



Australia's National
Science Agency

Darwin Living Lab Snapshot 2021-2022



The Darwin Living Lab: Science and
collaboration to support the liveability,
sustainability and resilience of Darwin



About

This report was delivered as part of the work of the Darwin Living Lab. The Darwin Living Lab was established to foster improvements in the liveability, sustainability and resilience of the city. The Darwin Living Lab is an initiative under the Darwin City Deal and is a 10-year collaboration between CSIRO and the partners of the Darwin City Deal: Australian Government, Northern Territory Government and the City of Darwin. The City Deal was signed by the Prime Minister of Australia, Chief Minister of the Northern Territory and Lord Mayor of the City of Darwin in November 2018.

More information and contacts available at: <https://research.csiro.au/darwinlivinglab/>

Acknowledgement

We acknowledge the Traditional Owners of the greater Darwin region, the Larrakia people, and recognise their culture, history and connection to this land and water. We pay our respects to their Elders past, present and emerging.

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This summary report is based on Darwin Living Lab projects. The authors would like to acknowledge the following contributors.

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P2. Analysis of CoD sensor network and integration with AirRater	Dr Erin Dunne and Jennifer Powell, CSIRO; Krishan Maheson and Jack Silburn, City of Darwin; NT EPA; BoM
P3. Towards a Digital Twin of Darwin to monitor and navigate change	Dr Sorada Tapsuwan, Dr Ray Marcos Martinez, Dr Natthanij Soonsawad and Guy Barnett, CSIRO; Peter Caccetta, Xiaoling Wu and Joanne Chia, Urban Monitor Team CSIRO Data 61; Ron Grinsell, Joshua Forner, Eric Lede, Krishan Maheson, City of Darwin; NT DIPL.
P4. Monitoring, Evaluation and Learning (MEL) baseline data collection	Dr Rachel Williams, Dr Seona Meharg and Dr Tim Muster, CSIRO along with DLL partners
P5. Larrakia-led Darwin biodiversity values	Adam Liedloff, Emma Woodward, Jodie Hayward and Jon Schatz, CSIRO; Lorraine Williams, Larrakia partner; Ben Smith, Larrakia Rangers.
P6. Developing local capacity to monitor and evaluate urban innovations using UAV's	Assoc. Prof Hamish Campbell , Dr Rebecca Rogers, Dr Deepak Gautum and Dr Hooman Mehdizadeh Rad, Charles Darwin University; Dr Shaun Levick, CSIRO.
P7. AirRater and outdoor worker heat stress	Dr Sharon Campbell, Dr. Amanda Wheeler, CSIRO (formerly ACU)
P8. Increasing the value of onsite renewables in Darwin through data driven analytics	Prof. Suresh Thennadil and Dr Hooman Mehdizadeh Rad, Charles Darwin University. Dr Subbu Sethuvenkatraman, Will Borghei and Stuart Hands, CSIRO Energy.
P9. Darwin Home Comfort Rating	Co-led by Johanna Kieboom, NT DIPL and Dr Dong Chen, CSIRO , with technical reference group of Professor Terence Williamson, University of Adelaide; Associate Professor Wendy Miller, QUT; Dr Mahsan Sadeghi, CSIRO and Ray Fogolyan, Home Star Australia

Cover Photo: Raintree Park, Darwin CBD, Charlie Bliss (2022)

Messages from our Partners

Commonwealth Department of Infrastructure, Transport, Regional Development, Communications and the Arts

The Department of Infrastructure, Transport, Regional Development, Communications and the Arts is proud to partner with the Darwin Living Lab as it continues its valuable work as a key initiative of the Darwin City Deal to position Darwin as a vibrant, connected and liveable tropical city.

The Department recognises the significant progress of the Darwin Living Lab over the course of 2021-22 in driving strategies, research and collaboration to produce evidence-based approaches for heat mitigation solutions and tropical urban design to inform the future development of Darwin.

The Department looks forward to further collaboration and engagement with the Darwin Living Lab, including opportunities to leverage off projects and outcomes to support a broader range of Australian Government priorities.

Northern Territory Government

The Northern Territory Government continues to collaborate with the Darwin Living Lab, established through the Darwin City Deal, as we prioritise reducing and adapting to heat-related climate challenges that adversely impact Darwin's liveability and economic growth.

The Lab has provided a vital stakeholder conduit and its critical science-based expertise to contribute insights and develop approaches to, as well as the imperative monitoring, evaluation and learning from cooling and greening efforts. This has seen the creation of the Home Comfort Rating System, implementation begin on the *Darwin Heat Mitigation and Adaptation Strategy* and evidence clearly demonstrating the positive effects of cooling and greening interventions delivered through the City Deal.

The Northern Territory Government looks forward to its ongoing role in the Lab by pursuing further joint projects and building community awareness of the Lab's work as we aim to make Darwin not only the thriving, cool but also liveable and vibrant capital of Northern Australia.

City of Darwin

City of Darwin is working with the Darwin Living Lab in progressing strategic actions that feed into the strategic direction of a cool, clean and green city.

In 2021 and 2022, we worked alongside the Darwin Living Lab in progressing actions within the Darwin Heat Mitigation and Adaption Strategy and both the City of Darwin Climate Emergency Strategy and Greening Darwin Strategy. Furthermore, in 2021, a desktop analysis of movement in Darwin was undertaken in order to identify the key transport benefits and challenges. After considerable input from key stakeholders and the broader community the City of Darwin Movement Strategy was finalised to deliver a modern and sustainable movement network.

So far the Digital Twin partnership has focused on data collection and analysis of trees around the municipality to define tree values and inform future street tree planting programs. City of Darwin looks forward to implementing upgrades to sensor networks and developing an integrated mapping framework with CSIRO to further progress the Digital Twin project.

Executive Summary

The CSIRO-led Darwin Living Lab was established to foster improvements in the liveability, sustainability and resilience of Darwin City. It is an initiative under the Darwin City Deal and, initiated in July 2019, is a 10-year collaboration between CSIRO and the partners of the Darwin City Deal: Australian Government, Northern Territory Government and the City of Darwin.

This document, covering the calendar years of 2021-2022, is the second in a series of biennial reports that provide a snapshot of the Darwin Living Labs activities, outputs and impacts. The first snapshot in 2020 highlighted the importance of making Darwin liveable, sustainable and resilient: to attract and retain talent, to lower resource use and emissions and to be resilient against shocks, disruption and natural disasters.

The Darwin Living Lab through its partnerships has been progressing the co-developed vision for Darwin to be the *'Thriving, cool capital of Northern Australia'*. Supported by a governance structure and operational principles that reinforce the long-term commitment to collaboration, experimentation and collective learning, the Lab has continued to mature its role within Darwin's strategies and operations. For example, the 'Feeling Cooler in Darwin' Heat Mitigation and Adaptation Strategy calls for the Darwin Living Lab's leadership and/or collaboration in 20 of the 30 listed actions. Similarly, the City of Darwin Greening Strategy 2030 has strong alignment with the DLL project 'towards a digital twin' that is developing a virtual model of urban vegetation for Greater Darwin. Furthermore, monitoring and evaluation of the Labs performance in 2020 called for increased inter-partner working and a more dedicated and specific approach to the formation of projects, and where possible, co-leadership of projects across partners. This close working between partners represents a move away from the use of 'Expressions of Interest' and other competitive processes to form projects, and towards targeted partner co-developed projects that deliver to partner strategies, such as:

- Darwin City Deal (Implementation Plan)
- Feeling Cooler in Darwin (Heat Mitigation and Adaptation Strategy)
- Northern Territory Government Climate Change Response: Towards 2050 Net Zero
- NT Infrastructure Strategy 2022 to 2030
- City of Darwin's Strategic Plan: City for People. City for Colour (and its associated sub-strategies)
- CSIRO Science Strategy for the Darwin Living Lab.

The CSIRO Science Strategy for the DLL frames projects, experiments and engagement with city actors as a means to assist "navigating change" in Darwin, and within this, progress specific research to influence change in both indoor and outdoor environments. The strategy has guided the integration of projects to answer key questions relevant to creating a cool, vibrant, sustainable and resilient Darwin.

During the period 2021-2022 the DLL has conducted activities and research in the following areas:

Indoor Environment: how to design and create cooler and more energy-efficient buildings?

- Project: **Increasing the value of onsite renewables in Darwin through data driven analytics.** A collaboration between Charles Darwin University (CDU), CSIRO, City of Darwin and ARENA that evaluated opportunities for improving the value of onsite renewables by connecting three Darwin buildings to the iHub Data Clearing House (DCH) to provide real time data.
- Project: **Darwin House Comfort Rating.** This co-led project between NT Government and CSIRO Energy, with collaborators from QUT and University of Adelaide is developing a user-friendly

tool with 'for information' living room and bedroom comfort ratings that can be used to improve passive thermal comfort outcomes in residential buildings. This will improve building resilience for future climates and reduce health risks when air conditioning is not available.

