# FEELING COOLER IN DARWIN

Darwin Heat Mitigation and Adaptation Strategy

CITY OF DARWIN

Australian Government

CSIRO

NORTHERN TERRITORY GOVERNMENT

# FOREWORD

The Darwin Heat Mitigation and Adaptation Strategy (the Strategy) is a joint project of the Northern Territory Government and the City of Darwin. It aims to help people experience the best of Darwin's lifestyle by reducing the seasonal impact of Darwin's hot and humid climate, and to help people adapt to future heat-related climate challenges.

The Top End of the Northern Territory has always been a warm and seasonally humid place to live. Well before Darwin was founded, Larrakia Traditional Owners lived in accordance with the seasonality of the region's climate and, as the city developed, progressive efforts were made to meet the challenge of living comfortably in hot and humid conditions. This Strategy aims to build on this history as well as respond to more recent planning and research.

Research commissioned in 2017 by the Northern Territory (NT) Government assessed the heat profile of the Darwin city centre and made recommendations on the potential for selected heat mitigation treatments to reduce city temperatures.[1] Further research has since been completed on the potential effectiveness of these treatments to reduce the cooling energy requirements of buildings and rates of heat-related illness.[2]

Based on this research, and funded by the Darwin City Deal[3] (the City Deal), the NT Government and the City of Darwin (CoD) are trialling recommended treatments such as shade structures, extended urban greenery and the use of alternate road and pavement products.

Established under the City Deal, the CSIRO-led Darwin Living Lab is informing and evaluating these and other heat mitigation measures to help make Darwin a more liveable, sustainable and resilient city,[4] and is expanding our understanding of heat beyond the city centre to the suburbs.[5]

The Strategy maps a path forward to help people feel cooler in Darwin. It has been prepared in collaboration with key stakeholders and combines expert knowledge, skills and resources to comprehensively address urban heat.

Delivered over 10 years, the Strategy will be reviewed every three years to allow the results of trials and additional research to determine further action.

I hope you will enjoy Darwin as a more comfortable and vibrant tropical city as a result of this Strategy.

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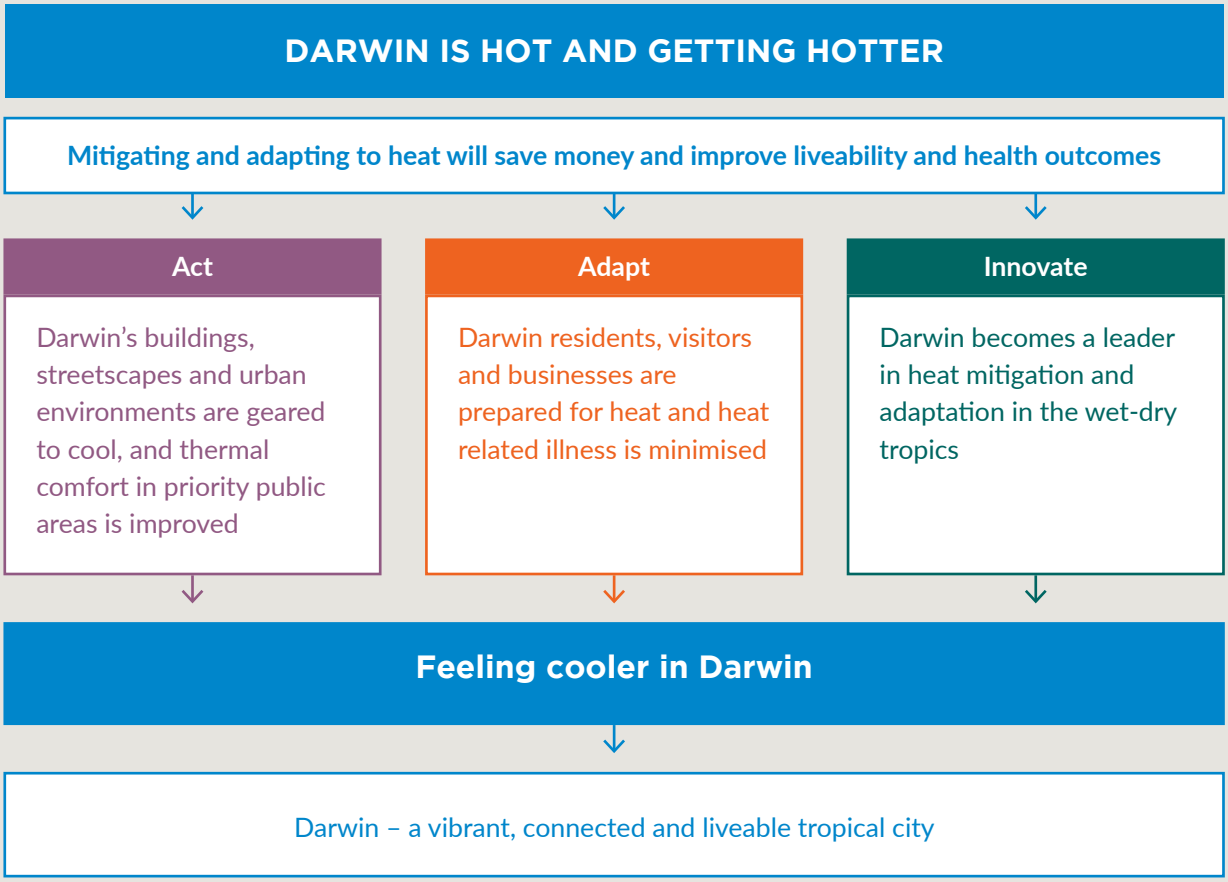
# EXECUTIVE SUMMARY

