targets.

Our model uses a suite of indicators to help understand the complex interactions between the various dimensions of urban spaces. We used a rigorous selection process to select key indicators that involved:

- A review of previous GI conceptual frameworks and theories.
- Semi-structured interviews of 21 Australian experts.
- Input from 373 Australian national and international stakeholders via online questionnaires.
- The development of an assessment matrix, which included descriptions, calculations and units for each indicator.
- The development of parameters, correlated and linked to GI characteristics and their context
- Developing and trialling the model via a number of software programs, including ENVI, iTree Eco and ArcGIS.
- Testing, validating and verifying the model through a case study in Sydney, Australia.



We identified 16 key indicators to evaluate the sustainability performance of GI. These indicators sit within four subcategories: ecological, health and well-being, sociocultural and economic. Each indicator represents key interactions between human health, ecosystem services and ecosystem health. The final list of indicators that our model can measure are:

- Climatic and microclimatic modifications
- Air quality improvement
- Reduced building energy used for cooling and heating
- Hydrological regulation
- Biodiversity protection and enhancement
- Improving physical well-being
- Improving social well-being
- Improving mental well-being
- Food production
- Opportunities for recreation, ecotourism and social interaction
- Improving pedestrian ways, walkability and connectivity
- Value of avoided CO2 emissions and carbon sequestration
- Value of avoided energy consumption
- Value of air pollutant removal/avoidance
- Reducing cost of car use by increasing walking and cycling

OUTCOMES and LESSONS

The success of GI planning and development hinges on the ability to understand and measure its multiple benefits. Our model, with its 16 indicators, will deliver fundamental information that can inform designers, decision makers and developers, helping them to identify and improve the elements of GI that hinder sustainability target success.

Our model highlights the value and benefits of sustainable urban development, such as GI, to assist industry professionals to make decisions that will shape the well-being of cities and their inhabitants.

HOW YOU CAN BENEFIT

Our model is user-friendly, straightforward and requires minimal data input, making it accessible to industry professionals.

Our model allows users to:

- Investigate impacts of urban development on existing GI.
- Test various scenarios for future developments.
- Identify suitable areas for GI installation and improvements
- Monitor performance against project sustainability targets.

Significant points to be made about the model are as follows:

- The model can **assess multiple key benefits of GI**, and how each of these factors contribute to reaching project sustainability targets.
- The final list of indicators was established based on international survey results with input from key experts, highlighting the potential to **use this model worldwide**.
- This model **serves as a rating tool** that assists landscape/urban designers and decision makers to identify challenges.
- The model provides an overview of the sustainability performance of existing GI. This data can inform future **policies and sustainability targets** that aim to improve sociocultural, health and environmental performance.
- This is a **multiscale model**, from micro to macro. It utilises the iTree Eco sub-model for the analysis of the environmental benefits of GI. iTree is unique in that it can estimate the ecological benefits of a single tree or shrub, and it is not limited by scale.

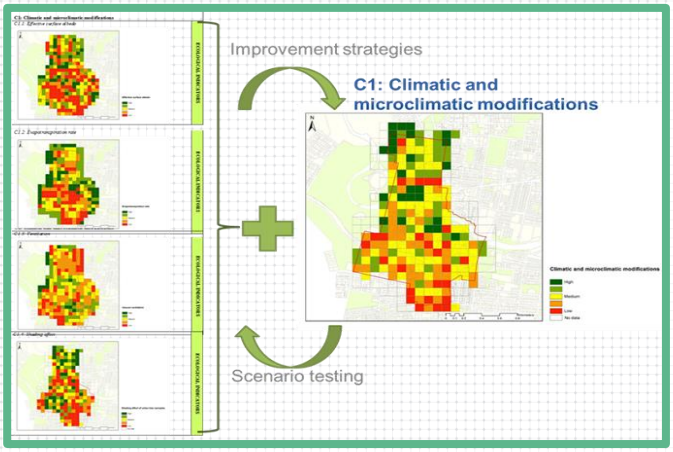


Fig. Snapshot of climate and microclimate indicators for scenario testing

LIMITATIONS and NEXT STEPS

Our indicator-based model is limited to a single case study, an area with a dense urban structure with limited space for increasing GI.

Our future research will apply the model to different locations of ranging development types (e.g. low vs high residential density) and land-use patterns. This will allow for comparisons between the sustainability performance of various GI within a range of urban contexts.

PROJECT TEAM

- Parisa Pakzad (PhD student)
- Dr Paul Osmond (Project leader)
- Infrastructure Sustainability Council of Australia (ISCA)- (industry partner)

REFERENCES

Pakzad et al. (2017). Developing key sustainability indicators for assessing green infrastructure performance. *Procedia Engineering*, 180, 146-156

FURTHER INFORMATION

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REDUCING THE ENERGY INTENSITY AND CARBON EMISSIONS OF WASTEWATER TREATMENT

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **Modern wastewater treatment operations are energy-hungry and carbon emissions intensive**
- **Significant potential exists to further optimise wastewater treatment performance through energy benchmarking**
- **This project is developing a suite of new energy benchmarks to enable the Australian water industry to optimise its wastewater operations for energy and carbon outcomes**

THE OPPORTUNITY / CHALLENGE

Wastewater treatment plays an essential role in safeguarding public and environmental health within the built environment. However, wastewater treatment operations are among the most energy-intensive activities carried out in our cities, with high levels of associated greenhouse gas (GHG) emissions.

This renders current wastewater practices unsustainable and optimisation of wastewater treatment plants (WWTPs) is needed to reduce the impact of operations and to enable the industry to achieve strategic energy and carbon neutrality goals. Energy benchmarking (Figure 1) offers a way to identify underperformance in energy efficiency and prioritise future optimisation efforts.

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Pioneering work by the South Australian water utility SA Water in WWTP energy benchmarking during 2010–2013 led to a broader recognition in the sector of the potential energy, carbon and cost savings from more efficient wastewater treatment operations.

This pioneering work, however, applied existing European methods and benchmarks without adaptation to suit Australian conditions, which in many cases affects the relevance and scale of identified efficiency opportunities.

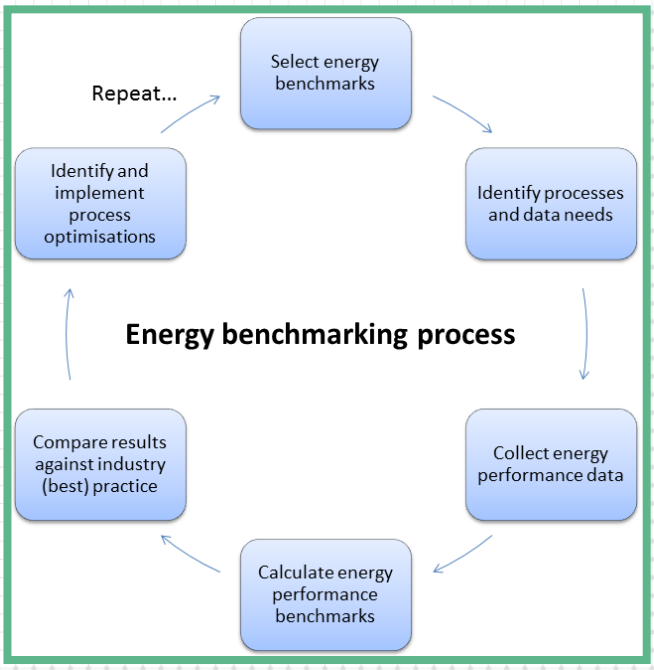

Figure 1. Schematic overview of energy benchmarking approach

OUR RESEARCH

Recognising the important differences in Australia in how wastewater treatment processes perform, the regulated treatment targets, and the nature of the wastewater itself which can affect the energy use performance of WWTPs, we are developing new locally-relevant energy benchmarks for use by the Australian water sector.

OUTCOMES

1. Review of energy benchmarking methodology

An initial part of the project has involved a comprehensive, critical review of European energy benchmarking methodology for communication to the water industry (inter)nationally. This review delivers for the first time a complete understanding of how European (German) energy benchmarking methods have been developed and applied, unlocking a valuable—but previously inaccessible—knowledge base to an international audience.

2. Development of energy performance benchmarks

Another project area has involved the use of a comprehensive national WWTP electricity use dataset, collected as part of a national water industry benchmarking assessment coordinated by the Water Services Association of Australia, to develop a suite of locally-relevant, Australian energy performance benchmarks for a range of key wastewater treatment processes (Figure 2). Once complete, this suite of new Australian energy benchmarks will allow water industry members for the first time to benchmark their energy use performance against their industry's own performance metrics, helping to unlock energy and GHG emissions savings from wastewater treatment operations.

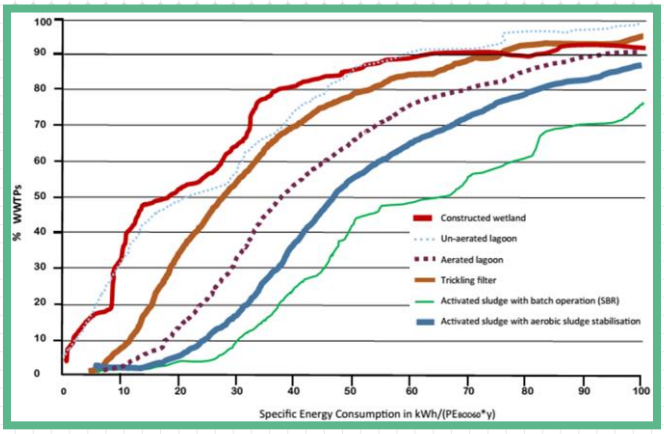

Figure 2. Frequency distribution of energy performance data to benchmark key Australian wastewater treatment processes.

3. Cost, energy and GHGs of recycled water operations

A third component of the research is investigating the cost, energy and GHG intensity of disinfection processes for the treatment and provision of recycled water. We are using case study data from full-scale wastewater treatment and water recycling facilities in South Australia to benchmark the relative performance of conventional disinfection using chlorination against more advanced ultraviolet (UV) disinfection technology across these three criteria. Preliminary outcomes from the disinfection case study work are providing information to water industry partners on the relative cost (capital and operational), energy use and GHG emissions performance of chlorine versus UV disinfection. This information will help inform future recycled water treatment strategies at the utility level and enable utilities to better interlink recycled water service provision with carbon and energy objectives.

HOW YOU CAN BENEFIT

Australian water industry members will benefit from having access to new and comprehensive information on energy benchmarking methodology. We will provide access to:

1. A suite of locally-relevant energy performance benchmarks to help utilities optimise their WWTPs for energy and carbon emissions savings
2. New insights regarding the economic and environmental performance of recycled water disinfection practices to inform treatment strategy.

NEXT STEPS

The project will run until early 2019, augmented by a new Utilisation Project in 2018 to operationalise the research outputs into a new energy benchmarking tool for the Australian water industry.

PROJECT TEAM

This is a collaborative project between the University of South Australia (UniSA), University of New South Wales (UNSW), SA Water and Sydney Water.

Research staff: Michael Short and Chris Saint (UniSA), Juan Pablo Alvarez-Gaitan and Richard Stuetz (UNSW), Rudi Regel and Nirmala Dinesh (SA Water), Greg Appleby (Sydney Water).

PhD students: Ilda Clos (UniSA) and Benjamin Thwaites (UNSW).

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DRIVING LOW CARBON TRANSITIONS AT A PRECINCT SCALE

CASE STUDY: SYDNEY'S BROADWAY PRECINCT

LOW CARBON LIVING CRC

KEY POINTS

- **Existing precincts have embedded systems, behaviours and technologies which are often very fragmented and inefficient.**
- **For our cities to successfully transition to a low carbon future, we need to address these challenges to identify a pathway to low carbon living.**
- **Using Sydney's Broadway Precinct as a demonstration site, our project sought to better understand the nature of existing precincts and identify the challenges and opportunities.**
- **The research focussed on the economic, stakeholder, governance and technological considerations to identify transition pathways to towards low carbon energy and water efficiencies.**

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THE OPPORTUNITY / CHALLENGE

Our existing urban form provides significant challenges and barriers to enabling a low carbon transition. Reducing carbon emissions and enhancing energy and water efficiency at a city scale will require a consideration of how we manage the existing urban form and the actions we take to effect change to low carbon behaviours and technologies. A city scale transition is incredibly complex due to the physical, social, economic and environmental scales; the challenge within this research is to focus how we break this challenge down into manageable scales.

Our research focused on how transition at a precinct scale provides a local context and governance structures that empower and unite communities by including them in decision-making processes. Precincts are characterised by physical proximity, diverse uses and similar key stakeholders, regulatory context, governance frameworks and service infrastructure. However, they are inherently complex and characterised by multilayered interactions between institutions, people, regulatory, financial and policy frameworks, and technological systems like water and energy. For example, the rapid pace of technology makes it difficult to assess long term investment strategies . The lack of open space can inhibit onsite capture and storage of water and renewable energy.

Precincts provide a unique opportunity for flexible, dynamic and local responses. Stakeholders can benefit from economies of scale to access technological innovations. The role of precincts has been recognised by the Australian government's National Carbon Offset Standard for Precincts which provides guidance for measuring, reducing, offsetting and reporting of operational emissions.

SYDNEY'S BROADWAY PRECINCT

This Sydney CBD precinct is broadly bound by Harris, Wattle, Mary Ann and O'Connor Streets. The study brought together a range of stakeholders including Brookfield, City of Sydney, University of Technology Sydney and NSW TAFE. Between them, these stakeholders hold a range of assets of different ages and uses including retail, educational, residential and commercial.

The Broadway case study provided a detailed set of baseline information in relation to governance, stakeholder value, and infrastructure and utility consumption. However, it did not consider embedded energy in materials, waste or transport.

OUR RESEARCH AND RESULTS

We explored and detailed the economic, stakeholder, governance, and technical barriers and drivers to transforming precincts to a low carbon and water future in the context of Broadway and lessons learned from a review of case studies and best practice. We identified the following barriers and opportunities:

Barriers

- Diverse stakeholders with wide-ranging levels of knowledge, values, social and local engagement.
- Varied asset mix with different maintenance and renewal strategies and timing.
- Political uncertainty around carbon and energy futures and associated investment risk.
- Challenges in integrating technology or solutions across multiple buildings.
- Fragmented governance and regulatory impediments.
- Rapidly developing technologies and economic models creating investment risk.

Enablers

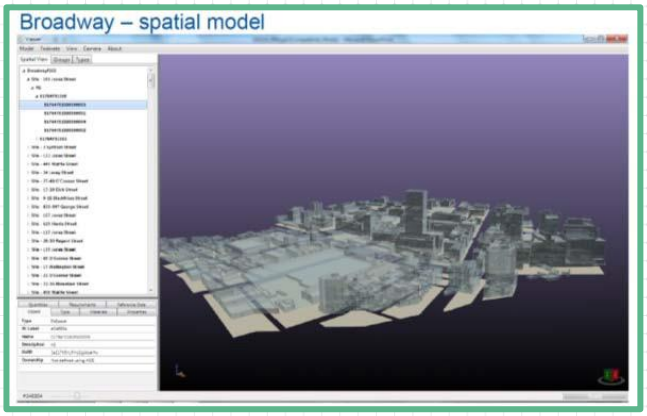
- Business models and governance models are innovating very quickly, often faster than the technologies.
- There is a new impetus and visions for sustainable living in the face of resource availability, cost and awareness.
- Rapidly developing technologies and practices such as peer-to-peer energy trading and offsite renewable energy.
- Declining cost of renewable technologies and energy storage in the face of rising network costs.
- Existing business models for sustainability supported by market increases in the cost of energy, water and waste.
- If a precinct is growing then addressing existing loads within the precinct may enable growth in development without needing to upgrade utilities.
- Data availability and social media is driving transparency and enabling alternative models for collective action and trade.