Outdoor Environment: how to cool and green the city for liveability in a changing climate?

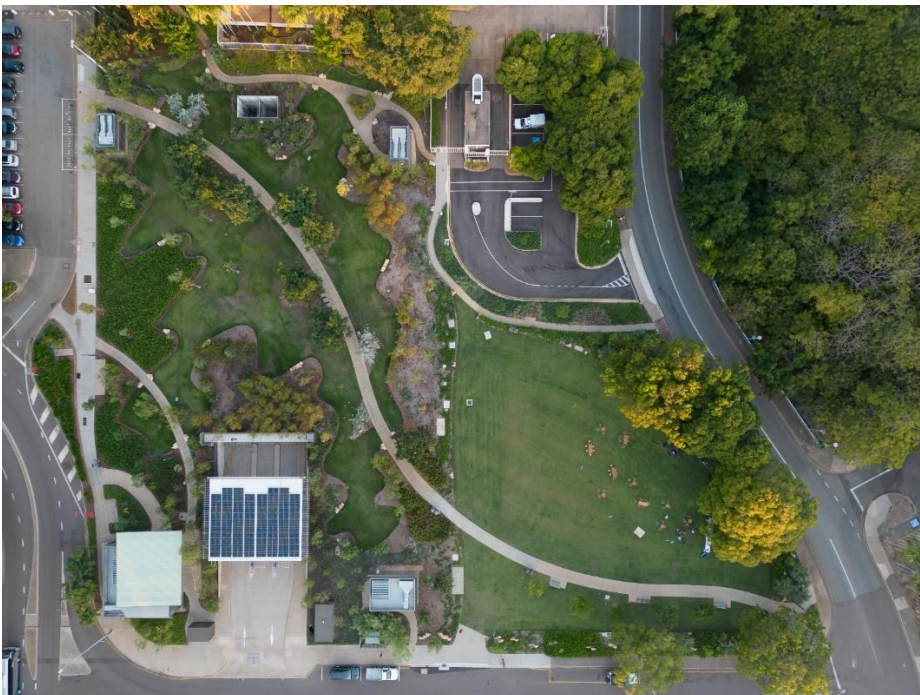
- Project: **Understanding community needs for urban green space in Darwin.** This CSIRO-led project undertook a 'Nature experience in the city' survey and conducted focus groups to research how different user groups in Darwin interact with green spaces. This helps to understand community needs and preferences for amenities and how different people value and use green spaces in Darwin. The research is providing insights on how to design green space to mitigate heat and be attractive, usable and beneficial to city residents and visitors.
- Project: **Larrakia-led Darwin biodiversity values.** With Larrakia leadership and the development of a network of groups and individuals, this project has been creating a baseline of Larrakia biodiversity values including habitats and native plant species that can be considered for Darwin urban greening and protection. The project has been generating audio-visual products of Larrakia sharing stories about change on Country and priorities for protecting and renewing biodiversity, and seeks to inform a biodiversity monitoring framework with Larrakia Rangers.
- Project: **Developing local capacity to monitor and evaluate urban innovations using UAV's.** A CDU-led project in collaboration with CSIRO to develop drone-based urban data collection capability through a PhD student project. The team has assembled a UAV capability with radiometric cameras that enable aerial thermography collection in the Darwin CBD and other zones of interest. Through CASA approval, flights have been undertaken to collect thermal imagery of Darwin to deliver high quality heat maps for incorporation into the Digital Twin.
- Project: **Analysis of Darwin environmental sensor network.** This project saw CSIRO scientists work closely with the City of Darwin 'Switching on Darwin' project team involving the rollout of environmental sensor units across the CBD and Greater Darwin. The project sought to resolve issues with data quality and recommend solutions and ongoing maintenance protocols in order to create datasets that could be used for public good and stimulate smart city innovation, and assist decision making and operations of Darwin city.
- Project: **Using AirRater to support heat stress guidance for outdoor workers.** Led by the University of Tasmania with collaboration and support from University of Southern Queensland, Australian Catholic University and CSIRO, this project sought to better understand the prevention and management of heat stress and poor air quality in Darwin, and the association between outdoor temperature, humidity and symptoms such as headache, dizziness and fatigue. The project recruited outdoor workers from Darwin-based organisations to use the [AirRater](#) app and conducted focus group discussions with outdoor workers, educators and sportspeople with the aim to understand the barriers and enablers in preventing and managing heat stress and poor air quality when working or being active outdoors.

Navigating Change: how to use science and technology to track progress and inform decisions?

- **Leadership and experimentation:** the core Darwin Living Lab team have curated DLL activities to create the partnerships, capacity and science to deliver impact for Darwin. It has increased experimentation in Darwin such as providing inputs to CDU's Danala (Education and Community Precinct) design, initiated precinct engagement activities such as 'Chalk the Campus' at Royal Darwin Hospital, and added capacity to both university-led and industry-led initiatives.

- **Knowledge brokering:** the Lab has continued to encourage knowledge exchange through public forums such as the annual Darwin Living Lab Symposium, the Darwin Living Lab Webinar Series, communication products (websites, newsletters, reports, media content) and the hosting and promotion of workshops to increase learning and to encourage new partnerships.
- **Implementation of co-developed strategy:** the Lab continues to support the Heat Mitigation and Adaptation Strategy Working Group and deliver its commitments within the Strategy.
- Project: **Towards a Digital Twin of Darwin to monitor and navigate change.** This CSIRO-led project in conjunction with CSIRO Data61 Urban Monitor™, City of Darwin and NT Government has been assembling spatial and temporal datasets for Darwin that can be used to develop a digital twin to monitor change, with an initial application focus on environmental economic accounting of the ecosystem services that are provided by Darwin’s green living infrastructure. A web-based prototype digital twin for Darwin has been developed, capable of generating automated reports of interactions between tree canopy, land surface temperature and socioeconomic vulnerability.
- **Monitoring, evaluation and learning:** the Lab has continued to implement and draw upon its monitoring and evaluation framework to support learning and functional improvements. This has enabled the development of a case study for the Darwin City Deal with an evaluation of the Lab’s contribution to the NT Government’s heat mitigation strategy and continues to identify improvements to DLL actions and document the value delivered to partners and stakeholders.

The Darwin Living Lab will continue its engagement with Darwin stakeholders and to expand its network of partners to progress the city toward a *‘thriving, cool capital of the North’*. To date the delivery of the DLL team has been recognised within a range of nationally-leading initiatives including [Australia’s National Climate Resilience and Adaptation Strategy 2021-25](#), [Australia’s Strategy for Nature 2019-2030](#), the [State of Environment Report](#), and we seek to expand on the foundations created so far, to further establish Darwin as a global leader in heat mitigation research and wet/dry tropical design.



Find out more at: research.csiro.au/darwinlivinglab

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1 Overview of the Darwin Living Lab

1.1 Vision: Who we are

The CSIRO-led Darwin Living Lab builds on City Deal investments by bringing together collaborators within the Vision of progressing Darwin as a *'thriving, cool capital of the North'*. The initiative aims to co-create solutions to local urban challenges, maximising opportunities for innovation and learning, and growing tropical city knowledge and expertise. The Darwin Living Lab will:

- Support innovation in urban heat mitigation by providing research evidence and expertise to inform Darwin's heat mitigation strategy, including identification and development of future trial initiatives and evaluations of their effectiveness;
- Develop the evidence-base for innovative, performance-based approaches to improve the energy efficiency of buildings in Darwin and the heat-related health outcomes of occupants for incorporation into urban design guidelines and building regulations. Creating local tropical city knowledge and expertise that can be translated into products and services for application in other tropical cities in Australia and the ASEAN region; and
- Monitor and evaluate Darwin Living Lab contributions to the liveability, sustainability and resilience of Darwin.