**The ten year Darwin Heat Mitigation and Adaptation Strategy has been developed by the Northern Territory Government and the City of Darwin. Its underpinning logic and aspirations are illustrated below:**



## The Strategy offers 30 recommendations organised under three goals to help people feel cooler in Darwin:

**Darwin's buildings, streetscapes and urban environments are geared to cool, and thermal comfort in priority public areas is improved.**

1. Identify and implement a suite of incentives and mechanisms to encourage developers, property owners, residents and others to mitigate heat.
2. Review and support planning and construction standards, codes and regulations to achieve better heat mitigation.
3. Promote information on how Darwin communities and businesses can act now to build, retrofit and plant shade trees to mitigate heat.
4. Include heat mitigation measures for public areas adjacent to new and priority existing government buildings and other assets.
5. Develop targets and support action towards increasing tree canopy cover.
6. Reduce the area of heat absorbing exposed surfaces such as bitumen carparks.
7. Increase shade by encouraging the installation of permanent and temporary shade structures.
8. Increase shade by allowing roofs, balconies below a specified height and green walls/planters to project into the public domain.
9. Encourage the installation of cool building technologies for public and private apartments and mixed-use housing development in commercial and central business zones during replacement or new construction.
10. Investigate and trial water sensitive urban designs that will help mitigate heat.
11. Support energy efficiency measures that reduce anthropogenic heat in the city and help with cooling affordability.
12. Support initiatives to promote active and micro-mobility transport, including cool travel routes.

**Darwin residents, visitors and businesses are prepared for heat and heat related illness is minimised**

13. Develop and promote communication products, tools and resources to assist the Darwin community to live and work safely in very hot and humid conditions.
14. Share Indigenous knowledge of ways to manage heat stress in the local climate with the broader Darwin population.
15. Continue to participate in the development of a National Heatwave Warning Framework to ensure an appropriate formal heat-health warning system for Darwin.
16. Develop and implement a plan(s) associated with the alert system that identifies and supports people who are especially vulnerable to heat stress in Darwin.
17. Ensure adequate public heat relief measures are available in Darwin, with particular attention to vulnerable populations.
18. Explore and trial methods to better prevent heat stress for people working or playing sport outdoors.
19. Implement heat adaptation-related actions in the NT Government's Climate Change Response: Towards 2050 Action Plan.
20. Finalise and implement heat adaptation-related actions in the CoD's Climate Emergency Discussion Paper and Draft Strategy.
21. Identify, learn from and promote actions that improve heat-related liveability in Darwin.
22. Analyse temperature and humidity data from the city centre and suburbs and report on trends to determine adaptation strategies.