Our report provides guidance in the following areas, contextualised using Broadway:

- The need for auditing the assets and consumption within the precinct to enable strategic management of asset lifecycles and carbon intensity decisions.
- The value of effective stakeholder engagement to improve legitimacy, transparency, relevance and credibility, and to support implementation.
- The need for stakeholder education and behaviour change to ensure motivation is combined with the necessary technical, operational and economic skill set to drive the transition.
- The need to understand the economic drivers around existing assets within a precinct and ensure effective business models are developed for different stakeholder typologies or technical solutions.
- The value of establishing a baseline of the social, political, economic, technical and environmental status quo in the district together with key trends, drivers and constraints, and using this to generate alternative future energy and water scenarios to help identify preferred situations.
- The multitude of decision making processes within a precinct and understanding how these can influence the carbon outcome for the precinct.
- The governance elements that need to be in place and the role of various actors such as government and the policy instruments that can facilitate systemic change.
- Consideration of procurement pathways, including for capital, security and perceptions of risk.
- Understanding the appropriate data needs.

Our report provides a structured and comprehensive analysis of low carbon transition management actions to guide and empower precincts to reduce their carbon and water intensity. We consider the financial and stakeholder drivers and necessary technological and governance frameworks. We also identify a range of ongoing challenges and opportunities and remaining questions.

The learnings have been applied in a number of precinct redevelopments or advisory projects including The Bays Precinct in Sydney, Waterloo Estate, Bondi Junction, Old Royal Adelaide Hospital Site and Sydney Metro.



NEXT STEPS

Our work has revealed a range of future research areas that would support precinct transitions, specifically:

- Identifying the emergence of “next generation business models” based on service delivery and reducing inefficiency.
- Development of flexible governance, risk management and economic models for precinct scale.
- Identifying the relationship of the investment implications of driving parallel energy efficiency outcomes with energy supply solutions.
- Investigation into existing regulatory and corporate risk mechanisms and their influence on transition.

PROJECT TEAM

AECOM, Brookfield, City of Sydney, Flow Systems, Swinburne University, TAFE Sydney, UNSW, UTS.

PROJECT REPORT(S)

Swinburne, R., Hilson, D. and Yeomans, W. 2016. Empowering Broadway. Phase 1 research report. CRCLCL.

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FURTHER INFORMATION

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Transforming food ‘waste’ into compost: reducing GHGs, landfill and fertilizers

PROJECT FACTSHEET

KEY POINTS

- **Inedible food scraps are an asset, not a waste product**
- **Composting can transform otherwise discarded organic material into a valuable resource, reducing greenhouse gas (GHG) emissions in the process**
- **We are investigating ways to (1) harness this opportunity (across various composting models and precincts) and (2) address the social challenges**

THE OPPORTUNITY / CHALLENGE

Currently, we divert much of our inedible food waste to landfill which releases around 9 million tonnes of CO_2-e p.a. Through composting this organic matter and using that compost to help grow food, there is an opportunity to improve crop production and to reduce landfill and GHG emissions. Returning carbon from food scraps to the soil via compost, can improve Australian soils while reducing water use as well as pesticides, herbicides and fertilisers.

The challenge is to get everyone involved in separating food scraps from inorganic waste materials for composting and to get food growers to use the resulting compost.

CRC for Low Carbon Living

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OUR RESEARCH

We are comparing models of onsite and offsite composting across different Australian urban precincts in terms of GHG reductions, the quality of the compost product (public health and soil quality issues), and people’s engagement with the composting process and compost product.

OUTCOMES

- A practical handbook of food separation and composting solutions for different types of urban form
- A national symposium tailored to waste management and sustainability areas of government and business.
- Cylibox – an in-vessel composter with a small ecological footprint

HOW YOU CAN BENEFIT

Our research can help you achieve low carbon living with respect to the management of inedible food waste. The research is unique in terms of the multidisciplinary comparison of offsite and onsite composting.

LESSONS

The production of compost from food scraps is most successful when driven by end user demand. Accordingly, we have learned that we need to ensure that the quality of this compost satisfies end users.

There is no one size fits all for successful management of food waste through composting. The human systems involved in food separation and composting are as important as the composting system, whether the context be a multi-unit residence, office block or café/restaurant.

NEXT STEPS

- Further investigation of piloting in a café precinct of a unique high-speed composter that takes paper, cardboard and food scraps (OSCA Bitesize).
- Further development, marketing and promotion of Cylibox
- Further investigation of supply chain issues in the market for compost.
- Case study of commercial composting in Australia as an example of the circular economy

PROJECT TEAM

Dr Vivienne Waller, Overall Project leader, Social research

Professor Linda Blackall, Microbiological and chemical research

Professor John Boland, Greenhouse gas accounting, Life cycle analysis

PhD students: **Charles Ling**, **Alex Jaimes Castillo**, **Katherine Thornton**

Partner universities: Swinburne University, University of SA, Melbourne University,

Industry partners: Sustainability Victoria, Urban Renewal Authority SA, City of Melbourne

PROJECT REPORT(S)

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FURTHER INFORMATION

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COOLING OUR CITIES: A DECISION SUPPORT TOOL FOR REDUCING URBAN HEAT

PROJECT OVERVIEW

LOW CARBON LIVING CRC

KEY POINTS

- **Cities are vulnerable to temperatures, and the task of cooling them has proved challenging.**
- **The CRCLCL is developing a decision-support tool that bridges the gap between research and practical application in urban microclimates by helping governments, developers and planners to mitigate vulnerability to urban heat island effects.**

THE OPPORTUNITY

Cities and their communities are vulnerable to extreme temperatures, especially when it comes to the elderly and the young. In recent years, the frequency, intensity and duration of extreme weather events have increased in Australia. For example, Richmond in north-western Sydney reached 47 degrees during heat waves in February 2017. Urban microclimates are affected by various factors, including population growth, waste heat from industry and transport, greenfield and infill development, densification and urban renewal.

The task of cooling cities, thereby improving outdoor thermal comfort and reducing energy consumption, has proved challenging. To develop heat mitigation strategies, we need to answer the following research questions:

- Can innovative urban development approaches reduce the heat island effect and minimise the impact of climate extremes on outdoor thermal comfort, human health and energy consumption?
- To what extent do urban form, parks, greenery, waterways, cool roofs and urban heat dissipation technologies help reduce urban heat island effects?
- What scenario analysis and decision-support tool are needed by governments and developers who do not possess the required technical knowledge to select the optimal mitigation techniques?

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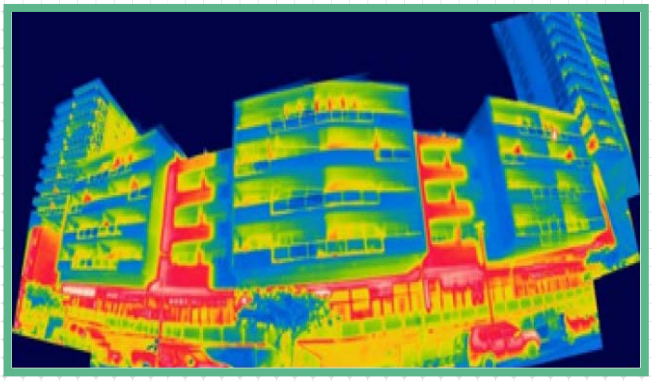

RESEARCH & STAGES

Our research methods include:

- Identifying one or more precincts in NSW with different urban forms, densities and roof and paving materials as exemplars.
- Monitoring and characterising the microclimate of exemplar precincts over warm seasons, including trends and progress toward mitigation performance targets.

- Designing a series of advanced mitigation options to address specific problems identified; Urban Heat Island (UHI) mitigation strategies and possible cooling interventions will be explored under varying urban form and building material scenarios.
- Predicting what-if scenarios of UHI mitigation performance under standard climate conditions; Providing 3D visualisation of analysis outcomes through a web-based platform.
- Integrating building information models (BIM) and precinct information models (PIM) with GIS to enable automated form classification and material identification; Supporting building and urban data interoperability.
- Developing optimal UHI mitigation solutions or strategies to meet multi-objective performance targets.

FURTHER INFORMATION

For more information about this project, please contact:

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PROJECT PARTNERS

- University of New South Wales (UNSW)
- Swinburne University of Technology
- City of Sydney
- Greater Sydney Commission
- NSW Office of Environment and Heritage (OEH)
- UrbanGrowth NSW
- BlueScope Steel
- AECOM
- Stockland
- Western Sydney Regional Organisation of Councils
- Southern Sydney Regional Organisation of Councils
- Parramatta Council
- Waverley Council
- Inner West Council
- Campbelltown City Council
- NSW Spatial Service

THE TOOL

Our Microclimate and Urban Heat Island Mitigation Decision-Support Tool will:

- Provide governments and the built environment industry with a systematic and structured scenario analysis to inform urban policy, development assessment and planning practices related to potential building and urban interventions. The scenario analysis it provides can be used to cool streetscapes and cities, decrease energy consumption, protect the health of the vulnerable, and improve comfort.
- Integrate scientific models with a range of mitigation techniques to perform urban heat island mitigation analysis across both building and urban scales. It will consider building coatings and roofs, urban form and density, greenery and infrastructure.
- Develop an Urban Heat Island Mitigation Performance Index to support governments in establishing performance targets for their planning controls. The Index will indicate the impact on street level temperature, health and mortality, precinct level energy consumption and other factors.

VALUE PROPOSITION

The tool will provide:

- A convenient, intuitive and efficient way for governments, developers and planners to mitigate vulnerability to urban heat.
- Support for evidence-based decisions and strategies relating to low carbon and climate adaptation in urban development.
- A bridge between research and practical application in urban microclimates.

MAINSTREAMING ZERO ENERGY HOUSING

PROJECT OVERVIEW

LOW CARBON LIVING CRC

BACKGROUND

Residential housing in Australia is recognised as a significant contributor of greenhouse gas (GHG) emissions, with the majority of emissions being generated during the operational phase of buildings. With around 100,000[1] houses built each year, and with the average operational GHG emissions in the order of 7 tonnes per dwelling[2], total emissions could be reduced by around 700,000 CO2-e per year if all new home were built as 'Zero Energy Homes'.[3] Simply put, Zero Energy Homes, (or Net Zero Energy Buildings), are designed and built to consume the same, or less, energy than they produce on an annual basis. Typically, ZEH buildings are highly energy efficient, through good design and quality construction, and include an appropriately sized roof-top solar power generation system to match their estimated power load during occupancy.

As Australia works towards meeting its carbon reduction target of zero emissions by 2050, the housing sector can play an important role in meeting this goal. Internationally the European Union and the State of California (USA) already have regulations in place to adopt ZEH for all newly constructed homes by 2020.[4,5] Meanwhile, Australia is still taking relatively early steps towards improving residential energy efficiency. This project aims to develop a better understanding of the construction cost implications and consumer interest of ZEH in Australia, whilst building industry support for ZEH homes amongst residential developers.

RESEARCH TEAM

The research project is being lead by Dr Josh Byrne and Professor Peter Newman of Curtin University. The research team will include post-doctoral research staff support, plus specialist input from CSIRO and Josh Byrne & Associates. The project will also draw on the experiences from other related CRCLCL and industry projects and activities, such as RP3029: Driving a National Conversation on Energy Efficient Housing, CSIRO Liveability and CSR Comfort Tune.

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PROJECT ACTIVITIES & ANTICIPATED OUTCOMES

Three ZEH display homes will be built in partnership with land developers in new display villages around Australia and used for data gathering and engaging industry. The activities for this project are grouped under three stages:

STAGE 1: RECRUITMENT OF PARTNERS

Stage 1 will focus on recruiting partner developers and builders who will be responsible for the delivery of the ZEH display homes. Recruitment will target different cities and regions around Australia (e.g. Perth, Canberra and Townsville) for the purpose of understanding the impact of different climate types and markets on cost and consumer interest. Expressions of interest to participate have already been received from a number of developers and these partnerships are currently being explored. An important part of the recruitment process of the partner builders will be to agree on ZEH and broader performance criteria of the display homes, plus formalise agreement on the methodology to capture the required data to evaluate the research questions.

STAGE 2: DESIGN AND CONSTRUCTION OF THE ZEH DISPLAY HOMES

This phase will see the Research Team facilitate design support for the ZEH display homes, drawing on additional CRCLCL researchers and partners as required. Each display house is likely to be different in terms of product. For example, they may be single or double story, fully detached or strata with common wall and services etc. The design responses and materials used will also be relevant to the particular location. The commonality to all the projects will be there need to work to agreed performance criteria and be targeted to the volume market. Each display house builder will be required to maintain cost documentation so that the cost implications of additional features or products that are linked to increased performance can be easily assessed and reported, with acceptance by industry.

STAGE 3: EVALUATION OF THE ZEH DISPLAY HOMES

In addition to capturing the practical industry learnings and detailed construction cost implications for the design and building phase as outlined above, information will also be collected on consumer and broader market interest in the features of the houses. A digital surveying tool will be used to enable feedback to be collected from visitors viewing the ZEH display homes and compare this to regular product of similar type in the same development. The survey will not be overtly ‘sustainability’ related but gather a wide variety of consumer preference data that can feed into the marketing departments of builders and developers. Video diary segments will capture the key stages of the project and will be used to communicate progress and learnings directly to industry via the CRCLCL and industry channels.

PROJECT SCHEDULE

Stage 1	
Secure partner developers/builders who are committed to building ZEH display homes and participate in the study with agreement on the methodology.	By April 2017
Stage 2	
Facilitate design support for the builders.	From Partner engagement through to commencement of construction
Apply (and test) industry leading evidence based tools for performance and comfort communication.	By June 2017
Oversee cost estimation and documentation so that the cost implications of additional features or products that are linked to increased performance can be easily assessed and reported.	Throughout construction (to be completed by December 2018)
Stage 3	
Undertake consumer research and market evaluation on the houses, plus performance monitoring.	January 2018 – June 2018
Reporting.	By December 2018
NOTE: The above timeline should be considered as a guide only. Final timing of milestones and deliverables can be negotiated during Stage 1.	

FURTHER INFORMATION

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REDUCING THE CARBON FOOTPRINT OF TOURISM AND COMMUNITIES – OUR LOW CARBON LIVING PROGRAM

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **We have developed a community-based program that enables tourism businesses to lower their carbon emissions and enhance sustainability**
- **Participating businesses:**
  - **are audited and rated on energy, water and waste**
  - **are provided with resources and other support to improve efficiency**
  - **become part of an online community network**

Visit the program here:
https://lowcarbonliving-bluemountains.com.au/

THE RESEARCH OPPORTUNITY

Worldwide, tourism accounts for 5% of Greenhouse Gas emissions and makes up 5.6% of Australia's emissions (Dwyer et al., 2010). The effectiveness of establishing sustainable, low carbon tourism has been demonstrated in other countries such as in the Lakes District, UK where a large number of small tourism businesses have achieved significant carbon reductions with the support of a national scheme. Research also suggests that one-third of tourists will selectively choose eco-friendly accommodation (Nurture Lakeland, 2011).

Australia is a popular tourist destination for both domestic and international tourists and thus has the potential to contribute significant energy, waste and water efficiencies through a targeted program that addresses the nuances of the Australian tourism industry.