1.2 Darwin Living Lab Principles

- **Shared Values** aligned to the ideals of 'liveability', 'sustainability', 'resilience' and 'innovative urban development'.
- **Value Creation** through creating monetary and non-monetary value for communities, stakeholders, and research partners.
- **Long-term Commitment** through the Darwin City Deal and partner agreements.
- **Ethical** experimental plans comply with national specifications for values, governance and review processes, including: voluntary participation, informed consent, confidentiality and anonymity.
- **Inclusion** through the welcoming of skills and competencies, and passion of partners and communities to deliver mutually beneficial outcomes.
- **Systems Focus** by combining the knowledge and skills of a range of disciplines and groups, seeking to avoid failures and difficulties across sectors.
- **Innovation** through exploring and experiencing new ways of working together, rather than replicating, or competing with, current practice and provision.
- **Transformation** over time through bold trials and demonstrations which test urban living options way beyond the current accepted "norm".
- **Knowledge** is created by new partnerships across sectors and jurisdictions and shared transparently to make evidence-based decisions and investments.
- **Experimentation & Learning** will be facilitated and used to build capacity and shared understanding of partners, stakeholders and communities.
- **Evidence-based** decision making is advanced through the creation of evaluation frameworks and tools for monitoring and assessing new urban form.
- **Curation** of partners and growth of social and institutional networks is nurtured, knowledge is actively passed on and scientifically-based impact frameworks are (developed, updated and) used to guide experimentation and learning.

1.3 Darwin Living Lab Governance

Governance arrangements support the Darwin Living Lab principles and feature a Management Committee (decision-making group) comprised of funding partners and the use of Advisory Groups comprised of local industry, community and diverse expert knowledge representatives. These structures support a novel governance that facilitates co-produced knowledge and the ability to challenge ‘business-as-usual’ decision making.

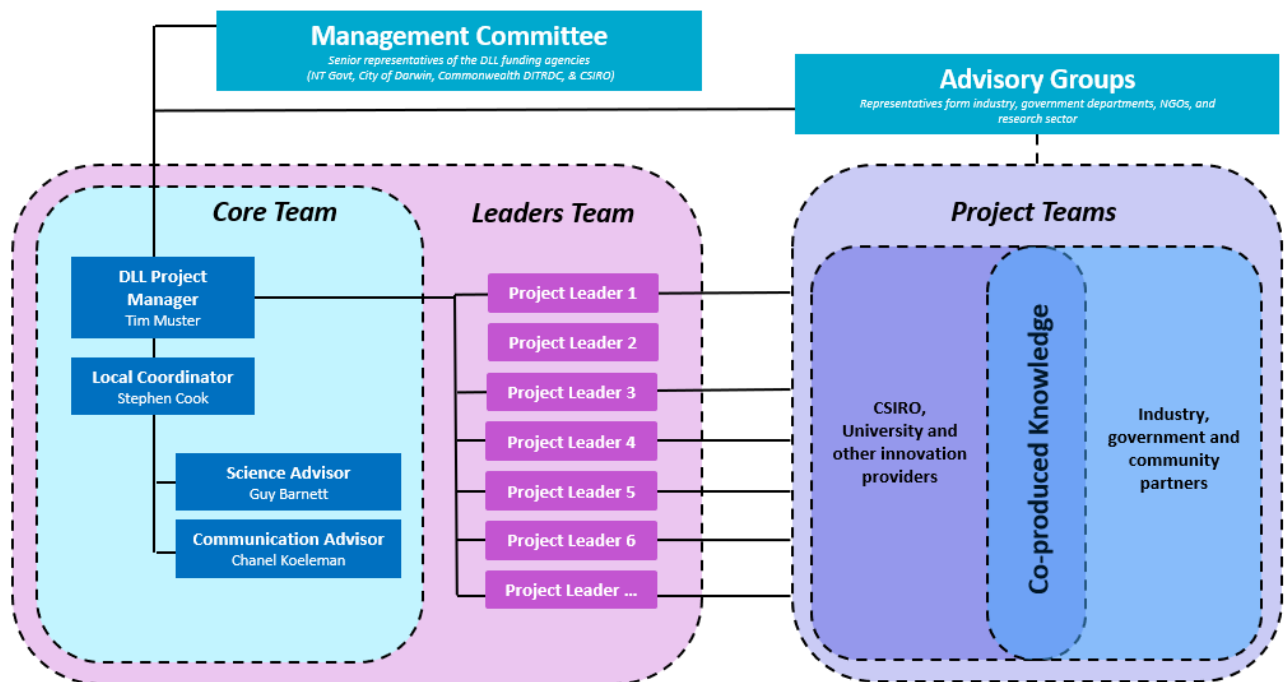


Figure 1: Darwin Living Lab Governance Structure

1.4 Management Committee 2022

- Dr Chris Chilcott, Research Leader, Northern Australia Development, CSIRO (Chair).
- Tiffany Karlsson, Acting First Assistant Secretary, Cities Division; Department of Infrastructure, Transport, Regional Development, Communications and the Arts.
- Jo Smallacombe, Department of Chief Minister and Cabinet, Northern Territory Government.
- Alice Percy, General Manager Innovation, City of Darwin.

1.5 Advisory Contributors

CSIRO in leading the Lab introduced a management structure in 2020 that utilises a ‘Core Team’ and a ‘Leaders Team’ to manage and coordinate DLL functions, and to deliver strategies and strategy implementation through projects and activities (Figure 1). The structure places an emphasis on collaborative (co-developed) projects forming between researchers, industry, government and community focusing on mutual interests and enabling new co-produced knowledge and learning.

Leadership of DLL projects, external to CSIRO, during the 2021-2022 period included:

- Dr Sharon Campbell (University of Tasmania) - Managing extreme heat and smoke in Darwin

- Johanna Kieboom (NT Government Department of Infrastructure, Planning and Logistics) – Darwin Home Comfort Rating
- Prof Suresh Thennadil (Charles Darwin University) - Increasing the value of onsite renewables in Darwin through data driven analytics
- Professor Hamish Campbell and Dr Rebecca Rogers (Charles Darwin University) - Monitoring urban heat with uncrewed aerial vehicles

2 Key outcomes and impacts for 2021-2022

2.1 Overview

The reporting of key outcomes and impacts are organised around key areas of research activity under the Darwin Living Lab Research Plan 2021-2023, which address the following questions for Darwin:

- Indoor environment: how to design and create cooler and more energy-efficient buildings?
- Outdoor environment: how to cool and green the city for liveability in a changing climate?
- Navigating change: how to use science and technology to track progress and inform decisions?

The place-based focus of the Darwin Living Lab grounds these science questions in the real world (Darwin, its governance structures, land and building owners, and diverse communities). There are also overlaps between the three science questions that require an integrated approach to projects that links social, economic, environmental and technological considerations at different scales (Figure 2).

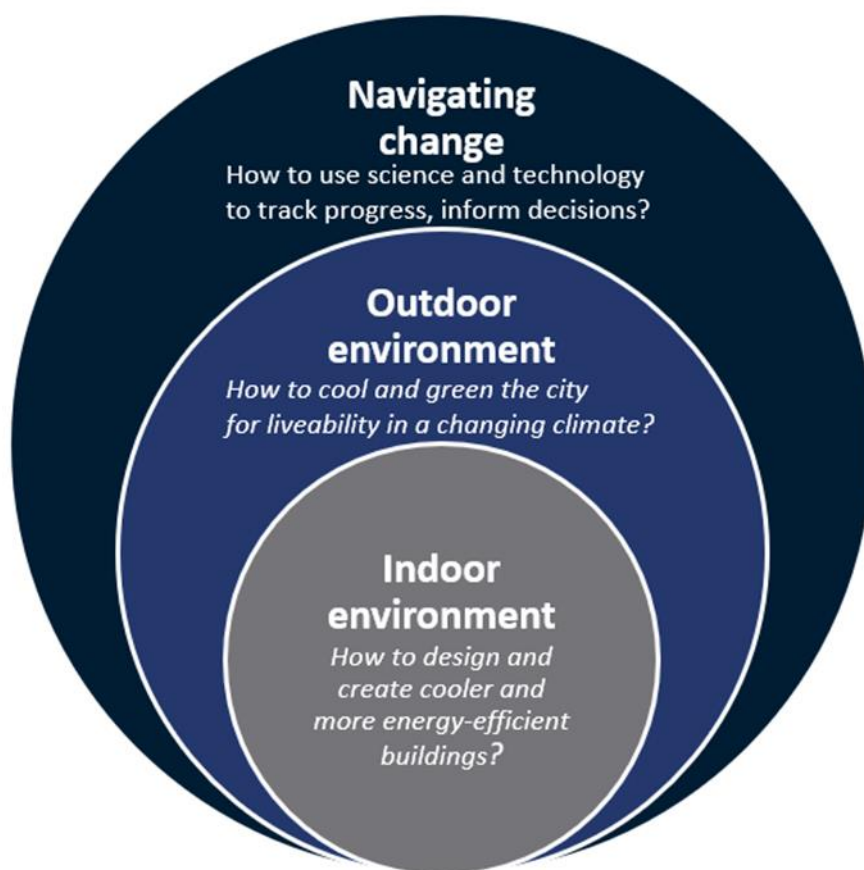


Figure 2: Key areas of research activity - Darwin Living Lab Research Plan 2021-23

2.2 Navigating change

Overview

The DLL is responsible for ‘tracking progress’ on cooling and greening the city, building local tropical city knowledge and expertise, and catalysing development of products/services for application in other tropical cities in Australia and the ASEAN region. Our research on Navigating Change has a focus on using science and technology to track Darwin’s progress in meeting the objectives of sustainability, liveability and resilience, and using this data and evidence to inform decision-making processes. This goes beyond ‘cooling and greening’ to a recognition of the wider economic, environmental and social factors at national and global scales that will shape Darwin over the coming years and decades.