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OUR RESEARCH

Using the Blue Mountains world heritage tourist destination as a case study, we investigated whether a market-based or dual incentive scheme could reduce the carbon, water and waste footprint of the tourism sector.

We established an education and technical support program, and recruited 30 businesses (a 'living lab') that were audited, rated and the results published on a dedicated website. We then monitored

and analysed reductions in water, energy and waste, web traffic and changes in occupancy rates.

RESULTS

We found that a multiple-incentive scheme worked best, that is, undertaking auditing and rating, developing a website and related promotion, and providing education and training. On average the recruited businesses reduced their carbon usage by 10-15% per year.

Our research showed that 82% of visitors and 91% of residents would choose a local business that has made an effort to reduce its carbon footprint.

The dedicated website made it easy for locals and visitors to make smarter decisions about which businesses they supported and how they could reduce their own carbon footprint.

OUTCOMES

Since we piloted the program in 2014, 95% of the businesses have remained in the program and have reported increased revenues. The number of participating businesses has also increased from 30 to nearly 70.

Our project has evolved into The Low Carbon Living Program, a community-based initiative that helps businesses and communities] reduce their carbon footprint. The program connects residents and visitors to local businesses who are reducing their carbon footprint by cutting back on waste and reducing energy and water use.

This program empowers everyone to address climate change by making positive decisions about their use of resources, where they shop and what services they support.

WHAT DO OUR PARTICIPATING BUSINESSES THINK?

> *The Low Carbon Living program is a win/win for not only businesses and their customers, but for our region as a whole. It's a no-brainer. We need this to maintain a healthy, sustainable business economy and environment in the World Heritage area.*

Vent Thomas, President, Blue Mountains Regional Business Chamber

> *Over five years of tracking and auditing at Lilianfels we have managed to reduce our energy consumption by 25% per customer.*

Huong Nguyen, Director, The Escarpment Group

NEXT STEPS

We are now transferring the program to the Southern Highlands, NSW, a collaboration with the Blue Mountains World Heritage Institute (BMWHI) and Wingecarribee Shire Council.

PROJECT TEAM

Dr John Merson - Program Director, BMWHI

Dr Alex Baumber - Carbon Analyst, UTS, Sydney

Chris Lockhart-Smith – Auditor, BMWHI

Annabel Murray - Program Manager Blue Mountains

FURTHER INFORMATION

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And visit our project website: https://lowcarbonliving-bluemountains.com.au/

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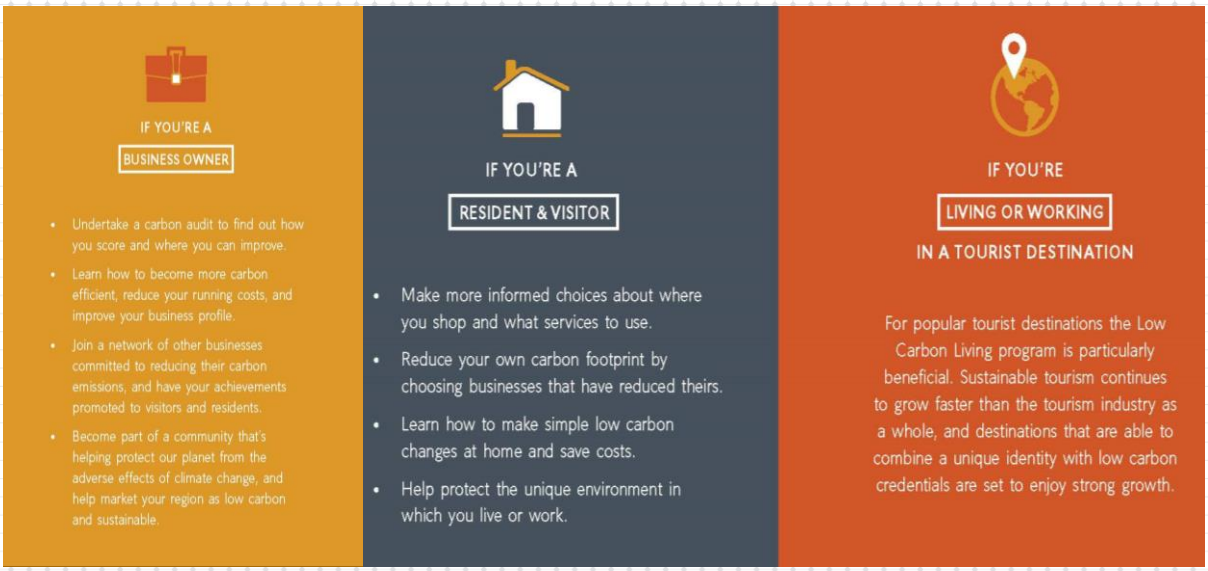
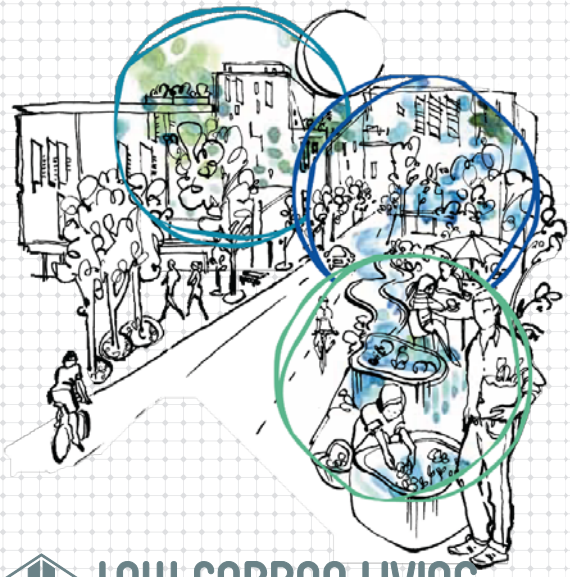


USING BEHAVIOUR CHANGE INSIGHTS TO TRANSLATE RESEARCH INTO POLICY & PRACTICE



LOW CARBON LIVING CRC

Guide Note for CRCLCL researchers

PURPOSE

This guide note has been provided to assist our researchers in enabling greater uptake and use of their research by applying insights from social and environmental psychology.

THE RESEARCH CHALLENGE

Our research projects are all about change. They advance new and innovative ways of doing things ranging from the simple to the transformational. Change can be exciting but also confronting because it alters the status quo and requires the investment of time and other resources during the transition. Those resources can be put to best use by knowing what to address, when and how. That's where our research comes into play.

THE RESEARCH OPPORTUNITY

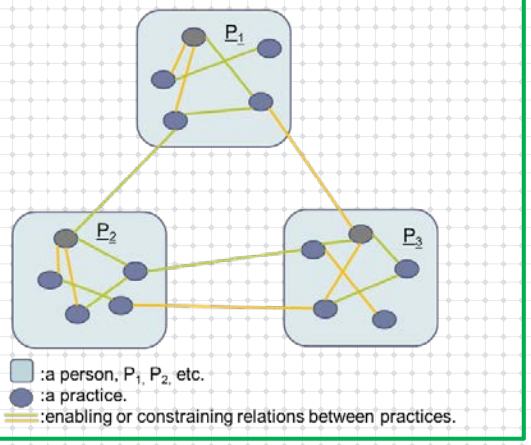
For our research to make a difference, we need to manage and support the change that end users must undergo to use it. However, changing behaviour can be tricky: people can resist change for emotional reasons, do not always act rationally, and can act differently depending on the context. People often say one thing, and do another. However, our research in behavioural economics and social psychology reveals that there are a number of matters that we can address to help support the uptake and use of our research.

WHY CHANGE CAN BE DIFFICULT

Our lives are filled with many different activities or practices that are intertwined in a complex equilibrium. So, we try to maintain our daily activities in equilibrium with each other and with those of others (Fig. 1). Thus, changing behaviour upsets this equilibrium and requires us to adjust our activities to keep things in balance.

When we ask a person to change a behaviour, we are asking them to navigate change in two layers. One is implementing change in the practices described above (Fig. 1). In a state of equilibrium, this layer is generally regulated thinking which is fast, efficient and habitual (Type I) where we use the best combinations of practised behaviours to maintain equilibrium and meet daily demands.

Fig. 1: Hypothetical Network of Individuals and their Activities



However, we cannot change our practices without first making the necessary changes in a second layer, namely that of our 'concepts'. This is the network of beliefs, attitudes, aspirations, goals and intentions that accompany our practices, day to day activities and interactions with others. Changing concepts requires us to invoke a more cognitively demanding type of thinking, namely a more deliberate and reflective assessment of what the change will achieve and how we can best achieve it (Type II thinking).

According to the reasoned action approach (Fishbein & Ajzen 2010) our intention is an important factor in determining what we do and how those actions can be changed. Intention, in turn, is influenced by a dynamic interaction of a range of psychological factors, namely:

- attitude (formed from our beliefs, goals, values and emotions)
- injunctive norms (what we think we should do)
- perceived social norms (what think others do), and
- perceived control (whether we think we can do it).

These psychological factors also interact with their context - the surrounding personal, social, institutional and physical factors both in time and space that dictate whether, in the circumstances, we have actual control to influence outcomes and change behaviour.

We talk with our friends and interact with others in our social networks to learn new ideas, to negotiate with others, and be encouraged by them to take on a new challenge. In doing, so we weigh up the 'costs of change' to ensure that we have the necessary physical and psychological resources (competencies, materials, equipment and an understanding of the change and its benefits) and can achieve a new equilibrium.

Therefore, we can encourage change by minimising these 'change costs' and highlighting the personal and inter-personal benefits of the new regime. Further, to sustain a change, we need to ensure that people repeat the new behaviour until it becomes routine within a newly formed equilibrium. This moves us from the 'costly' deliberate Type II thinking back to the more efficient, fast and sustainable Type I thinking.

INSIGHTS FROM OUR RESEARCH

A combination of audience-focussed actions is more likely to bring about a desired change. As a rule of thumb, taking the following steps may assist the uptake and use of your research:

Focus on resolving problems and play up the research strengths, making clear any limitations. Don't be overly concerned about perfection - people seek solutions that offer a satisfactory or adequate outcome, rather than expending additional resources on achieving an optimal solution.

Engage with and listen to stakeholders to understand what they value, how they operate in day to day life, what barriers might exist to the uptake of your research and who they associate with (and whether these 'associates' help or hinder the uptake and maintenance of the new behaviour). In sum, knowing the range of criteria that potential stakeholders use to make decisions around a new behaviour allows us to tailor our approach. More specifically:

- Keep things simple because when we get overwhelmed by decisions the cognitive effort increases and we tend to replace rigorous analysis with simple rules and to seek advice from others, thus resorting to norms and recommendations.
- Recognise that some people are more ready for change than others, so prioritise and target stakeholders based upon their motivational profile - spanning from a basic desire to an internalised commitment, considering values that people communicate as well as those which they act on. Be mindful of signals and body language that can indicate the level of commitment. At least in early stages, target the 'converted' and 'early adopters'.
- Be knowledgeable of individual differences in motivation. Identify, understand and relate to users' personal intrinsic and extrinsic values to capture those who identify with relevant mental models. Appeal to (a) hedonic goal frames (short-term, low effort), (b) gain goal frames (building resources) and (c) normative goal frames (doing it for 'the team').

Overcome knowledge and practical barriers. Boost the capabilities and other resources that users need to use your research, e.g. via a guideline, user manual etc. Adopters need to understand and feel comfortable that they have the capacity to adopt a new approach.

More specifically:

- Clarify the pathway of adoption in simple language including in relation to relative advantage, compatibility, simplicity, trialability, observability and sustainability.
- Promote benefits that do not emphasise sunk costs (costs that have already been incurred and cannot be recovered). Sunk costs can inhibit future choices if a person feels regret from not having benefitted from the original choice and rather than rationally comparing marginal costs and benefits, they may invest further resources to reinforce an initial decision.
- Present contextual cues to overcome the inertia of habits. Automatic responses to contextual cues are difficult to change, but can be shifted by changing the context, so that routinized behaviours are not triggered by relevant cues. This is sometimes conceptualised as 'unfreezing' undesired behaviour and then 'refreezing' with new cues when the desired behaviour is achieved.

Know and promote the costs and benefits (outcomes) of adopting your research. Outcomes are not only economic but span psychological and social ones such as a sense of empowerment, comfort, convenience or opportunity for socializing. Factor in potential impacts on the comfort, convenience, sense of empowerment and social interaction of others. More specifically:

- Associate the research with feel-good values - understand and promote not only the instrumental function of your research but the also the symbolic and emotional ones.
- Provide more immediate rewards – users respond better to immediate rewards than future ones.
- Nudge uptake through positive reinforcement and indirect suggestions
- Use positive message frames that also emphasise good social impacts and the potential losses of not adopting the research rather than the gains of doing so. Use imagery and other cues to evoke emotions.
- Generate a buzz around the innovation by providing normative messages, and distribute them via social networks, peers and trusted opinion leaders. People are often strongly influenced by the perceived views of close and trusted others.
- Model and demonstrate the benefits of your research, and ideally allow users to experientially trial and test it, thus allowing them to take ownership.

AUTHORS

Kashima, Yoshi; **O'Brien**, Léan; **Moglia**, Magnus; **McNeill**, Ilona and **Summerhayes**, Stephen.

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FURTHER INFORMATION

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SCHOOLS: TAKING THE LEAD IN OUR LOW CARBON TRANSITION

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **Many school buildings are old and inefficient**
- **There is no national benchmark for energy/water efficiency of school buildings and little guidance available for schools to increase their operational performance**
- **We are tracking how our community-led low carbon program is enabling 15 schools to maximise their operational efficiency and achieve carbon neutrality and, in turn:**
  - **Reduce utility bills and CO_2 emissions**
  - **Improve the health, comfort and wellbeing of students and teachers, which can translate to productivity and learning outcomes**
  - **Demonstrate community leadership, participation and learning**
  - **Support a transition to a low carbon future**

THE OPPORTUNITY

School buildings and facilities are part of Australia's ageing building stock, and are becoming increasingly inefficient. Endeavours to improve energy efficiency are hampered by the absence of a national performance benchmark, a lack of information of how schools can best reduce their emissions and increase their operational performance (which, in turn, provides healthier and more comfortable education and learning environments), and limited financial resources for funding low carbon initiatives.

Credit: Jean Paul Horre

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Nevertheless, studies have demonstrated the abundant carbon abatement opportunities that exist by retrofitting and upgrading the sector's ageing building stock. If the main barriers can be overcome, schools provide an unparalleled opportunity for energy efficiency and liveability gains, while simultaneously educating the next generation about sustainability and low carbon living.

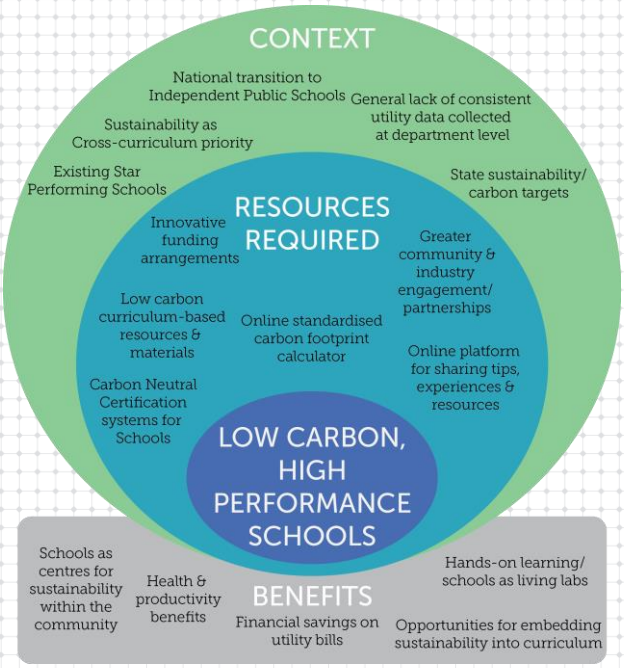
OUR RESEARCH

Our research has designed, and is tracking how a new Low Carbon Schools Program can help to reduce the operational carbon emissions from energy, water and waste in school buildings. The program also builds community awareness, increases knowledge, and provides motivation for similar initiatives to be implemented in the home. Fifteen schools were chosen to participate in the trial (10 primary and five secondary). The schools ranged in size from 80 students to 1400, though in 2016, the numbers increased significantly for several schools .

The program was developed through the following steps:

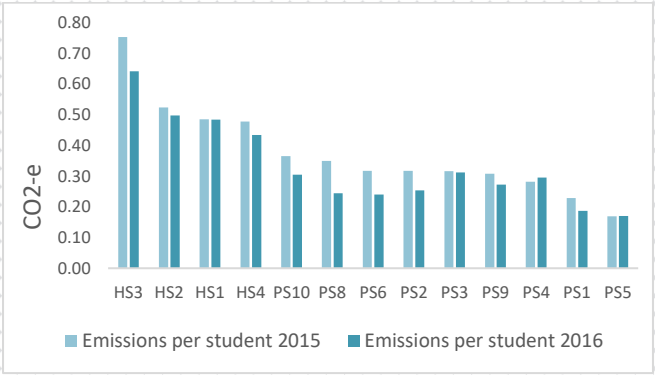
- Identification and mapping of existing sustainability and low carbon school programs across Australia
- Examination of the barriers and enablers for schools pursuing carbon reduction

- Development and testing of an innovative, data-driven, scalable low carbon schools program, using lessons learnt.



RESULTS

The total emissions generated by the 15 schools from a 2015 base year was approximately 3770tCO_2-e. Collectively, the 15 participating schools have identified over 592 low carbon actions. Approximately 219 of these have been implemented with the remaining 375 to be implemented in late 2017. While most schools have reduced their per capita emissions and costs against the baseline, greater reductions are expected by the end of 2017.



OUTCOMES

Our program has enabled schools to track their carbon emissions and costs, create realistic low carbon actions plans and a systematic approach to implementing them. Monthly 'meet-ups' allow participants to share experiences and break down barriers.

Various new community partnerships have been formed during the program, one of which has resulted in a tree planting program. Carbon footprint data collected by the program established the number of trees needed to offset the schools' total carbon emissions for 2015. Students, parents and school staff planted over 20,000 trees, which is enabling all 15 schools to become carbon neutral; an achievement beyond our expectations.

Credit: David Baylis

Our research and the development of our program has resulted in:

- Significant carbon reduction and financial savings on utilities
- Potential improvements in health, wellbeing and productivity
- Increased student learning opportunities around sustainability, climate change and low carbon living
- Community engagement creating the opportunity for intergenerational and societal change.

NEXT STEPS

A national pilot is being launched in 2018 (The ClimateClever Initiative), underpinned by new, innovative, data-driven online tools, and learning resources. These include:

- A national online carbon footprint calculator
- A building audit tool
- An interactive action plan and engagement platform
- A cost-benefit carbon calculator that provides simple return-on-investment calculations
- New curriculum-based resources (including lesson plans) tailored to the online tools and low carbon initiatives.

This program will provide abundant STEM opportunities and will assist schools in meeting the National Sustainability Cross Curricula Priority. Ultimately, the program can help schools and Education Departments exceed their low carbon goals and reduce costs. The National Pilot will be available to all schools. To register interest or join the national pilot, visit http://simplycarbon.com.au/.

PROJECT TEAM

Project Leader: Dr Vanessa Rauland - Curtin University
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REPORT

Rauland, V., Odell, P., Hall, S., Newman, P. and Lewis, A. 2014. **Low Carbon, High Performance Schools - Scoping Study**. CRCLCL

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OUR FREE ONLINE VOCATIONAL TRAINING AND EDUCATION IN CARBON REDUCTION

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **In collaboration with Sydney TAFE, we have developed a training series to provide knowledge and skills to support action on low carbon living**
- **The training comprises four standalone online modules available free here: https://lowcarbonliving.sydneytafe.edu.au/**
- **The training targets tradespeople, contractors and owners of small to medium sized businesses**
- **We pilot tested the training in project RP3010 which is reducing the carbon footprint of tourism industries - https://lowcarbonliving-bluemountains.com.au/**

THE OPPORTUNITY / CHALLENGE

Research demonstrates that education and training can support changes in behaviour. However, in relation to supporting tradespersons, contractors and small business owners develop low carbon behaviours and practices, there is a dearth of high quality and freely available vocational training.

To address this gap, we partnered with Sydney TAFE to produce a series of free online learning modules.

The objective of our project is to support businesses, tradespeople and consumers to both embrace low carbon living and work collaboratively to advocate and deploy low carbon solutions.

CRC for Low Carbon Living

We are a national research and innovation hub supported by the Commonwealth Government's Cooperative Research Centres programme that seeks to enable a globally competitive low carbon built environment sector.

With a focus on collaborative innovation, we bring together practitioners from industry and government with leading Australian researchers to develop new social, technological and policy tools for facilitating the development of low carbon products and services to reduce greenhouse gas emissions in the built environment. For more information visit www. lowcarbonlivingcrc.com.au/

OUR TRAINING AND EDUCATION IN CARBON REDUCTION

Our training comprises four modules:

1. Introduction

This module introduces the concepts and terminology around carbon, greenhouse gasses and global warming. It equips learners with the foundation knowledge and functional vocabulary.

2. Carbon accounting and the value chain

In this module, participants learn about the principles of carbon accounting. It explores the way carbon is measured and sets the foundation for practical applications in module 3. A Value Chain topic examines the classic business value chain to low carbon living.

3. Principles of carbon conversion

This module explores carbon conversion, a method used to estimate the amount of carbon produced using common industry units. In some countries, this method is also used to underpin carbon trading. Participants also learn how to calculate their own carbon output.

4. Low carbon living, and developing a business case for low carbon work

By completing this module, participants will be able to identify sustainable practices and materials, and demonstrate their cost-effectiveness. It will provide instruction on developing a coherent business case to present this information.

BENEFITS

The Low Carbon training and education program:

- is freely available
- is hosted on an intuitive and easy-to use website that maintains a record of progress
- provides a learning and qualification pathway
- Links to existing skill sets within recognised training packages:
  - EASCON401A Implement procedures for sustainability and reduce onsite carbon footprint
  - MSMENV672 Develop workplace policy and procedures for environmental sustainability
  - MSS015001A Measure and Report Carbon Footprint
  - MSS20312 Certificate II in Competitive Systems and Practices
  - MSMENV672 Develop workplace policy and procedures for environmental sustainability

HOW YOU CAN ENROL

Sign up for a free account here: https://lowcarbonliving.sydneytafe.edu.au/login/signup.php

Access the TAFE NSW Sydney - Low Carbon Living open learning material here: https://lowcarbonliving.sydneytafe.edu.au/

The TAFE NSW homepage has a range of courses that will teach you more about low carbon living - https://www.tafensw.edu.au/.

PROJECT TEAM

Rick Duynhoven, Assistance Faculty Director, Sydney TAFE

Dr. John Merson, Executive Director, Blue Mountains World Heritage Institute

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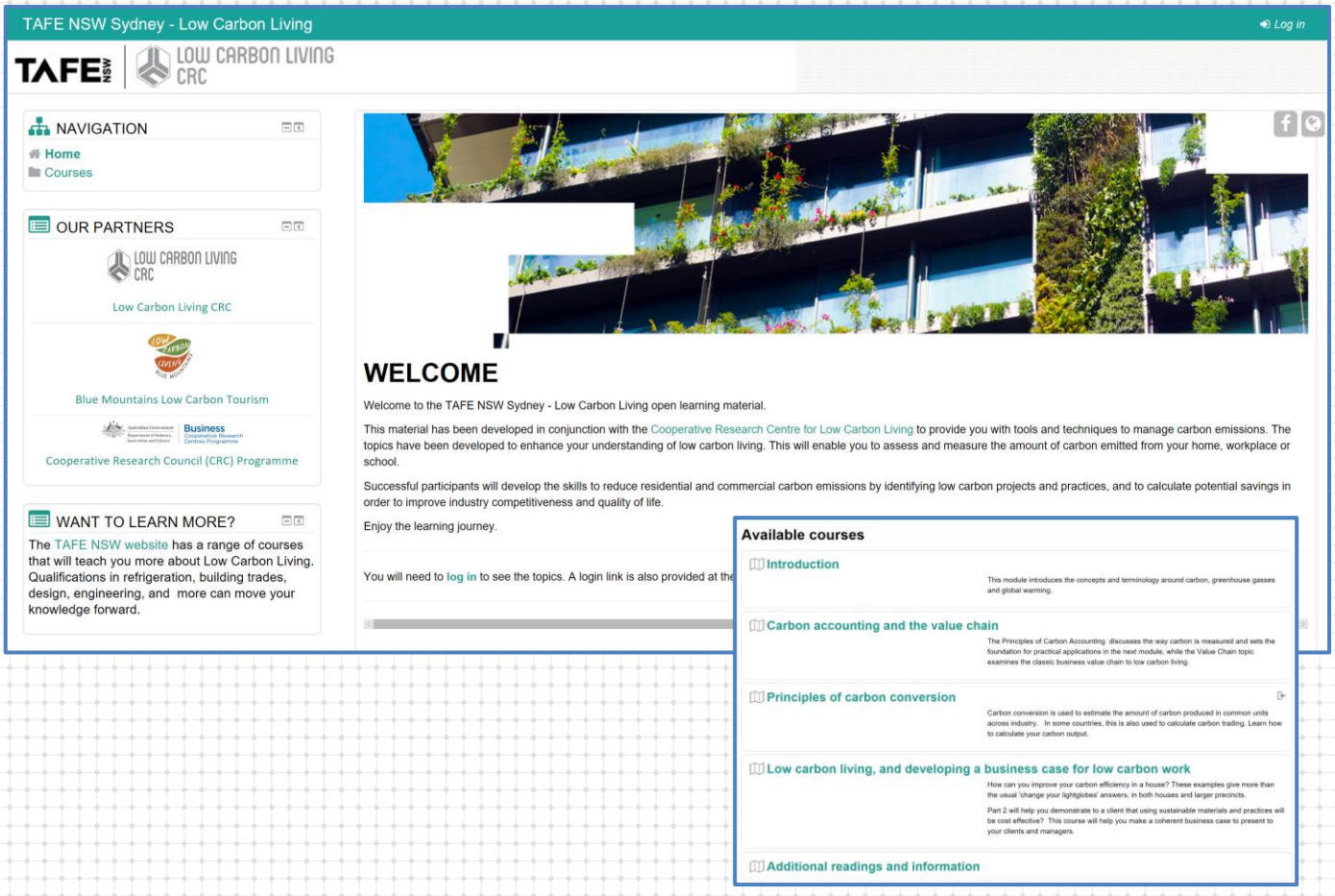

10 HOUSES AS LIVING LABS: UNDERSTANDING HOW PEOPLE AND PRACTICE AFFECT HOUSING PERFORMANCE

CASE STUDY

LOW CARBON LIVING CRC

KEY POINTS

- **We established 10 Western Australian houses, with above-standard energy and water efficiency, but varying in design and occupancy, as embedded living labs**
- **Over 2-years, sensors we installed recorded energy and water consumption, solar generation, and temperature**
- **We also established a behavioural change program to gather qualitative and further quantitative data**
- **We found that while high performance houses used less energy m², performance among them varied significantly because of differences in PV performance, peoples' practices and home maintenance**
- **Our project highlights the need for houses to be viewed as a system of practice; incorporating both occupants and their everyday practices**

CRC for Low Carbon Living

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With a focus on collaborative innovation, the CRCLCL brings together property, planning, engineering and policy organisations with leading Australian researchers. It develops new social, technological and policy tools for facilitating the development of low carbon products and services to reduce greenhouse gas emissions in the built environment. For more information visit www.lowcarbonlivingcrc.com.au/

THE OPPORTUNITY / CHALLENGE

Recent research has found that low-emission buildings do not meet their full potential and the main reason for this is related to occupancy. Within houses, occupants' practices, or behaviours, can affect energy and water use. This means housing performance cannot be addressed solely through improvements in technology.

Our project presented the opportunity to measure baseline energy and water use, then assess whether an introduced behavioural change program influenced occupants' practices and resource consumption, and ultimately housing performance.

RP3033

OUR RESEARCH

Over two years, we monitored 10 houses within the City of Fremantle and compared performance to estimated design predictions. We also carried out research to understand occupant practices and how they interact with technology, in order to develop a bespoke behavioural change program.

Our project, which supports the CRCLCL's Research Program 3: 'Engaged Communities', contributes qualitative and quantitative research to help understand why occupants behave the way they do and how communities can transition to low carbon lifestyles.

Our methodology:

- Incorporate a mix of houses with above-standard energy and water efficient technologies. Our living labs included high performance houses (rated as having 6 stars under the Nationwide House Energy Rating System (NatHERS)) and retrofitted older houses
- Install sensors in each house to monitor grid electricity, gas, water use and internal temperature. Where relevant,

stored rainwater use and solar PV electricity production was also monitored

- Collect data during the first year to determine a baseline of resource consumption, household temperature and occupant practices free from any intervention
- Enlist occupants at the beginning of year two in a behaviour change program consisting of audits as well as access to a feedback system
- Conduct longitudinal interviews with occupants
- Analyse data with a mix of quantitative and qualitative methods

OUTCOMES

Our project provides insight into the way housing occupants interact with technology, their practices and behaviours, and the effect this has on overall house performance, including energy and water use.

Project learnings will be incorporated in the White Gum Valley Living Lab project (RP3033) to inform technology and automation design that helps occupants reduce energy and water use.

Our project also found while high performance houses used less energy per m^2 than 6 star rated NatHERS houses, there was significant energy variation between houses with the same rating, because of differences in practice, as well as issues associated with the house's construction and maintenance, as well as placement and performance of PV systems[3].

LESSONS

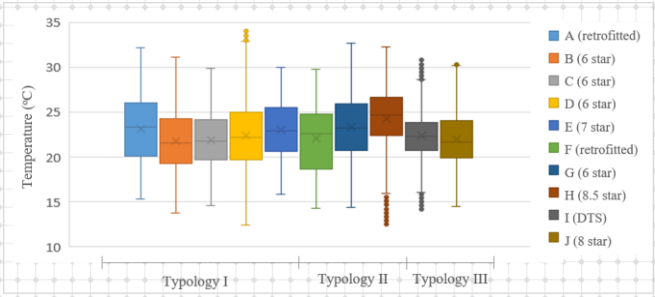
Our project highlights the need for houses to be viewed as a system of practice; incorporating both occupants and their everyday practices.

It shows how practices are influenced by skills, meaning and technology[1] and that these practices are often interlocked, or dependent on one another[2]. Skills refers to the knowledge of the practice and understanding of its implementation; technology denotes the physical elements that are involved in the execution of the practice, such as infrastructure and objects; and meaning is the reason for a practice to be undertaken.