Objectives

- Fostering collaboration and learning opportunities that connect local expertise with national and global knowledge on best practice for heat mitigation and tropical design
- Maintain effective governance that ensures strong engagement with partners and alignment of DLL activities with their strategies and priorities
- Work with partners to co-develop an approach and stories for ‘Tracking Darwin¹’ to measure, monitor and evaluate change in Darwin’s liveability, sustainability and resilience
- Encourage experimentation and innovation in improving heat mitigation and liveability outcomes for precincts

Key outcomes and impacts for 2021-2022

Building capacity and expanding networks

Over 2021-2022 the Darwin Living Lab increased stakeholder networks and built embedded partner collaboration on key projects. There has been significant activity to increase public engagement and outreach. Key outcomes and impacts have included:

- Successful webinar series that provided the opportunity for regular knowledge sharing and learning between local, national and international speakers on topics related to current Darwin Living Lab projects. These webinars were recorded and made available on the [Lab website](#) to provide an ongoing resource. The following topics were covered:
 - Planning better green spaces for our communities
 - Digital twins for navigating change in Darwin
 - Managing health risks to outdoor workers from extreme temperature and poor air quality
 - Energy efficiency and renewables in moving towards a cooler Darwin
 - Enabling a more liveable, sustainable and resilient Darwin through effective financing
- The Lab has delivered and supported a range of events that enabled community engagement in exploring heat mitigation and liveability approaches for specific precincts, while also

¹ Working name for project, naming of final output will be defined in collaboration with project partners

developing partnerships with several schools and other organisations to deliver STEM development activities for students. Highlights over 2021- 2022 have included:

- 'Chalk the Campus' at Royal Darwin Hospital (RDH). RDH staff and precinct users gathered in May 2022 to share how they experience heat when outside at RDH. Participants raised issues and highlighted the pavement with chalk to indicate where heat mitigation solutions could be considered. The outputs are informing the RDH campus greening project and have raised awareness through resulting media coverage.



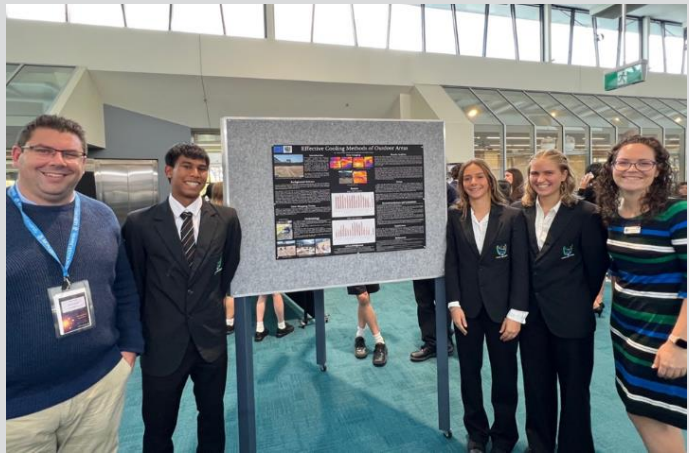
Figure 3: 'Chalk the Campus' event at Royal Darwin Hospital

- The Lab supported the NTG in developing and delivering the Heat Mitigation display in the Activate Darwin Hub in the Smith Street Mall. This included providing expert talks, science content and materials for interactive displays to inform the community on efforts to cool the city. The display Open Day attracted more than 500 community members on the day and more than 300 people in the following weeks.
- The Lab has partnered with several organisations to engage students and deliver STEM development opportunities. This included working with Questacon for the Invention Convention to provide a 'Cooling the City' challenge, delivering a heat mapping activity for the Young Indigenous Women's STEM Academy and supporting Charles Darwin University's STEAM Spectacular as part of National Science Week. The Lab has also partnered with several schools in the Darwin region through CSIRO's STEM Professionals in Schools program to deliver activities that provided opportunities for students to develop skills in scientific inquiry and problem solving around climate adaptation. These engagements are now ongoing (see example for Darwin High School).

- The Lab has sought opportunities to build networks and awareness of projects being delivered under the Darwin City Deal through a range of forums, which have included presentations to:
 - Annual Conference of Ecological Society of Australia 2021
 - Darwin International Virtual Trade Show 2022
 - Australian Water Associations 'Water in the Bush' 2022
- The Lab convened a stakeholder roundtable to identify Northern Territory priorities for the National Environmental Science Program, Sustainable Communities and Waste Hub.

Darwin High School

The Lab was invited to run a heat mapping activity with students from Darwin High School's Environmental Science Centre for Excellence. The heat mapping was used to inform a tree planting program based on identified hot spots. Several students used thermal cameras and heat stress meters for further investigations on effective approaches for outdoor cooling with results presented by students to the Australian Science Fair in Melbourne.



Students from Darwin High School at the Australian Science Fair

Images used with permission from Darwin High School

The Lab has identified and developed several new partnerships to build impact, which have included:

- Collaboration with Capital Insight and CDU on the design of Danala (Education and Community Precinct). This included providing input to procurement documentation for smart building integration and participating in design workshops on HVAC, solar PV, public realm and energy efficiency.
- Ongoing engagement with Royal Darwin Hospital to support efforts through their sustainable healthcare initiative for cooling the public realm of the hospital. This has included data collection to validate cooling benefits of campus greening and collaborating on presentations to national health and climate change conferences.
- Supported CDU researcher on City of Darwin funded project to better understand the relationship between canopy density of different tree species and cooling benefits. Data

collection was undertaken at CSIRO Berrimah site for different configurations of greening that quantified cooling benefits for wet and dry seasons.

- Collaboration with CDU on a successful proposal to ARENA on accelerating renewables integration into buildings through data driven analysis (led by Prof Suresh Thennadil) in collaboration with City of Darwin. The [project](#) was developed through a partnership between CDU and the Lab, which has helped grow the impact of the Lab in addressing challenges in efficient energy management in buildings and integration of renewables.

Darwin Living Lab Symposium 2022: Knowledge into Practice

The 2022 Symposium was the chance to return to in-person events after the disruption due to the COVID-19 pandemic. The 2022 Symposium had a focus on translating knowledge into practice, while developing awareness of cooling initiatives and supporting research underway. The Symposium encompassed three themes, which were explored through presentations, panel discussions and interactive workshop sessions.

- Navigating change in Darwin – How is Darwin changing, what are the challenges and tensions at play, and what mechanisms are there for Darwin to transition to a cooler and thriving capital city?
- Community and Indigenous knowledge for improving heat-related liveability – What approaches are being used to cool urban landscapes and how can green infrastructure provide increased heat mitigation and biodiversity outcomes for Darwin?
- Advancing energy efficiency and indoor thermal comfort in Darwin – How can Darwin’s built environment and occupant behaviour be adapted to improve indoor thermal comfort while reducing emissions associated with cooling indoor spaces?

The Symposium was well attended, with more than 90 registrations. Participants represented all levels of government from several agencies, peak industry bodies, private businesses, universities and traditional owners. Outputs from the symposium including keynote presentations are available [here](#).



Moving from strategy to implementation

The Darwin Living Lab fostered collaboration between local City and Territory leaders and knowledge experts to ensure the latest science and information on urban heat was available to the Northern Territory Government and City of Darwin as they developed Darwin’s Heat Mitigation and Adaptation Strategy. Land surface heat mapping highlighted the characteristics of areas that were hotter than average and community vulnerability to heat stress. The review of global approaches to heat mitigation provided recommendations on potential next steps and strategic actions that could be tested in future trials and pilots in Darwin.

The Lab supported the launch of the [Heat Mitigation and Adaptation Strategy](#) by the Hon Eva Lawler MLA, Minister for Infrastructure, Planning and Logistics, in December 2021 that sets out 30 actions to be delivered over a 10-year timeframe. The Lab Research Plan has set 3-year strategic priorities that align with the implementation of the Heat Mitigation Strategy and Darwin City Deal reporting. The CSIRO core team is active in the Strategy Working Group that provides cross-government oversight, coordination and implementation of the deliverables under the Strategy. This includes supporting the City Deal partners' commitment to revitalising Darwin's City Centre, including through cooling and greening, and the vision for Darwin as articulated in the City Deal.