For instance, showers taken to relax are usually longer than showers taken in the morning to get ready for the day ahead. Moreover, timing of showers is dependent on interlocked practices such as going to work. These practices, however, can realign when context changes.

This project has also demonstrated how lifestyle and comfort influence occupants' energy and water use. Early research shows occupants' habits, family structure, willingness to save money, environmental awareness, attitudes and presence of renewable energy all contribute to the frequency, timing and intensity of heating and cooling houses.

Fig. 2: Temperature distribution in the 10 living labs in 2015



NEXT STEPS

Further work needs to be done to ascertain how automation can be implemented to make houses more energy and water efficient, while ensuring that occupant needs are still being met.

This living lab is now part of a review by Professor Greg Morrison, Curtin University, to identify business models and commercialisation best practices for living laboratories globally.

PROJECT TEAM

PhD candidate Christine Eon, Curtin University
Dr Josh Byrne, Curtin University

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1. McMeekin, A., Southerton, D. 2012. Sustainability transitions and final consumption: practices and socio-technical systems. Technology Analysis & Strategic Management. 24, 345-361
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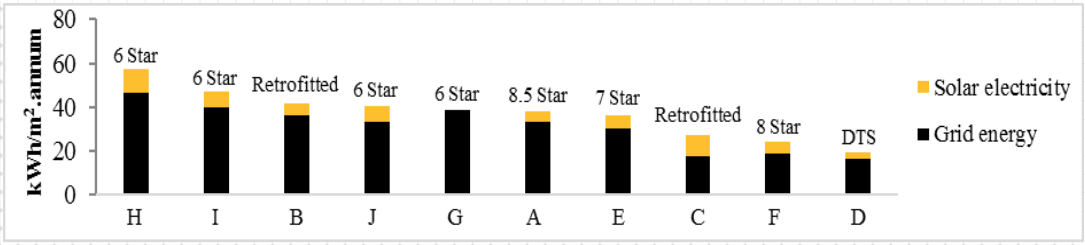
3. Eon, C., Murphy, L., Byrne, J., Anda, M. 2017. Verification of an emerging LCA design tool through real life performance monitoring. World Renewable Energy Congress XVI, 5-9 February 2017, Murdoch University, Western Australia

Figure 1: Total energy use m^2 in the 10 living labs in 2015



USING AGENT BASED MODELLING TO IDENTIFY EFFECTIVE WATER CONSERVATION POLICIES

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **Water companies require tools to help them evaluate the likely success of proposed water conservation efforts.**
- **Agent-Based Modelling (ABM) provides an opportunity to use state of the art behavioural science to model the outcomes of a range of potential policy initiatives.**
- **We are developing an ABM to help understand how water-users make decisions around water conservation. This will improve the ability to develop and target programs, and help inform investment decisions.**

THE OPPORTUNITY / CHALLENGE

Customer behaviour and the development and adoption of water efficient appliances are the two biggest uncertainties in estimating the future long-term demand for water.

Community members consistently highlight that they value investment in cost-effective water conservation programs. Understanding how we can promote the adoption of water efficient behaviours and technologies will help water companies invest in economical programs that customers want and respond to.

OUR RESEARCH

We are developing and piloting an ABM approach to better understand the decisions made by community members when they are presented with a range of water conservation products and services, or are selecting water using appliances and fixtures such as washing machines and taps.

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Our ABM aims to predict the actions of different segments of the community when interacting with each other and things around them. The model will explore the future uptake of water efficient technologies and water using behaviours in customers' homes and businesses. It will capture the decisions that customers make, as well as understanding how and why they make them.

The output of our model will provide holistic evidence to water companies to support their delivery of water conservation initiatives. This, in turn, can increase urban resilience to water supply shortages, improve planning capabilities, reduce greenhouse gas emissions, and reduce the cost of water supply.

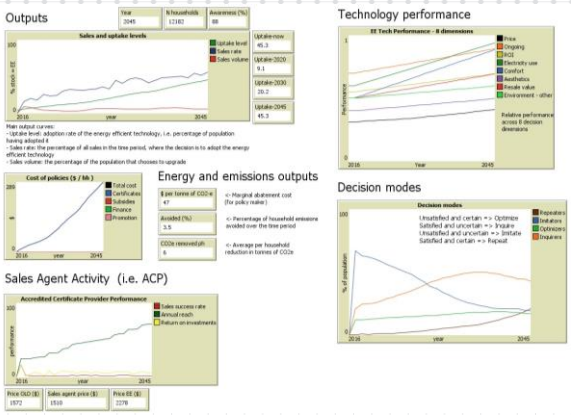

Figure 1: Elements of our ABM

RESEARCH QUESTIONS

We will address the following research questions:

- What influences consumer behaviour in changing patterns of water usage under a range of scenarios?
- What incentives motivate early adopters to implement new technology solutions?
- How can uptake be accelerated using non-financial interventions?
- What is the influence of drought conditions and awareness on customer behaviour?
- What groups will make changes that lead to the desired water savings?
- What are the links between water use and energy consumption
- How can water conservation programs lead to energy and carbon reductions?

INTERVENTIONS EXPLORED

We will develop our model using two of Sydney Water's water conservation programs:

WaterFix

The residential WaterFix program allows customers to choose the type of plumbing service they need to improve water efficiency in the home, providing customers with a choice of services to suit their needs. This service includes replacing showerheads, toilets and taps, and repairing leaks by a qualified plumber.

The program has been successful since its inception in 1999, and will provide a significant amount of data on customer preferences and decision-making for our ABM.

Rainwater tank service and maintenance

This project aims to increase the use of existing rainwater tanks by providing repair and maintenance services for customers.

Residential rainwater tanks provide an opportunity to reduce the demand for drinking water on a day-to-day basis. Water from rainwater tanks can be used to water gardens, flush toilets and do clothes washing. However, Sydney Water research has found that many tanks perform below expectations in terms of energy efficiency and in their ability to reliably provide water.

OUTCOMES

Our model seeks to embed into business processes a holistic, customer-driven approach to the evaluation of water conservation programs. It will have utility in relation to the design and development of programs (Figure 2) to funding and acknowledging broader community benefits. It will support the following functions:

- Develop and design of new water conservation related products and services.
- Assess potential opportunities to revisit old and existing programs.
- Provide evidence to support a more holistic evaluation of water conservation programs
- Inform the estimation of the future water demand

By assisting water organisations understand how customers may respond to stimuli that could change their water using behaviour, we expect that our research will contribute to:

- Proactive management of future water demands by embedding water conservation in day-to-day business
- Increased resilience to droughts and other supply shortages through water conservation
- Combatting ineffective spending on water conservation projects for crisis management
- Improving long-term demand forecasting
- Avoiding expenditure on additional supply options through the management of peak and average demands.

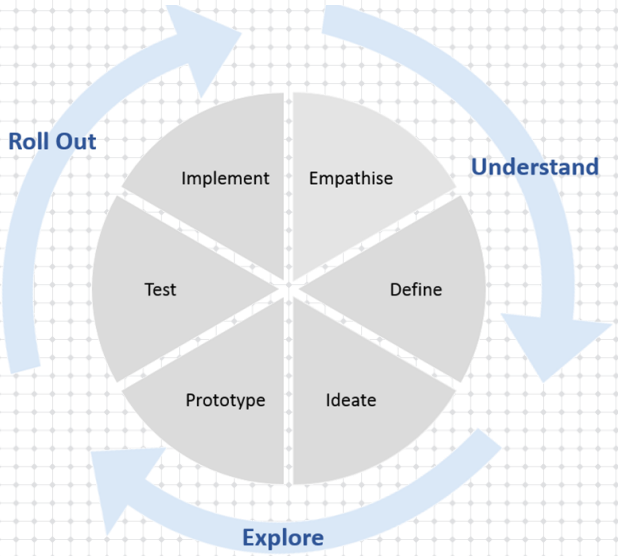

Figure 2: Development and design process

TIMELINE

The pilot project was initiated in 2017 will be completed in 2018.

PROJECT TEAM

This is a collaborative project between CSIRO and Sydney Water as part of the Low Carbon Living Cooperative Research Council (CRC), which builds on world-leading research in the energy efficiency sector.

Project leader: Magnus Moglia, CSIRO Land and Water

Team: Stephen Cook and Sorada Tapsuwan (CSIRO), Marcia Dawson, Jonathan Dixon, Bronwyn Cameron, Andre Boerema (Sydney Water).

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ADDRESSING AUSTRALIA'S WORSENING ENERGY DEPRIVATION

POLICY NOTE

LOW CARBON LIVING CRC

SUMMARY

- **Broad engagement with lower income households, industry, government and other stakeholders reveals that energy deprivation is an increasing problem in Australia which impacts upon the social wellbeing of communities.**
- **There are a wide range of financial and non-financial barriers limiting the ability of lower income households to address energy deprivation.**
- **The government's approach to energy and support mechanisms varies from state to state and nationally, further exacerbating the problem.**
- **We present a range of policy recommendations across three categories, namely information provision, financial assistance, and regulatory controls.**

CRC for Low Carbon Living

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THE PROBLEM

Household energy prices have risen and are expected to increase significantly in the coming years, creating more widespread energy deprivation (flow-on impacts of inadequate access to energy) across Australia.

Energy deprivation can have wide ranging impacts, including on mental health (e.g. due to social isolation), physical health (e.g. through malnutrition), and decreases in future opportunities (e.g. impacts on schooling).

> "I mainly skip meals. I've gone 4 days without eating because I've had a bill I've got to pay." (Older, single interviewee, TAS).

These impacts are experienced by lower-income households (viz our research on lower income barriers to low carbon living).

While escalating energy costs are a significant contributor to energy deprivation, especially when costs rise much faster than income (Figure 1), impacts are exacerbated by stringent conditions for financial assistance, difficulty accessing information, the low quality of many lower-cost homes, and the reluctance of landlords to implement energy performance upgrades to rental homes.

There has been little research on energy deprivation in Australia and in other western societies.

Our research shows that the negative impacts of energy deprivation remain, affirming previous Australian research on energy deprivation (Chester & Morris 2012).

Australia's energy future is a topic of national interest, highlighted by the 2017 Federal Government inquiry into modernising Australia's electricity grid.

EXISTING POLICY

Carbon reduction policies have been in place in Australia since the mid-1980s. The direction of these policies has generally followed international initiatives (such as through the UN Framework Convention on Climate Change and its subsequent Kyoto Protocol and the Paris Agreement).

These policies, however, typically work on short cycles despite broad acknowledgement that outcomes may not be immediate but longer term.

Concurrently, all states and territories set their own carbon reduction and energy policies. While generally working in conjunction with those set at the federal level, these state/territory-level policies have had a stop-start history. As a result, most industry and non-government organisations have only been able to provide assistance and support on a relatively short-term basis.

> Energy deprivation encompasses a range of concepts that lead to inadequate access to energy including energy poverty, energy justice and energy vulnerability.

POLICY OPTIONS & IMPLICATIONS – ANALYSIS & EVALUATION

Energy deprivation is relevant to multiple ministry portfolios, as well as to industry and the non-government sector because it can have significant and long-term impacts on social wellbeing, particularly for vulnerable groups like those on lower incomes. Importantly, energy deprivation can potentially compromise Australia's future productivity.

> "A pay-on-time discount is useless, mostly because they're not going to have the money, you know, to pay up front, direct debit. No one's got the money to do that if you're in that spot." (Energy advocate).

While the Clean Energy Target can help ensure a low carbon and sustainable future for Australian energy generation, the coal industry continues to receive significantly more direct and indirect government subsidies than the renewable sector (IMF 2015). This has not only resulted in a significantly lower proportion of Australian electricity being generated from renewable sources than from coal, but also in higher retail prices (Clean Energy Council 2017; GreenPower n.d.).

This is further complicated by the number of states and territories with different policies and regulations to the Federal Government. There is also a lack of competition and consumer choice in some states and territories due to the varying extent of energy sector privatisation.

There are measures in place to assist lower-income households in meeting their energy bills, including the energy supplement available via the Department of Human Services, and energy retailer hardship programs such as payment plans. However, according to our study participants these have had little effect on countering the sharp rises in energy costs and do little to encourage consumers to switch to renewable energy.

> Lower income households are those within the lowest 20 per cent of income earners in their state or territory's capital city.

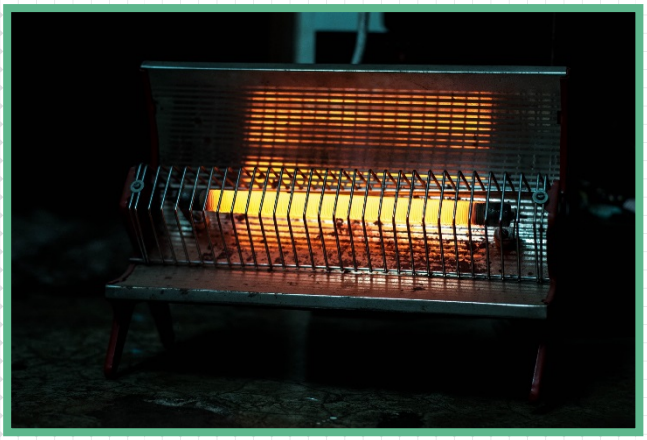
Our research reveals that as more upper- and middle-income households generate solar power on their roofs, those who cannot afford or have the right to do so will be burdened with a larger share of infrastructure upkeep costs. This issue has been recognised overseas, but it is also a concern for vulnerable groups like lower-income households here in Australia (Ebert 2016).

OUR RESEARCH

Our project, undertaken as part of the CRC for Low Carbon Living between October 2015 and September 2016, interviewed 164 lower income households and 18 stakeholders (including service providers, advocates and charities) to understand the barriers faced in transitioning to low carbon living. Vulnerable households were categorised across the typology identified in a previous CRCLCL study (Burke & Ralston 2015): young singles, single-parent families, large families, and older singles/couples.

The interviews were underpinned by a detailed review of state, national and international literature. Research methods included focus group interviews, one-on-one interviews and workshops.

We workshopped potential solutions with 33 policymakers and service providers across four states and territories (New South Wales, South Australia, Tasmania, and the Northern Territory) that represented four different climatic zones in Australia and both metropolitan and regional settings.



Lower-income households reported long delays in receiving energy efficiency advice and of being notified of assistance programs (and often only as they were being wound up). When available, this information is mostly provided online, and our study participants noted that they often did not know how or what to search for, and many could not afford home computers and internet connection. This highlights the lack of accessible information and reflects international evidence (Brunner et al. 2012) that lower-income households may not have the resources to implement change without assistance.

> "I don't have internet hooked up at my place […] I can't afford it. It's a luxury." (Young, single interviewee, NSW).

An extra layer of difficulty for lower-income households is that many (76 per cent) live in rental properties that are often poorly insulated and furnished with inefficient appliances that they were not allowed or could not afford to replace.