The Lab has worked closely with the City of Darwin in the development and delivery of their aligned strategies, in particular Climate Emergency and Greening Darwin strategies. The Digital Twin is being co-developed with the City of Darwin to ensure that it can provide value in informing and evaluating actions and targets under the Greening Darwin Strategy. Monthly meetings between the CSIRO and City of Darwin have proven an effective approach for sharing progress and identifying opportunities for aligning Lab research projects with City of Darwin strategic priorities.

Communication and knowledge brokering

The Darwin Living Lab [research page](#) is the central website maintained for the Lab, which includes information on current projects and upcoming events. This website provides the repository for published reports, webinar recordings, newsletters and other outputs. The website also allows interested people to register to receive updates and invitations for upcoming events. There are now more than 300 people registered for updates, with the website traffic continuing to grow over the project with more than 2,400 visitors in 2022 – increasing from 1,300 visitors in 2020.

A beta version of the *Your Tropical City* [website](#) provides a resource on tropical living and design for Darwin residents as well as those wishing to build and do business in Darwin. The website highlights opportunities to improve thermal comfort and liveability with buildings and public open space, primarily within the Darwin CBD but with relevance to the greater Darwin area. The website will be updated in 2023 with the focus on translating research output for a broader community audience.

The Lab has featured in several media stories, with interviews on ABC local radio and stories published on ABC online.

- [How we can cool our cities with heat mitigation in a warming world?](#)
- [Climate is warmer but this workplace is cooler and greener, thanks to its staff](#)
- [Darwin heat stings as parts of city still without shade trees years after Cyclone Marcus ripped through](#)

Developing impact

There is ongoing interest in knowledge products being developed from the Lab to be applied in other jurisdictions particularly in the development of a digital twin tool to monitor and evaluate changes in urban heat, greening and community vulnerability. Several agencies from other cities have reached out to discuss how the living lab approach could be applied for their particular context. The experience of the Darwin Living Lab has informed the inclusion of a living lab in Desert Knowledge Australia's [Strategic Plan 2023-2025](#) to collaborate on research to support remote communities. There are ongoing discussions between DKA and CSIRO to support the standing-up of this Living Lab in Central Australia.

The Lab was featured in the Department of Agriculture, Water and the Environment's [*National Climate Resilience and Adaptation Strategy 2021-2025*](#). The Lab provided an example of an approach to adapt the built environment to a changing climate.

The Lab provided a case study – *a digital twin of Darwin to monitor and navigate change* – to the Department of Agriculture, Water and the Environment's biennial report on [*Australia's Strategy for Nature 2019-2030*](#). The case study highlighted the sharing of knowledge across different levels of government, the community and researchers on nature-based approaches to climate adaptation.

Monitoring, Evaluation and Learning (MEL)

The Darwin Living Lab MEL survey was conducted in December 2020 and again in December 2022. These activities were undertaken as part of the Tracking Darwin framework to regularly review DLL operations and progress to inform improvements in how the DLL is operating and learn how to effectively develop and implement an urban living lab. A copy of our approach to Tracking Darwin is available at: [*Williams R, Meharg S and Muster TH \(2020\) Tracking Darwin – a framework for monitoring, evaluation and learning about change in Darwin and its impact of the Darwin Living Lab.*](#) The co-developed 'theory of change' highlighted impact pathways for the Lab, which are summarised below.

Impact pathways revisited

- Develop and foster innovation in urban heat mitigation for Darwin that improves liveability and grows the economy
- In partnership with government, industry and community, identify and test new ideas and approaches
- Work with the Larrakia as the traditional custodians of the Darwin region, to respectfully learn from their cultural knowledge about living with heat
- Develop infrastructure and analytics for tracking change in Darwin's liveability, sustainability and resilience
- Build the capacity and networks for collaborative governance to guide urban transformation
- Utilise effective co-production processes to develop and deliver outputs that are tailored to user needs and attract wider involvement from across CSIRO and all partners
- Annual Monitoring, Evaluation and Learning will provide a reflection on whether expected impact is being achieved and provide instruction on where future effort should be placed

The 2022 MEL survey went out to those who have had a significant involvement with the Lab over the previous year, including the Management Committee and key project partners. The survey response rate was low with only 11 responses (four completed) from 50 targeted participants. A 30-minute interview was offered as an option to provide input, which was accepted by one participant. The Lab will revisit the MEL survey design and engagement approach in 2023 to increase the response rate. The following summarises what aspects participants viewed as working well and areas for improvement.

Aspects of the Lab that are working well

- Participants felt that the Lab has contributed to a clearer sense of Darwin's future, and that projects are helping to move towards the vision of Darwin as a *'thriving, cool capital of the North'* and that they had a role to play in achieving this vision. There was also support for the statement that trust has been built or strengthened among people involved in the Lab and the Lab has provided additional capacity to work collaboratively.
- It was highlighted that activities such as the Symposium and 'chalk the campus' helped to build visibility of the Lab, which has contributed to awareness more broadly outside of Darwin and

the potential for adopting similar approaches by agencies in other cities both in Australia and internationally.

- It was noted there is a high degree of trust in the CSIRO-led Lab from delivery so far and the activities were highlighted as a positive in the Three Year Review of the Darwin City Deal.
- Participants identified that the Lab has contributed to the establishment or strengthening of networks both through informal partnerships and networking opportunities, as well as formal partnership through the Heat Mitigation and Adaptation Strategy Working Group. Overall it was viewed that CSIRO was engaging well through being responsive and providing regular catchups.
- Most participants identified that the Lab had contributed new knowledge and innovation in managing and mitigating heat stress, while implementing actions under the Heat Mitigation and Adaptation Strategy provides a mechanism for impact.

Aspects of the Lab that could be improved

- There was generally the view from participants that, as yet, no new leadership styles have emerged as a result of the Lab and there have been no changes to institutions or rules (formal or informal) as a result of the Lab that can contribute to the vision of Darwin.
- Participants identified agencies and organisations they would like to see more involved in the Lab, which included Power and Water Corporation, industry groups (esp. developers) and nearby local governments (Palmerston and Litchfield) and highlighted that there is the need to focus on building and strengthening collaborations outside of the core Lab partners.
- It was highlighted that a challenge can be staff turnover and movements among key partners, and that changes in Government priorities means there is an ongoing need to build awareness of the benefits and outcomes being delivered both across Government (including at the Ministerial level) and the community in Darwin and beyond.
- It was highlighted that Darwin Living Lab partners are often dealing with many competing demands, so there is a need to ensure that the Lab clearly communicates so that partners are aware of issues and that they can be confident that CSIRO has the project in-hand.

In addition to the MEL, a survey was conducted at the conclusion of the 2022 Symposium which asked participants what type of engagement events they would like to see the Lab support in the future, which highlighted the following:

- More school and STEM engagement and developing community awareness through demonstrations and explanatory signs and apps that support citizen science.
- More engagement with the industry sector, particularly through peak bodies as this provides the opportunity to develop awareness and maximise participation in the Lab's activities across all community stakeholders.
- Workshops that develop future projects and collaborations across government, industry and the wider community. These workshops could be focused on specific issues to allow for more detailed discussions that can help to resolve sticking points and develop future research ideas and collaborations.

- The Lab should engage and raise visibility of research products at other public events in Darwin that can help develop awareness more broadly of cooling initiatives and how it relates to the daily lives of people from across the community.

Next steps

A current focus of the Lab is the delivery of the inaugural ‘Tracking Darwin’ output that will provide a public-facing commentary on the key challenges for Darwin’s liveability, sustainability and resilience. The issues explored will be within the remit of the Lab with a focus on the collection of datasets that can help monitor change in Darwin from efforts to cool the city and improve liveability and inform future policy and decision-making to deliver system benefits of liveability, sustainability and resilience. The data stories are being collated around the following challenges:

- Reducing the Urban Heat Island – there are a number of initiatives underway to reduce temperature and improve the liveability of Darwin – what works and what doesn’t?
- Healthy outdoor environments are an important part of liveability – how do the people of Darwin interact with the outdoor environment and how does that outdoor environment return benefit?
- Water for cooling – how much is needed for a cool and liveable Darwin, and how much pressure does that put on a sustainable and resilient water supply for Darwin?
- Sustainability towards net-zero – what is the situation, and how can Darwin, with all its challenges, adapt to a net-zero future?
- Improved indoor liveability – how can improvements in tropical design lead to more liveable and sustainable indoor environments?

2.3 Outdoor environment

Overview

Darwin is experiencing a significant increase in the annual average number of days above 35°C with projected increases from 11 (historical average 1981-2010) to 43 by 2030 and to between 111 and 265 days by 2090². The warming climate will pose liveability challenges to Darwin residents with the urban heat island effect meaning that the built-up areas of the city will be particularly hot in the future. Meanwhile, population growth and land development may place increasing pressure on existing green spaces.