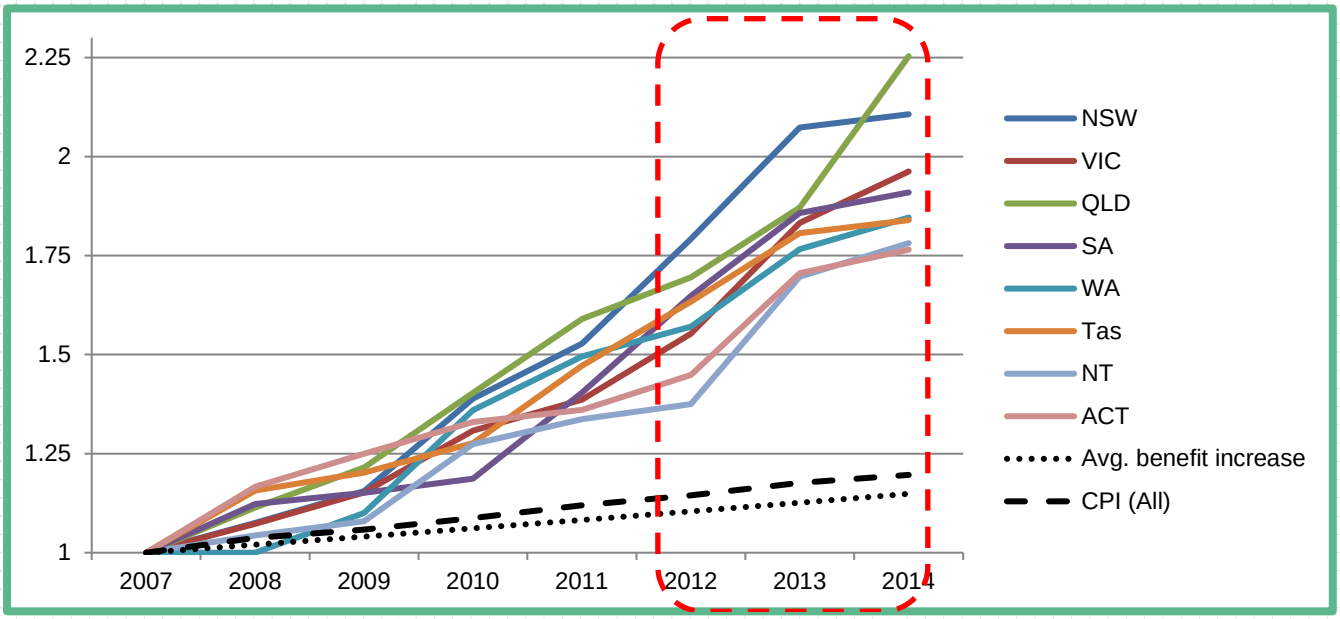
> "The landlord wasn't interested in insulation. We offered to put solar panels on but he wouldn't hear of it, and he wasn't interested in insulating the ceilings which is a pity." (Older couple in private rental, TAS)

Renters are also precluded from accessing incentive and subsidy programs such as solar rebates.

Landlords, particularly private investor landlords, are reluctant to introduce upgrades because they would not be receiving any immediate benefits. This is referred to as split incentives.

Our findings represent a cross-section of Australian conditions and policy settings. Our policy recommendations are synthesised to take into account these geographic and policy differences.

Figure 1: Increases in electricity retail prices across Australian states/territories since 2007 compared to the consumer price index and average benefit increases



Source: ABS (2016). *Consumer price index, Australia, Jun 2016*, Cat. No. 6401.0. Canberra: Australian Bureau of Statistics. Chester, L. (2015). "The privatisation of Australian electricity: Claims, myths and facts." *The Economic and Labour Relations Review* 26(2): 218-240.

POLICY RECOMMENDATIONS

Energy deprivation is becoming a critical issue worldwide.

Quantitative measures like fuel poverty are being called into question in favour of those that emphasise more nuanced, real-life impacts such as energy deprivation (Bouzarovski & Petrova 2015; Pachauri & Spreng 2011).

There is no single panacea to addressing energy deprivation, but rather a number of policy initiatives could improve the situation in Australia (see overleaf):

THE PROBLEM	RECOMMENDATIONS
FINANCIAL ASSISTANCE	
Overcoming split incentives An increasing number and proportion of Australians are living in rental accommodation for the long haul (Stone et al. 2013; Wood et al. 2013).	Federal level Higher tax incentives within negative gearing for landlords who improve the energy efficiency of their investments. State/territory level Changes to tenancy legislation to give tenants greater rights to modify their rented homes. This would also encourage greater take up of assistance programs such as solar rebates.
Ensuring sustained funding to deliver longer term outcomes Many assistance programs aimed specifically at helping lower-income households with energy efficiency and low carbon living have come and gone in Australia. Often, these were pilot studies that were not further funded, despite positive outcomes.	Nationwide Long-term assistance programs to ensure outcomes and embed the success of early efforts.
INFORMATION PROVISION	
Educate via the right channels Online information may have a wider reach generally, but it is not a practical platform for many lower-income households with budgetary or skill limitations.	Nationwide Provide simple, eye-catching energy efficiency information in a multitude of formats and access points to ensure that it reaches low income households. Some jurisdictions are already taking this approach, but for the most part distribution and promotion of information is still limited.
Getting the message across simply There are regulations governing the type of information (including details about support programs) energy retailers must provide to customers on their energy bills. However, this information is often rather technical and difficult to understand. With no standard presentation of information, customers switching energy retailers have difficulty finding comparable information. There is industry resistance to standardising the presentation of billing information.	Nationwide Simple presentation of bill information to increase consumer knowledge of their energy consumption and efficiency levels. Widespread adoption of infographic-based information (Figure 2) that can be easily understood by people of different language proficiencies and capacity levels.
REGULATORY CONTROLS	
Higher retail prices of renewable energy as a strong deterrent The higher retail prices of 'green' energy is a significant deterrent for lower income households (none of our study participants purchase renewable energy).	Federal level Increase the proportion of renewable energy generation. Reduce direct and indirect subsidies to the coal industry. International examples, such as in in Germany, Namibia and Turkey, show how adjustment packages can be successfully implemented (Sovacool & Dworkin 2014: 286-7). These not only redirect subsidies from non-renewables to renewables, but also provide '"targeted cash transfers" to vulnerable groups' and retraining opportunities.
Improving the thermal efficiency of homes at the lower end of the market Improved thermal efficiency can drastically increase the comfort and reduce the energy spending of lower-income households. Evidence from the UK (Evans et al. 2000) shows that low quality housing in the UK costs ~£2 billion annually in medical expenditure. All European Union states have had mandatory energy performance disclosure since 2010 (EU 2010). The UK (Pinsent Masons 2015) and New Zealand (Cabinet Social Policy Committee n.d.) have both recently introduced regulations that set minimum standards (including for insulation) for rental properties.	State/territory level Extend minimal energy efficiency standards for new builds (NatHERS, or BASIX in NSW; Heffernan et al. 2017) to existing homes, which are far greater in number than new builds. This is especially important for rented homes, which often have poorer efficiency levels than owner-occupied ones (see above) due to split incentives. Amend residential tenancy legislation to give tenants greater power to modify rented homes for energy efficiency.

With sharp rises in energy costs and sluggish income growth projected, it is very likely that the incidence of energy deprivation will continue to increase. Energy deprivation cannot be addressed overnight, but it is possible to track the impact of policy and industry changes over the short, medium and longer term:

Shorter term: Distribution and up-take of information; increase in purchase of renewable energy; decreased demand on charity assistance.

Medium and longer term: Improved self-reported health (including mental health); landlord uptake of incentivised upgrades and improvements.

FURTHER INFORMATION

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ACKNOWLEDGEMENT & DISCLOSURE STATEMENT

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We do not work for, consult, own shares in or receive funding from any company or organisation that would benefit from this policy brief. They have no relevant affiliations beyond their academic appointments.

PROJECT PARTNERS

- The Salvation Army
- NSW Office of Environment and Heritage
- Council of the Ageing

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Figure 2: Example of an energy-saving visual guide

Source: SA Government 2015

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LIVING LABS OPEN INNOVATION NETWORK: INTEGRATION AND PRODUCTS

Factsheet

KEY POINTS

- **Our suite of research projects across three programs includes 17 Living Labs**
- **We have organised the Living Labs into a typology so users can understand where knowledge can be sourced and its different uses**
- **We are now creating an integrated open innovation network of our 17 Living Labs to provide further opportunities for entrepreneurs, innovators and policy makers to learn and experiment**
- **We will also develop a toolbox to allow users to access key findings across the network**
- **Further details on each individual Living Lab can be found in the lab specific factsheets**

THE OPPORTUNITY

The diverse set of 17 Living Labs we have established offers and opportunity to unite them into an integrated open innovation network which provide a range of tools and products for innovation in cities which are greater than the sum of the individual elements.

THE TYPOLOGY

A Living Lab brings together business, society and researchers to demonstrate, prototype and mainstream high-performance products and services for low carbon living in our cities and regions. The integration of our Living Labs will fill the knowledge-utilisation gap, providing leading technology in a form ready for uptake.

Our Living Labs have been established to address one or more of the following challenges:

- the complexity of socio-technical change,
- how to engage with society at large
- the provision of place and space for experimentation

CRC for Low Carbon Living

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They can also be organised into the following typology (Table 1):

1. Purpose built Living Lab which provides a place for co-creation and prototyping
2. Embedded Living Lab which provides insight from real-life environments
3. Urban Living Lab which is a place and space to providing scale up (new innovation) and scale out (replication)
4. Community based Living Lab which is a space for sharing knowledge and innovation

Living Lab typology	Project code	Project name	Location
Purpose	RP1010	CRC House Factory Future Illawarra Flame SBRC	Sydney Melbourne Wollongong Wollongong
Embedded	RP3009 RP3009	Josh's House 10 House Labs	Perth Perth
Urban	RP2018 RP3017 RP3017 RP3017 RP3033 RP3043	Broadway Bowden Greater Curtin Lochiel Park Swinburne Tonsley White Gum Valley Beyond WGV	Sydney Adelaide Perth Adelaide Melbourne Adelaide Perth Perth
Community	RP3020 RP3011 RP3010	Schools Yarra Livewell Blue Mountains	Perth Melbourne Sydney

TOOLBOX

Our open innovation network will provide a range of practical tools that can be developed on request and that are based on the knowledge generated. These include:

- Measurement technologies and the interpretation of data generated through Living LabsMixed (qualitative and quantitative) methods to assess the importance of the interaction between humans and technology
- Rating schemes, predictive analytics and a low carbon readiness index
- Systems of practice for the home and assessing the relevance of achieving low carbon through automation
- Approaches to community engagement
- Demonstration of new technologies
- Business model for economic sustainability of Living Labs

NEXT STEPS

The open innovation network will create a legacy project that provides a series of dynamic environments offering products and services for business and society. If you wish to be involved in this process then we welcome your expression of interest.

PROJECT TEAM

Christine Eon, Curtin University
Saskia Pickles, Curtin University
Professor Greg Morrison, Curtin University

FURTHER INFORMATION

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Eon, C. and Morrison, G.M. 2017. A systematic literature review to identify best practice business models for Living Labs. Technology Innovation Management Review (submitted manuscript)

THE BUILT ENVIRONMENT: A TOOL & FRAMEWORK FOR CREATING ECONOMIC, SOCIAL & ENVIRONMENTAL VALUE

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **We have developed a new way for built environment practitioners to strategically consider and prioritise the environmental, social and economic issues most relevant to a project and its location.**
- **The process increases long term value and reduces risks by viewing and aligning projects more directly with a range of potential benefits through a rigorous and strategic lens.**
- **Our framework underpins an intuitive decision support tool that links strategic decision making with implementation and performance management, enabling progress to be measured against a range of existing industry indicators such as Green Star.**

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THE RESEARCH OPPORTUNITY

We live, work and learn in buildings, spending ~80% of our time in them, so it's no secret that initiatives in the built environment sector have the potential to deliver significant value for the environment, our society and the economy.

Unfortunately, when it comes to built environment projects, there is often a missing link between corporate strategy and sustainability opportunities and risks, lessening the potential to create social, economic and environmental value. The segmented nature of the built environment sector can create a breakdown in communication along a project's lifecycle, and cost, delivery time and other pressures can erode long term value creation.

The built environment industry faces issues such as climate change, natural resource preservation, personal wellbeing, community connectedness and economic prosperity, all requiring attention in order to maximise organisational outcomes. In addition, stakeholder expectations are shifting. Increasing disclosure requirements, greater public awareness and scrutiny, and the uptake of international frameworks such as the United Nations Sustainable Development Goals, are catalysing conversations about how stakeholders should respond appropriately to sustainability issues and the way in which value can be created for a wider array of beneficiaries.

What's needed is a rigorous and reliable decision support tool that can help people working in the built environment sector to identify, align, prioritise, magnify, measure and communicate the economic, social and environmental value of building initiatives.

WHAT WE DID

1. Understanding and measuring value

We first undertook a comprehensive desktop review of global practice and rating tools.

2. Value capture

Guided and informed by a diverse stakeholder advisory committee and interviews with industry experts, we developed and pilot tested a Built Environment Impact Framework.

3. Value creation

Taking the Framework as a foundation, we developed a Built Environment Impact Guidance Tool for professionals to identify,

understand and prioritise the issues that matter most for their specific project.

THE FRAMEWORK

Members of the built environment industry are expected to have a vision and a legacy for the buildings, precincts and cities they build and we have created a framework to help them conceptualise, prioritise, articulate and build great places.

Our Framework encourages and supports strategic conversations about impacts – both positive and negative – of the built environment, and how projects can help deliver benefits across economic, environmental and social dimensions and to a broader range of stakeholders.

5 THEMES & IMPACT STATEMENTS:
Identify the impact themes within which the project has the greatest opportunities to help or hinder

18 ISSUES:
Prioritise the issues and opportunities. within each theme, that the project is best placed to impact (i.e. the change it seeks to create)

38 GOALS:
Identify and select goals for the project to focus on under each prioritised issue

54 INDICATORS:
Identify and measure progress against indicators that align with existing reporting and measurement frameworks in the industry

THE IMPACT TOOL

We have designed the Built Environment Impact Guidance Tool to help project teams navigate the content of the Framework and to establish a strategic conversation about economic, social and environmental outcomes in the context of a specific project (e.g. master planning of a precinct or a development bid proposal).

The Tool provides a practical process for a team, to develop a vision for a building project, prioritise the thematic areas and issues that are most material to its stakeholders, and identify tangible goals and indicators to embed their vision into the project's design, implementation, monitoring and reporting.

The Tool complements existing building rating tools such as Green Star. It is a process-based and qualitative decision support tool that helps identify broader value opportunities of built environment projects, helping link vision and strategy to prioritisation and action.

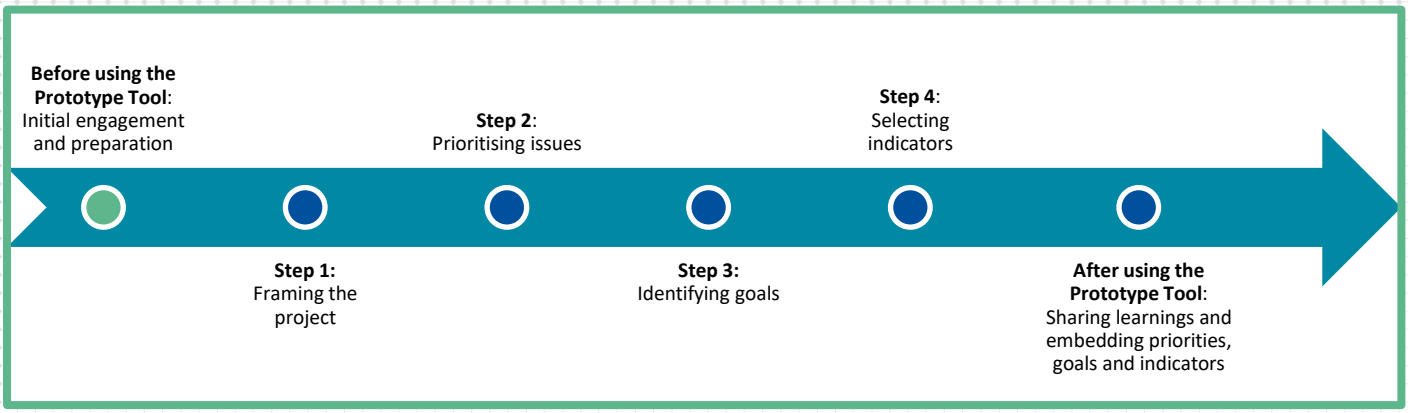
The Tool Is intuitive, open source, scalable (from single building to regions) adaptable and readily integrates with existing decision-support systems.

Our tool will help you:

- Leverage the unprecedented opportunity for the built environment sector to address social and environmental issues through a robust, evidenced based, prioritisation process.
- Align the priorities of key stakeholders, improve communication and clarity around decision making and actualise under-realised value creation.
- Clearly articulate project goals and measure progress against indicators

READY TO INTEGRATE

The use of the Tool is a process to be owned by a project team and implemented for a particular project, site or development in mind, ideally at the earliest possible stage with key stakeholders. Completing the Tool involves four key steps outlined below which enable a project team to explore the project's sustainability impacts more thoroughly and prioritise issues that have the greatest opportunity for impact.



CALL US FOR A TRIAL

Built environment professionals and project teams can trial and tailor our Tool to start maximising and better communicating value in their projects.

To access the Tool, please contact us:

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LOW CARBON BUILT ENVIRONMENT KNOWLEDGE HUB: ACCESSIBLE, CONCISE, AUTHORITATIVE EVIDENCE

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **Our project is developing a knowledge hub solution to connect and make accessible, for policy makers and industry practitioners, the wealth of scattered and highly varied low carbon built environment research**
- **This solution will:**
  - **narrow the gap between research, policy and practice by facilitating the translation and synthesis of built environment evidence**
  - **present the wide variety of evidence types and formats in an easily accessible way**
  - **include an open access website offering collated content, the ability to contribute research and to connect with people in your specialist field**

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THE OPPORTUNITY / CHALLENGE

In the built environment, policy makers and practitioners are challenged in finding, using and providing evidence to support their decision-making processes. All are looking for assistance to help them identify information faster, from trusted sources, and in a format that is readily understood.

Our project addresses these opportunities by collecting the latest evidence in low carbon living and offering that information via an easy to use online service. Our curation of this collection will improve evidence discoverability and our synthesis and translation will improve accessibility. We will also support those involved in research, or interested in research outcomes, to collaborate to draw upon existing and build new evidence.

OUR RESEARCH

The first stage of our project was to investigate the diverse needs of built environment stakeholders and to understand what evidence is currently used in both policy and industry decision making, how it is identified and applied, and what knowledge exchange solutions are required.

Our research included three workshops, a survey completed by 47 respondents across all sectors, and 21 interviews with key stakeholders. This identified the following current behaviour in evidence-based decision-making:

- Policy makers look for authoritative evidence to support policy proposals
- Policy makers want this information often on short notice and in easily digestible formats
- Industry practitioners look for supporting evidence of their decisions
- Industry practitioners want evidence to be easily found
- Researchers look to show the impact of their research
- Researchers have trouble in finding funding for further research while industry and government people have difficulty in finding researchers to conduct research

These research outcomes informed our online solution.

OUTCOMES

Our project is developing a new, online knowledge hub that enables policy and practitioners to easily access the latest evidence for achieving a low carbon living built environment. This solution will deliver value through improved:

- discoverability – through better metadata collection on quality research
- accessibility – through translation of quality research
- visibility of good practice – through review of quality research

We will do so through four key services:

1. collecting, curating and synthesising the latest in research
2. promoting the use of these outputs
3. facilitating the translation of these research outputs for improved accessibility
4. connecting people and evidence that in turn leads to the creation of new evidence through further research projects

The project will also establish the ongoing business model to ensure durability of these services.

VALUE PROPOSITION

Our research forms a solid base for dissemination of research evidence to policy and practitioners, promoting the activities of the CRC for Low Carbon Living and supporting future research collaboration activities in the built environment.

Our overall solution aims to:

- improve transparency of the source of evidence
- assist in filtering the evidence required
- identify further research opportunities.

PROJECT TEAM

Prof Peter Graham, Amanda Lawrence, Michelle Zwagerman

The team brings expertise and experience in collating and disseminating information about the built environment. Peter Graham is Deputy Director of the Centre for Urban Transitions at Swinburne University of Technology, CRC-LCL Node Leader and Executive Director of the Global Buildings Performance Network (http://www.gbpn.org). He has more than 15 years' experience in international advocacy, research and education in sustainable building design, construction, evaluation and policy.

Amanda Lawrence has extensive knowledge in the library and information sector. Amanda is the Research and Strategy Manager at Analysis & Policy Observatory.

Michelle Zwagerman has extensive experience in project and product delivery.

The project is supported by the members of the Steering Committee.

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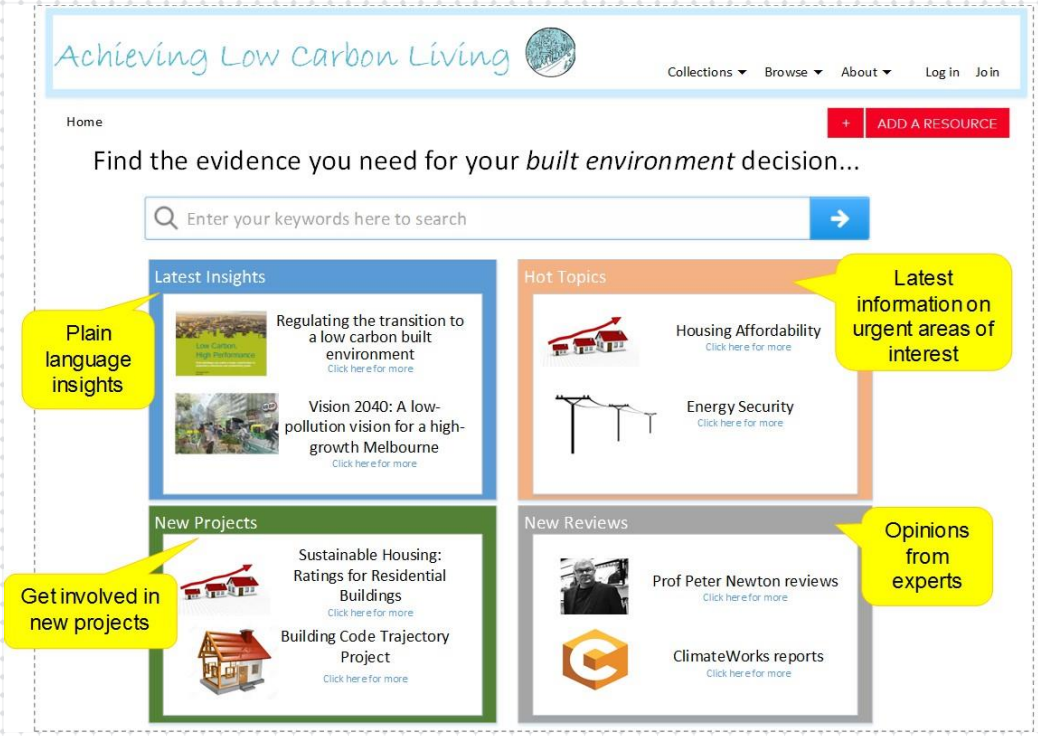

EVIDENCE-BASED PRACTICE AND POLICY: A SYSTEMATIC REVIEW PROCESS FOR THE BUILT ENVIRONMENT

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **Our project will systematically explore the wealth of scattered and highly varied evidence that exists in relation to low carbon built environment research.**
- **We aim to narrow the gap between research, policy and practice by developing a bespoke approach to synthesising built environment evidence.**
- **We will draw upon best practice systematic review processes used by other scientific disciplines.**
- **Practical outputs include protocols, procedural tools and guidelines tested across two case study/demonstration projects.**

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THE OPPORTUNITY / CHALLENGE

In the built environment, gaps between research and practice and between research and policy hinder our transition to a low carbon future. Research is often dispersed, complex, trialled in a small number of experiments or 'living labs', and difficult to access. This makes it hard for policy- and decision-makers to know what research is available and how reliable it is.

A systematic review process is required to provide a comprehensive, objective and accurate assessment of the body of evidence on a defined issue. However, the nature of research in the built environment means that standard synthesis tools, which were primarily developed in medical and social sciences, have limited application. Thus, these tools need to be modified and adapted.

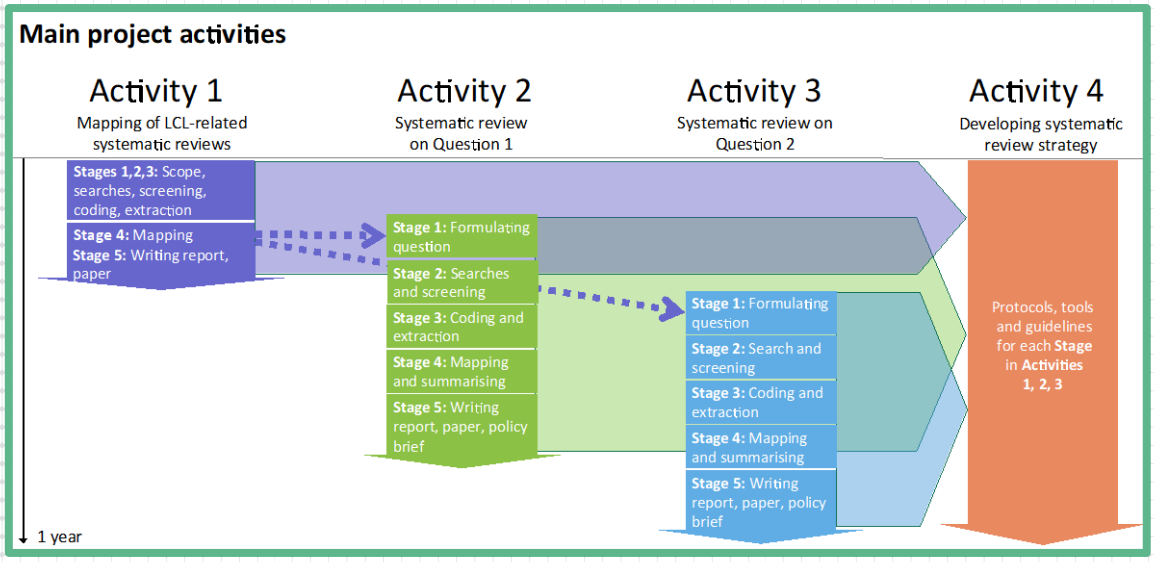
Our project will address this opportunity by developing a context specific platform for evidence synthesis in the built environment.

OUR RESEARCH

We will develop an evidence synthesis methodology with supporting resources, including protocols and guidelines, which have been demonstrated, trialled and tested in relation to two topic areas.

Our project, which supports and builds the CRCLCL's Knowledge Hub (SP0008), will facilitate the creation, dissemination and access to low carbon living research through a number of integrated activities (see figures on the next page):

- Mapping existing systematic evidence reviews related to low carbon in the built environment
- Developing study and review protocols
- Performing a systematic search of bibliographic databases and grey literature
- Defining transparent study selection criteria
- Classifying studies, extracting and coding data
- Visually summarising the data via systematic evidence maps
- Translating findings into policy briefs for the two topic areas
- Identifying possible future meta-analyses (quantitative evidence summaries)



OUTCOMES

Guided by an expert steering committee, the project will develop a new, systematic, robust, transparent and comprehensive approach to mapping, assessment and communication of low carbon research in the built environment sector.

We will assess the quality of existing research syntheses and present results visually to identify priority areas for synthesis. This systematic map of evidence synthesis will aid identification of suitable questions for case studies and future research. The whole process will be documented in detail and serve as the basis for creating guidelines and tools suitable for the built environment.

VALUE PROPOSITION OF OUR RESEARCH

Our research will form a solid base for establishing a practice and culture of performing rigorous research syntheses, complementing the activities of the CRCLCL Knowledge Hub and extending its influence. The project also has the potential to foster future collaboration among researchers for improved evidence synthesis in the built environment.

PROJECT TEAM

A/Prof Shinichi Nakagawa, Dr Malgorzata Lagisz

The team brings expertise and experience in adapting research evidence synthesis methodologies to novel questions and research areas. A/Prof Nakagawa has developed new methods for quantitative research synthesis and is a member of the Society for the Research Synthesis Methodology (membership by invitation-only). He has led multiple systematic reviews and meta-analyses of research evidence on a broad range of topics. Dr Lagisz has extensive experience in conducting and evaluating systematic reviews and meta-analyses, as well as training students and researchers in this area.

In-depth knowledge of the built environment will be brought by the Project Supervisor, Prof Mattheos Santamouris, and the members of the Steering Committee. A full-time Postdoctoral Associate will be employed for this project.

FURTHER INFORMATION

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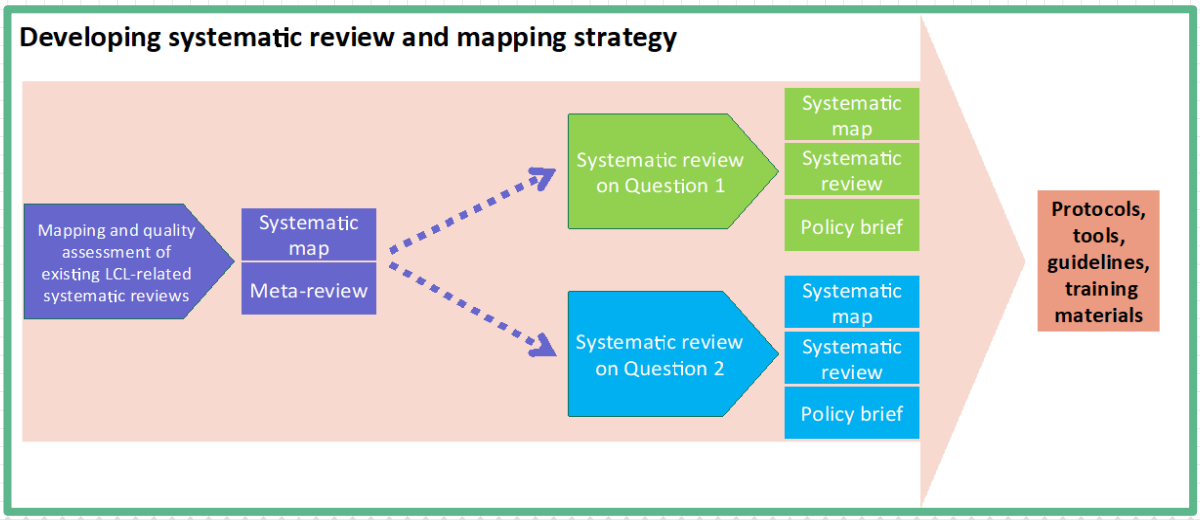

BEST PRACTICE POLICY & REGULATION FOR A LOW CARBON BUILT ENVIRONMENT

POLICY GUIDE NOTE

LOW CARBON LIVING CRC

KEY POINTS

- **Australia's policy and regulatory environment for energy efficiency and carbon outcomes in the built environment is out of date and needs review**
- **The delay in taking up building efficiency opportunities has been estimated at $43 billion over 10 years, with an additional 397 Mt CO_2-e of greenhouse gas emissions being produced.**
- **The CRC for Low Carbon Living recommends expanding and updating existing national regulatory and policy measures in the short term, followed by a thorough review and rationalisation in consultation with states, territories, industry and the community.**

THE NEED

Australia's policy and regulatory environment for energy efficiency and carbon outcomes in the built environment lags well behind that of other OECD countries, and well behind market realities.