The City of Darwin has declared a Climate Emergency and has prepared an integrated strategic response, while the Northern Territory Government has released its Heat Mitigation and Adaptation Strategy. Yet data and knowledge gaps remain that, once identified, would optimise design and management of Darwin’s urban forest and urban heat mitigation action. Our research on the Outdoor Environment will develop better understanding of how people interact with the outdoor environment

² Moise, A. et al. 2015, Monsoonal North Cluster Report, Climate Change in Australia Projections for Australia’s Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia

in Darwin, informing city improvements and design guidelines, and helping decision-makers to make strategic decisions on how to cool the city and provide thermal comfort.

Objectives

- Measure changes and effects of urban greening and cooling initiatives, identifying the most cost-effective approaches for heat reduction that maximise benefits to the community and environment.
- Encourage more comprehensive recognition and representation of indigenous perspectives and knowledge on nature-based solutions informing policies and practices for shaping Darwin's urban environment.
- Improve scientific understanding of the water balance required to support greening and cooling initiatives in Darwin and consolidate the wider knowledge and practices for improving human thermal comfort into public guidance.

Key outcomes and impacts for 2021-2022

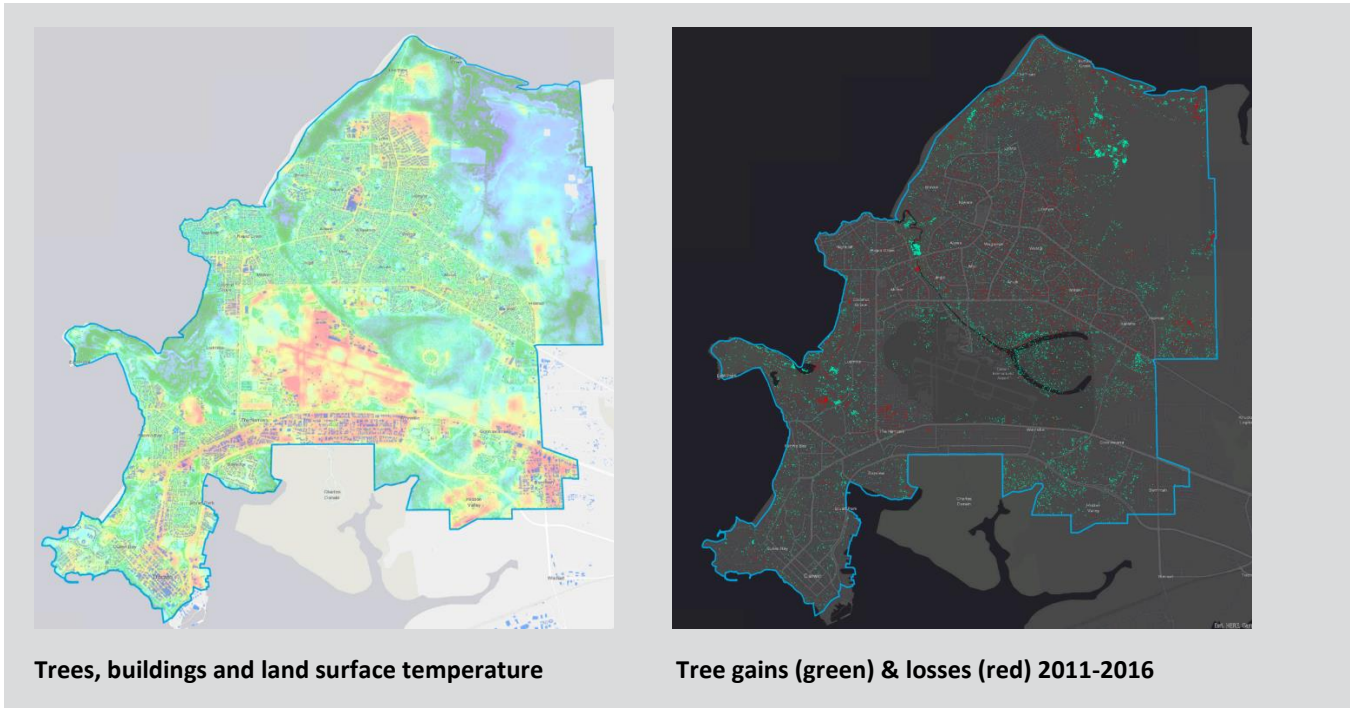
Digital twin to provide evidence-base for supporting decisions on cooling and greening strategies and monitoring outcomes

The Lab has developed a virtual model of Darwin, i.e., a [digital twin](#). This will enable city managers such as the City of Darwin to monitor change in key indicators (e.g. canopy cover, temperature and air quality), and test the impact of changes in asset management and scenarios of urban development. The initial application of the Digital Twin involves evaluating the economic value and return on investments of cooling and greening initiatives, specifically around increasing and maintaining Darwin's urban forest. The digital twin currently allows investigation of urban vegetation impacts on land surface temperatures at a much finer resolution than previously possible.

The Lab has worked closely with the City of Darwin to undertake analysis of tree planting scenarios. The analysis of scenarios developed through this work were incorporated in the digital twin to evaluate trade-offs and inform the City of Darwin Greening Strategy. Our work identified the key costs and benefits to be included in valuing ecosystem services of tree planting.

Urban Monitor: City scale analysis of digital aerial photography

In collaboration with the CSIRO's [Urban Monitor](#) team, the Lab generated high-resolution (0.2 metre) maps of presence, area, condition, volume and height of urban vegetation (e.g. trees, shrubs and grass), impervious surfaces (e.g. buildings, roads), and bare ground and water for the years 2011, 2016, and 2021. This information, coupled with local tree inventory data about species composition and condition was used to quantify and value the stocks and flows of ecosystem services provided by urban vegetation based on the international System of Environmental and Economic Accounting (SEEA) framework. This can be used to assess net changes in tree cover down to lot scale and provides a benchmark to evaluate future changes in tree canopy cover.



Ongoing data collection to monitor and evaluate heat mitigation trials

The Lab has undertaken monitoring of Stage 1 heat mitigation trials to determine their effectiveness in reducing urban heat island effects. Initial ground-based thermal scans of reflective and lighter coloured road surface trials demonstrated that they provide a surface cooling effect up to 7°C when compared to conventional road surfaces. Shading provided by greening and shade structures were found to reduce surface temperatures by up to 20°C when compared to adjacent areas with no shade (Figure 4). LiDAR scanning of the State Square precinct greening provides data to measure the rates of tree growth and mortality, and to model the shading and cooling effects of green spaces on the urban environment.

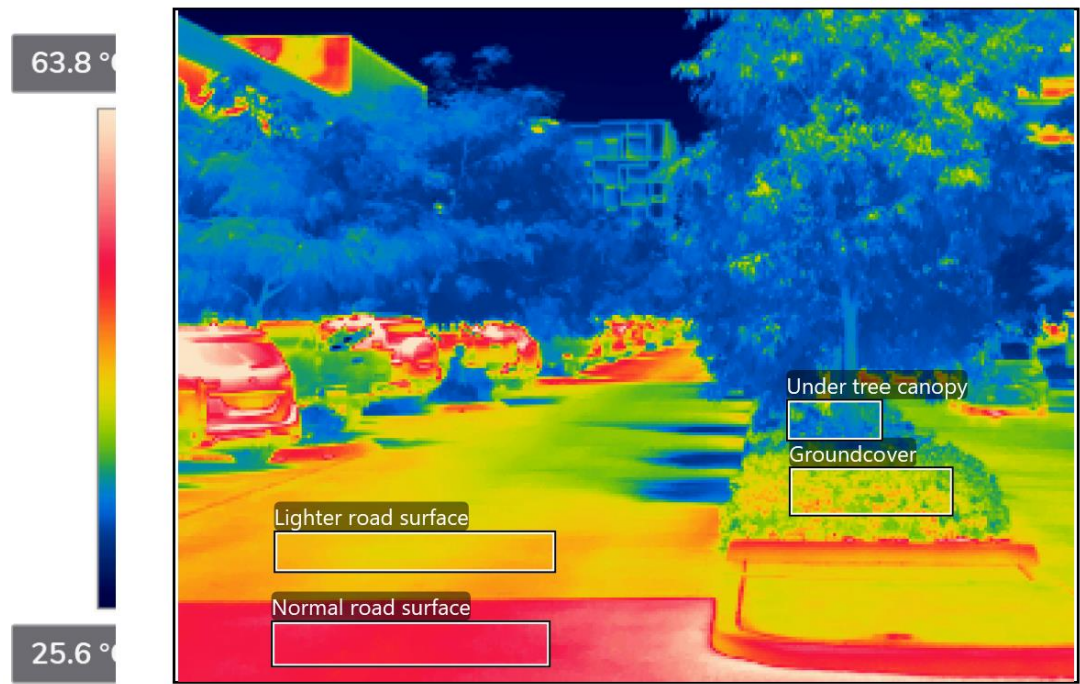


Figure 4: Thermal image taken of Cavenagh Street, Darwin, in November 2021

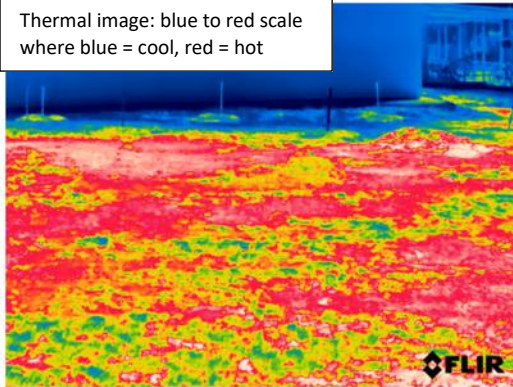
A [CDU led project](#) in collaboration with CSIRO has developed drone-based urban data collection capability through a PhD student. This has involved the use of drones with radiometric cameras to collect thermal imagery of Darwin to deliver heat maps to a quality for incorporation into the Digital Twin. Wet and dry season drone thermal imaging has been undertaken at the development site for Danala, which has highlighted the challenges for outdoor workers – see this [link](#) for images.

The Lab analysed City of Darwin's environmental sensor network. This [project](#) saw CSIRO scientists work closely with the City of Darwin 'Switching on Darwin' project team following the rollout of an environmental sensor network across the CBD and Greater Darwin. The project sought to resolve issues with data quality and recommend solutions and ongoing maintenance protocols in order to create datasets that could be used for public good and stimulate smart city innovation and assist decision making and operations of City of Darwin.

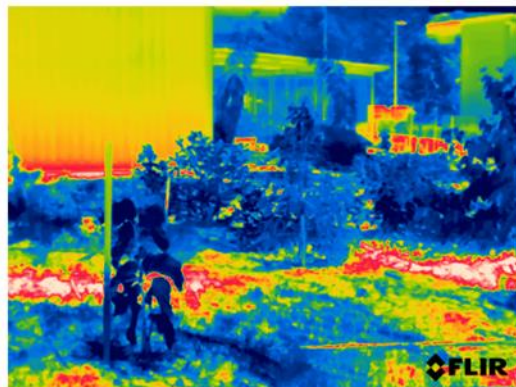
Validating surface cooling benefits of Royal Darwin Hospital's campus greening

The Lab has worked with Sustainable Healthcare Committee at Royal Darwin Hospital to monitor the benefits of the campus greening projects. Measurements highlighted the surface temperatures of planted areas were more than 20 °C cooler than surrounding paved surfaces. These images demonstrate the relative cooling effects of shaded and irrigated green spaces and the transformative effect of planting zones over a relatively short period of time in a wet/dry tropical climate, which reflects the correct selection of tree species for the sites and the use of dry season irrigation to maintain plant growth.

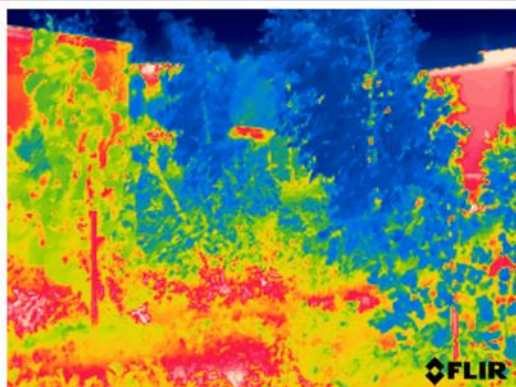
Thermal image: blue to red scale where blue = cool, red = hot



15 Dec 2021



16 Sep 2022



11 Mar 2023

Improved guidance for outdoor thermal comfort in Darwin

The Lab undertook a [project](#) on managing extreme heat and smoke in Darwin for outdoor workers and other vulnerable groups. Led by the University of Tasmania with collaboration and support from the University of Southern Queensland, Australian Catholic University and CSIRO, this project sought to better understand the prevention and management of heat stress and poor air quality in Darwin, and the association between outdoor temperature, humidity and symptoms such as headache, dizziness and fatigue. The project recruited outdoor workers from Darwin-based organisations to use the [AirRater app](#) and conducted focus group discussions with outdoor workers, educators and sportspeople with the aim to understand the barriers and enablers in preventing and managing heat stress and poor air quality when working or being active outdoors. The [report](#) provided key recommendations to address these findings.

Understanding community values for greenspace and biodiversity

A [project](#) co-led by Larrakia elder, Lorraine Williams, is working to develop a baseline assessment of Darwin's biodiversity through targeted interviews, an online survey, and engagement with key stakeholders. The project will develop a shared understanding of the processes that threaten the persistence of biodiversity in Darwin and begin to develop a set of recommendations for approaches aimed at monitoring, maintaining and enhancing urban biodiversity while keeping Darwin cool.

The project Understanding Parks and Green Spaces in Darwin undertook a 'Nature experience in the city' survey and conducted focus groups, to research how different user groups in Darwin interact with green spaces. This will help to understand needs and preferences for amenities, and how different people value and use green spaces in Darwin to progress green space design to mitigate heat and be attractive, usable and beneficial to city residents and visitors.

Next steps

- The Lab is developing a platform to host the digital twin, which will enable partners and eventually the broader community to access and interrogate datasets, such as the change in tree canopy over the last decade and land surface temperature.
- The Lab is working with partners to monitor and evaluate heat mitigation and sustainability approaches being implemented in Darwin City Deal projects, such as the Civic and State Square revitalisation.
- The Lab is engaging with the NT Government's Office of Water Security and Power and Water Corporation's Living Water Smart program to evaluate the role of water sensitive urban design in a cooler and greener Darwin.
- Interviews and place-based recording of biodiversity knowledge with Larrakia people is continuing, and we are working with the Larrakia rangers to design and test how ecological monitoring might track the impacts of environmental stressors, including climate change, on biodiversity values.

2.4 Indoor environment

Overview

One of the major adaptations to heat (and humidity) in buildings in the tropics is the use of air-conditioning. Since the 1970's house designs in tropical Australia have shifted from 'high set' passive designs promoting natural ventilation and air movement, to tightly sealed 'temperate style' housing with high thermal mass and reliance on air-conditioning.³ The energy required to cool the typical residential building in Darwin has been projected to increase by 78% by 2060 due to climate change⁴. Our research on the Indoor Environment explores alternative design solutions for tropical climates, working with governments, industry and design experts to test solutions that offer improved thermal comfort and reduce energy demand. The research will also support the NT Government's ambitious target to achieve 50% renewable energy electricity consumption by 2030.

Objectives

- Establish smart building platforms that allow data-rich energy management in commercial buildings, demonstrate effective ways to integrate renewable energy production and energy efficiency to manage demand and support net-zero emissions targets.
- Contribute to the science and build evidence that informs building energy policy (Section J of the National Construction Code).
- Model relationships between residential building energy efficiency and indoor thermal comfort using CSIRO AccuRate software, creating outputs tailored to Darwin's climate and design professionals.

Key outcomes and impacts for 2021-2022

Increasing the value of onsite renewables in Darwin through data driven analytics

The Lab commenced a [project](#) that was led by CDU in collaboration with CSIRO Energy and City of Darwin. The project, which was supported by the Australian Renewable Energy Agency (ARENA) connected three existing non-residential buildings in Darwin to the [Smart Building Data Clearing House](#) (DCH). This provided insights on the approaches and barriers to upgrading existing buildings to be capable of handling digital technologies that make use of near real time data and micro services available in the DCH. The DCH can identify opportunities in Darwin for existing building stock to optimise the use of renewables and reduce energy consumption through demand response strategies.

Darwin Home Comfort Rating

This co-led [project](#) between the NT Government and CSIRO's Building Energy team, with collaborators from Queensland University of Technology (QUT) and University of Adelaide is developing a user-friendly tool with 'for information' living room and bedroom comfort ratings that can be used to improve passive comfort outcomes in residential building. As well as improve building design and resilience for future climates, and to reduce health risks when air conditioning is not available.

³ Oppermann, E., et al., *Heat, health, and humidity in Australia's monsoon tropics: a critical review of the problematization of 'heat' in a changing climate*. WIREs Climate Change, 2017. 8(4)

⁴ Haddad, S., et al., *Holistic approach to assess co-benefits of local climate mitigation in a hot humid region of Australia*. Scientific Reports, 2020. 10(1): p. 14216.