Existing regulations have not been updated over a period when energy prices have risen dramatically and some technology costs for high efficiency, low carbon solutions have fallen significantly.

This means Australian households and businesses are paying unnecessarily high energy costs. Indeed, ASBEC and ClimateWorks estimate the delay in taking up building efficiency opportunities could cost Australia $43 billion over 10 years, with an additional 397 Mt CO2-e of greenhouse gas emissions set to be produced[2].

What's more, the absence of a forward trajectory for regulatory settings under the National Construction Code is creating regulatory uncertainty, and increasing the risk of investment in low-carbon products, services and business models.

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OUR RESEARCH

The CRCLCL undertook a study comparing Australian and global best practices in policy and regulation in relation to the energy and carbon performance of the built environment[1].

We examined opportunities and barriers relating to the adoption of best practices in Australia, and proposed a set of optimal measures, at national, state/territory and local levels, along with an indicative pathway for their implementation.

Reasons for policy and regulatory delay

Our study found the key reasons for the delay in policy and regulatory action in Australia to be:

- Key regulatory measures have not been iteratively updated (e.g. minimum energy performance standards (MEPS) for buildings have not been updated since set in 2009, and are not currently set for updating until 2019 or 2022).
- Australia has been wary of using some policy models commonly found overseas, including national energy savings

targets and related schemes, and market transformation initiatives that bring down the cost of high-performance equipment (e.g. high performance glazing).

- Compliance with the MEPS for buildings is widely acknowledged to be poor, reducing the potential for expected savings to be achieved, and generating unexpected and unnecessary costs for households and businesses.
- Policy review and updating processes and timelines are discretionary, and achieving consensus with the COAG Energy Council is challenging.
- The Government's regulatory offsets policy and the 'gate-keeping' role of the Office of Best Practice Regulation are key reasons for the lack of regulatory progress.
- Studies have found a systematic conservative bias in regulation impact assessment, with costs commonly overstated and benefits understated.

To address these issues in the short term, it is recommended that the Australian government, working with states and territories, require ambitious outcomes from existing initiatives such as the National Energy Productivity Plan and the 2017 Climate Policy Review. This would include:

- Significantly lifting minimum energy performance standards in the 2019 National Construction Code for residential and commercial buildings, to the degree that maximises net social welfare.
- Remove existing state variations to the Code that weaken its impact, notably including BASIX in NSW (or aligning BASIX stringency requirements with NCC requirements), and variations in the NT.
- Expanding the scope of mandatory building disclosure to all buildings for which existing ratings tools are available – including all residential buildings and all commercial buildings covered by NABERS tools.
- Eliminating scope limitations within the mandatory disclosure program that limit its effectiveness, such as primary purpose provisions and by further reducing size thresholds to 500m^2.
- Re-invigorating the MEPS and labelling program for appliances and equipment by significantly streamlining RIS and removing regulatory offset requirements; expanding its scope to include building products; requiring that regulatory outcomes maximise net social benefit; and requiring regulatory reviews for all standard on a three-yearly cycle.

At state/territory level:

- In addition to removing state variations on energy performance, removing Code provisions that distort fuel mix choices for space and water heating.
- Undertaking a large-scale audit of compliance with NCC energy performance requirements, publishing the results, and – in collaboration with local government – putting in place systematic and permanent arrangements to ensure compliance.
- Ensuring that all building practitioners require appropriate accreditation to practice, including continuous professional development and competency-based training.

For local government, key short term initiatives would include:

- Collaborating with State Governments and building surveyors as needed to ensure that building approval processes lead to verified Code compliance.
- Putting in place systems to capture and publish de-identified data on key building activity and outcomes including NABERS/NatHERS ratings, audit outcomes for new building work and key statistics on local building activity including area demolished, refurbished and new build by building type.

It is recommended these short-term steps are followed by:

- A thorough review and rationalisation of policies and regulations in consultation with states, territories, local government, industry and the community.
- Designing and implementing the longer-term processes of market transformation that will enable a rapid transition to the low- and zero-carbon built environment of the future, while maximising economic, environmental and social benefits.

This would be expected to lead to initiatives including:

- An ambitious national energy savings target.
- A national energy savings scheme, that would replace existing schemes in NSW, Vic, ACT and SA and provide targeted assistance, where justified, focused on lifting the performance of the existing building stock.
- Universal and continuous mandatory disclosure of building performance – using simplified and low-cost processes including ratings tools.
- A long-term trajectory to net zero emissions for all buildings, including an evidence-based and least cost strategy for attaining this outcome, and full integration of renewable energy into building standards.
- National Construction Code governance and process reforms, including national legislation, rules-based processes for Code change that minimise discretion and delay; state variations would require justification by way of a regulation impact assessment; higher standards at state and local levels would be encouraged rather than discouraged.
- A shift to post-construction verified performance targets in the National Construction Code, with full integration of renewable energy into building solutions, and full disclosure of verified outcomes

- Institutional reforms to create an expert and independent body to undertake buildings research, policy analysis, Code/standards development and data collection/publication.
- Adding a market transformation program to the MEPS and labelling program, with market transformation initiatives undertaken in a prioritised manner to enable the most efficient technology choices to be available to Australian households and businesses at competitive prices.

FURTHER INFORMATION

For more information about this project, please contact:

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1. CRC for Low Carbon Living, *Best Practice Policy and Regulation for Low Carbon Outcomes in the Built Environment*, .April 2017.

2. ASBEC/ClimateWorks, *Low Carbon, High Performance: how buildings can make a major contribution to Australia's emissions and productivity goals: summary report*, May 2016, p. 15.

Cooling Western Sydney: Mitigating heat for comfort, health & sustainability

PROJECT FACTSHEET

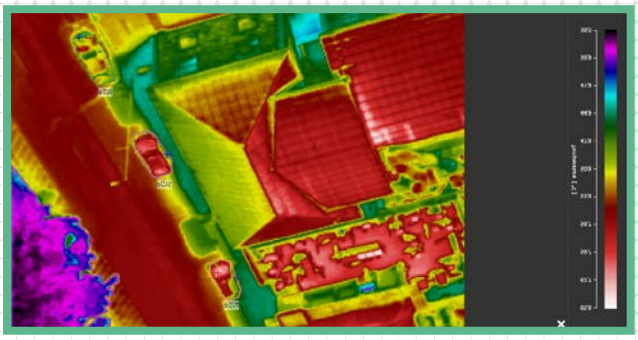
LOW CARBON LIVING CRC

KEY POINTS

- **When urban areas become too hot, our comfort and health declines, while our energy consumption and peak electricity demand grows.**
- **To help create a more liveable and sustainable Western Sydney, we are assessing the cooling potential of water-based and the other heat mitigation technologies.**

THE CHALLENGE

Urban spaces can heat up more than the rural areas surrounding them. This is known as the urban heat island (UHI) effect. The rise of global temperatures is exacerbating urban overheating, with implications for our communities.



The prevalence of UHIs has been well documented in major Australian cities. For example, in Sydney's Western Suburbs during summer, urban temperatures can sit 7-10°C higher than in neighbouring locations.

Urban overheating is a problem because it:

- Makes indoor and outdoor environments less comfortable
- Raises the concentration of several harmful air pollutants
- Increases health risks for vulnerable sections of the community, including the elderly
- Considerably increases the amount of energy used to cool buildings, driving up peak electricity demand

CRC for Low Carbon Living

The CRC for Low Carbon Living (CRCLCL) is a national research and innovation hub that seeks to enable a globally competitive low carbon built environment sector and is supported by the Commonwealth Government's Cooperative Research Centres programme.

With a focus on collaborative innovation, the CRCLCL brings together property, planning, engineering and policy organisations with leading Australian researchers. It develops new social, technological and policy tools for facilitating the development of low carbon products and services to reduce greenhouse gas emissions in the built environment. For more information visit www. lowcarbonlivingcrc.com.au/

When properly implemented, strategies like water-based technologies, urban greenery and cool roofs and pavements can decrease ambient temperatures and mitigate urban heat islands.

Our study is evaluating the potential for technologies like these to make a difference to urban temperatures in Western Sydney. We are using advanced methods to simulate microclimates and then assessing the impact of mitigation strategies on thermal comfort, energy consumption, peak electricity demand and people's health.

RESEARCH METHOD

Our research method involves:

1. Identifying mitigation technologies and defining their characteristics.
2. Simulating the temperature distribution in Western Sydney both before and after mitigation technologies are applied.
3. Assessing the impact of mitigation technologies on energy consumption, peak electricity demand, mortality and environmental quality.
4. Developing proposals to implement the mitigation technologies in selected zones.

OUTCOMES

The outcomes of our project will include:

- A detailed map of the ambient temperatures in Western Sydney during extreme weather conditions
- A detailed map showing the decrease in temperature and ambient temperature in Western Sydney caused by five types of mitigation technologies
- A full quantified assessment of the impact of mitigation technologies on energy consumption, peak electricity demand, resident health, thermal comfort and the environment
- A full report with the results, analysis, conclusions and maps of the climatic potential of each technology.

FURTHER INFORMATION

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VALUE PROPOSITION

This study will offer new knowledge about the potential for water-based and the other mitigation technologies to reduce ambient temperatures in Western Sydney, and evaluate the impact on energy, comfort and the health of people.

Local governments, state agencies and industry can incorporate the results of this study into their planning practices, and objectives towards countering the UHI and climate change.

PROJECT TEAM

- Cooperative Research Centre for Low Carbon Living (CRCLCL)
- University of New South Wales (UNSW)
- Sydney Water

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UNSW Faculty of Built Environment

REDUCING CARBON THROUGH AMBITIOUS IMPROVEMENTS TO THE BUILDING CODE ENERGY REQUIREMENTS

PROJECT FACTSHEET

LOW CARBON LIVING CRC

KEY POINTS

- **The operation of buildings accounts for almost a quarter of Australia's carbon emissions and over half of electricity demand**
- **Improving the minimum standards for energy efficiency in new construction is a key opportunity to reduce these emissions and reduce energy costs**
- **We are working with the Australian Sustainable Built Environment Council and ClimateWorks Australia to develop the evidence base supporting the introduction of long-term targets and a trajectory for the energy provisions of the National Construction Code**

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THE OPPORTUNITY / CHALLENGE

The building sector is responsible for 23 per cent of Australia's carbon emissions. Research shows that improved building energy efficiency could significantly reduce these emissions[1].

The Australian Sustainable Built Environment Council (ASBEC), the peak body for sustainability in the built environment, has identified that improving the minimum standards for energy efficiency of new buildings can assist deliver carbon emissions reductions.

The National Construction Code (Code) sets minimum standards for new building work in Australia. Although the Code is reviewed every three years, there have been no increases to energy performance since 2010.

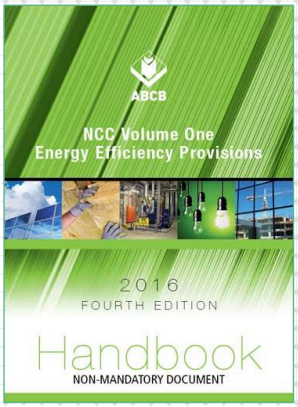
The Building Code Energy Performance Trajectory project, a partnership between ASBEC and ClimateWorks Australia, brings together researchers, key industry stakeholders and government policy makers to develop an industry-led evidence base for the adoption of ambitious long-term targets and forward trajectories for progressive increases in energy performance for new building work under the Code. We believe that his approach with clear benefits for a range of stakeholders will foster and support the necessary changes to the Code.

To develop the trajectory requires research on the feasibility and cost-effectiveness of energy efficient buildings, as well as stakeholder consultation to understand the drivers and barriers.

OUR RESEARCH

As a central component of the Trajectory project, we are investigating the feasibility of staged increases to the energy performance requirements of the Code. We will address a number of research questions:

- What long-term target or targets for increased energy performance for a range of building types should the Code aim for?
- What feasible changes can be made to the design and construction of each building type?
- What are the costs and benefits for each building type?
- What are the assumptions and inputs for the cost-benefit analyses?
- What are the differences between achieving the proposed trajectories for high energy performance buildings compared to decarbonisation of the grid and uptake of renewables?



Our research project will be carried out in three stages:

1. Develop trajectories

We will develop an energy model and undertake cost-benefit analyses with input from the model to formulate energy performance trajectories for eight building types.

The analyses will be informed by a literature review of potential stringency paths and zero and near-zero energy buildings, and data on technology projections for future efficiency of building components. Modelling will allow us to investigate the best combinations of technologies to achieve overall performance improvements. Our analyses will also address potential unintended consequences such as condensation issues resulting from air tightness.

2. Assess costs and benefits

In this stage, we will quantify the benefits of achieving the proposed targets for building owners, occupants and the public (from state, territory and national perspectives).

We will focus on any additional upfront costs, energy savings, emissions reductions and wider costs and benefits including health and energy network benefits (demand, peak demand, prices etc).

3. Understand the technological barriers

We will propose solutions for key technology and skills/capability barriers to achieving the proposed trajectories.

OUTCOMES

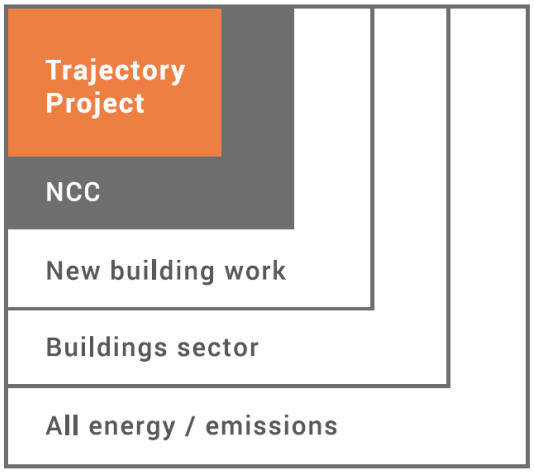
Our project will provide an evidence base to support ambitious yet attainable long-term minimum energy performance targets for new buildings within the Code.

The targets will reflect the range of benefits that energy efficiency delivers based upon a comparative analysis of similar initiatives in other countries and detailed modelling. They will be accompanied by recommendations to address the likely barriers that can impede change by industry, government and consumers.

Potential outcomes that increased energy performance standards will deliver include:

- Catalyse **market transformation** in the sector by providing a strong regulatory regime for future minimum standards, stimulating investment and innovation in low-energy building design, construction, materials and technologies
- Deliver higher **performing buildings**, resulting in:
  - Emissions reductions
  - Improved energy productivity, including more efficient use of energy infrastructure in new NCC-compliant buildings
  - Energy cost savings
  - Improved health and comfort for building occupants

Our project will form one piece of the puzzle in decarbonising the built environment. The Building Code Energy Performance Trajectory project focuses on increasing stringency, however there will need to be complementary work to improve compliance with the Code, upgrade existing buildings and leverage experience in the building sector to decarbonise Australia's broader economy. Our research is an important step in unlocking and cascading emissions reduction opportunities.



PROJECT TEAM

- University of Wollongong
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Australian Sustainable Build Environment Council (ASBEC)
- ClimateWorks Australia
- Energy Action
- Strategy Policy Research
- Donald Cant Watts Corke

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REFERENCES

Australian Sustainable Built Environment Council (ASBEC). 2016. Low Carbon, High Performance. ASBEC, Australia.