Professor Wendy Miller of QUT led a comprehensive analysis that provides the evidence to support the development of a comfort rating tool with 'for information' living room and bedroom comfort ratings for Darwin dwellings (final report available [here](#)).

The Home Comfort Ratings have been implemented in a trial version of CSIRO's accredited Nationwide House Energy Rating Scheme (NatHERS) software, AccuRate. This can be used on a voluntary basis for design optimisation and can complement the current energy ratings used to demonstrate compliance with National Construction Code energy efficiency requirements (Section J).

Darwin Home Comfort Rating Forum

The project hosted a community and industry forum to launch a new Home Comfort Rating system for Darwin residential building designs. This forum included presentations on the science that underpins the ratings, and a live demonstration of how Home Comfort Rating can be used to optimise home design for improved thermal comfort outcomes. There was also the opportunity for questions to the project team and a discussion around next steps, which includes running a trial of the software with local building assessors.



Next steps

- Rollout of Darwin Home Comfort Rating in trial version of AccuRate. This will include working with key industry and government stakeholders to design the project, which will include providing incentives for accredited building energy assessors to trial the approach.
- Develop communications material that build community awareness of how the Comfort Rating can be used in house design/purchase decisions to improve thermal comfort and reduce reliance on air conditioning.
- Explore use of smart building data analytics for identifying and evaluating opportunities for energy demand strategies and increased adoption of onsite renewables in non-residential buildings. This research can help support the adoption of new energy efficiency provisions for all new non-residential buildings in the Northern Territory from 1 October 2023.

3 Applied research projects 2020 – 2023

Strategic purpose	Project Title	Project Partnerships	Scope	Benefits and Impact
Heat mitigation, liveability & tropical design	P1. Understanding community needs for urban green space	Dr John Gardner and Dr Brenda Lin , CSIRO	Understand how different user groups in Darwin interact with green spaces and how their needs and preferences for amenities and benefits vary.	Green spaces in Darwin can be re-designed to be more functional, attractive and beneficial (assist with cooling) to residents and visitors.
	P2. Analysis of CoD sensor network and integration with AirRater	Dr Erin Dunne and Jennifer Powell , CSIRO; Krishan Maheson and Jack Silburn, City of Darwin; NT EPA; BoM	Assess CoD environmental sensor network data against NT EPA/BoM reference sites to prepare maintenance and calibration protocols, enabling reliable live data reporting.	Provide localised heat and air quality data for use in AirRater App and other data portals. To provide ongoing evidence to report on spatial and temporal trends.
Tracking Darwin baseline & implementation	P3. Towards a Digital Twin of Darwin to monitor and navigate change	Dr Sorada Tapsuwan , Dr Ray Marcos Martinez and Guy Barnett , CSIRO; Ron Grinsell, Joshua Forner, Eric Lede, Krishan Maheson, City of Darwin; NT DIPL.	Acquisition of spatial and temporal datasets for Darwin to develop a digital twin to monitor change, with initial application focus on environmental economic accounting of ecosystem services provided by Darwin’s green infrastructure.	Evaluate the economic value and return on investment of cooling and greening initiatives, through a data platform to understand, monitor and navigate change in Darwin. Assist Darwin to be a truly Smart City through evidence-based decision making.
	P4. Monitoring, Evaluation and Learning (MEL) baseline data collection	Dr Rachel Williams, Dr Seona Meharg and Dr Tim Muster , CSIRO along with DLL partners	A framework for monitoring and evaluation of the DLL to support learning and inform decision-making within the DLL. In parallel with the Digital Twin, it will monitor the impacts of the Lab and trajectories of Darwin’s liveability, sustainability and resilience.	Maximise value of the DLL and its projects. Darwin and partners learn how to improve liveability and how to get better at it. Provide an evidence-base for liveability outcomes (i.e. activation of public spaces, improved thermal comfort, reduced carbon emissions).
	P5. Larrakia-led Darwin biodiversity values	Adam Liedloff , Emma Woodward and Jon Schatz , CSIRO; Lorraine Williams, Larrakia partner; Ben Smith, Larrakia Rangers.	A working list of Larrakia biodiversity values including habitats and native plant species, that can be considered for Darwin urban greening and protection.	Darwin’s unique sense of place is developed through the lens of engagement with Larrakia Traditional Owners and the Larrakia rangers to incorporate Indigenous knowledge to enhance wellbeing and urban greening.

Capability development with partners	P6. Developing local capacity to monitor and evaluate urban innovations using UAV's	Assoc. Prof Hamish Campbell , Dr Rebecca Rogers, Dr Deepak Gautum and Dr Hooman Mehdizadeh Rad, Charles Darwin University; Dr Shaun Levick , CSIRO.	A collaboration between Charles Darwin University and CSIRO to develop new urban data collection capability through a PhD student. The project will assemble a light-weight fixed wing unmanned aerial vehicle (UAV) with radiometric cameras to enable aerial thermography collection in the Darwin CBD and other zones of interest.	Enhanced local capacity to undertake aerial radiography in Darwin. Provision of aerial radiography data at sufficient cost, scale and resolution to evaluate the effectiveness of city heat mitigation initiatives. DLL-CDU collaboration leads to further innovative proposals.
Managing heat stress	P7. AirRater and outdoor worker heat stress	Dr Sharon Campbell , Dr. Amanda Wheeler, CSIRO (formerly ACU)	Investigation of how vulnerable individuals in the Darwin region of the Northern Territory (NT), Australia, perceive and manage episodes of extreme heat and poor air quality.	Identify gaps in education, infrastructure and policy that could improve the lives and protect the health of vulnerable people living, working and playing in Darwin.
Indoor thermal comfort and energy efficiency	P8. Increasing the value of onsite renewables in Darwin through data driven analytics	Prof. Suresh Thennadiil and Dr Hooman Mehdizadeh Rad, Charles Darwin University. Dr Subbu Sethuvenkatraman and Will Borghei, CSIRO Energy.	Evaluate the opportunities to improving the value of onsite renewables in legacy non-residential buildings by connecting three Darwin buildings to the iHub Data Clearing House (DCH) to provide near real time data.	The outcomes from this project will highlight opportunities in existing building stock that can accelerate the uptake of renewables and reduce energy consumption.
	P9. Darwin Home Comfort Rating	Co-led by Johanna Kieboom, NT DIPL and Dr Dong Chen, CSIRO (Melbourne), with technical reference group of Professor Terence Williamson, University of Adelaide; Associate Professor Wendy Miller, QUT; Dr Mahsan Sadeghi, CSIRO and Ray Fogolyan, Home Star Australia	This project is developing a user-friendly tool with 'for information' living room and bedroom comfort ratings that can be used to improve passive comfort outcomes in Darwin residential building design. The project aims to demonstrate a methodology transferable to other NT and Australian climate zones.	The outcomes seek to give consumers, designers and builders better evidence for house design/selection decision making that build resilience for future climates and to reduce health risks when air conditioning is not available. Energy use from air conditioning is a major contributor to greenhouse gas emissions and climate change.

4 Financial Reporting

4.1 Partner investments

The Darwin Living Lab is a 10-year project running from July 1st 2019 to June 30th 2029. Seed funding of \$6.8 million has been provided by the following partners:


Commonwealth	\$2.7m
CSIRO	\$2.1m
NT Government	\$1.0 m
City of Darwin	\$1.0 m.

Building upon seed funding, additional cash revenue of \$19,143 was sourced through AIRAH to conduct the project *Increasing the value of onsite renewables in Darwin through data driven analytics*. Additional in-kind resource was sourced from CSIRO Energy strategic funds (\$171,185) and partners (\$20,040) to undertake energy-focused projects *Darwin House Comfort Rating* and *Increasing the value of onsite renewables in Darwin through data driven analytics*.

4.2 2021-22 Expenditure

The Lab Management Committee approved resources to be front-loaded within the first four years of the Darwin Living Lab with a view to accelerate early impact. Detail on project expenditure is provided below for the 2021-22 period and whole of life for the Darwin Living Lab.

Item	Project resources secured from aligned programs (Jan 1 2021 - Dec 31 2022)	DLL Project expenditure (Jan 1 2021 - Dec 31 2022)	Total project expenditure (Jan 1 2021 - Dec 31 2022)	DLL Project expenditure (whole of life to Dec 31 2022)
Labour	\$109,575	\$756,153	\$865,728	\$1,276,614
Labour Overhead	\$78,484	\$633,056	\$711,540	\$1,075,951
Operational costs/procurement	\$3,166	\$350,217	\$353,383	\$544,793
Total Position	\$191,225	\$1,739,426	\$1,930,651	\$2,897,358



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