**Darwin becomes a leader in heat mitigation and adaptation in the wet-dry tropics**

23. Undertake a series of initial projects to establish platforms and baselines for innovation in heat mitigation and adaptation.
24. Host symposiums, think tanks and webinars to catalyse and develop new ideas for heat mitigation and adaptation.
25. Identify, develop and test innovative heat mitigation and adaptation approaches for Darwin.
26. Investigate and implement innovative opportunities to highlight best practice and cutting edge heat mitigation and climate sensitive design.
27. Partner with research organisations, especially those based in Darwin to continue to improve heat mitigation and adaptation.
28. Exchange heat mitigation and adaptation knowledge with other cities, especially those with similar climates.
29. Explore opportunities to deliver heat mitigation and adaptation products and services nationally and internationally.
30. Establish and implement an awards program to recognise excellence and innovation in heat mitigation and adaptation.

# ABBREVIATIONS

| Abbreviation | Full Title |
|---|---|
| AG | Australian Government |
| BoM | Bureau of Meteorology |
| CDU | Charles Darwin University |
| CMC | Department of the Chief Minister and Cabinet |
| CoD | City of Darwin |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| DEPWS | Department of Environment, Parks and Water Security |
| DIPL | Department of Infrastructure, Planning and Logistics |
| DLL | Darwin Living Lab |
| DoH | Department of Health |
| EOI | Expression of Interest |
| GEMS | Greenhouse and Energy Minimum Standards |
| LST | Land Surfaces Temperatures |
| NatHERS | National House Energy Rating Scheme |
| NGO | Non-Government Organisation |
| NT | Northern Territory |
| NTG | Northern Territory Government |
| UAV | Unmanned Aerial Vehicle |
| UNSW | University of New South Wales |

# STRATEGY CONTENTS

# 1. INTRODUCTION

**The Darwin Heat Mitigation and Adaptation Strategy is an initiative of the Darwin City Deal in acknowledgement that heat, and how we respond to it, influences Darwin's future. The Strategy builds on detailed baseline research[1,2,5] to:**

- **describe the heat challenge that Darwin faces, why it's important to take action and what success looks like (Sections 2, 3 and 4)**
- **outline heat mitigation and adaptation opportunities relevant to the wet-dry tropics in terms of built and living infrastructure (Section 5), people (Section 6) and innovation (Section 7).**

As City Deal partners, the NT Government and the City of Darwin have developed the Strategy with the support of the CSIRO's 'Darwin Living Lab', a 10-year City Deal initiative to catalyse efforts to cool and green the city through science and collaboration. For the next decade, engaging and partnering with community members, business, NGOs, researchers and other stakeholders will remain a priority of the Strategy.

Darwin has a wet-dry tropical climate, experiencing warm, balmy dry seasons and hot, humid monsoonal wet seasons (Figure1). Larrakia people have a more detailed way to describe seasons. For the Larrakia, there are seven seasons guiding the hunting and gathering of foods.

Temperature increases due to climate change, as well as already relatively high city temperatures, means that mitigating and adapting to heat are critical to maintaining and growing Darwin as a vibrant, connected and liveable tropical city; the vision of the City Deal.

'Feeling Cooler in Darwin' has three key goals:

- Darwin's buildings, streetscapes and urban environments are geared to cool, and thermal comfort in priority public places is improved.
- Darwin residents, visitors and businesses are prepared for heat, and heat-related illness is minimised.
- Darwin becomes a leader in heat mitigation and adaptation in the wet-dry tropics.

Although the Strategy focuses on the city centre and the City of Darwin local government area, most of its actions are relevant to Palmerston, Litchfield Shire and Top End communities.

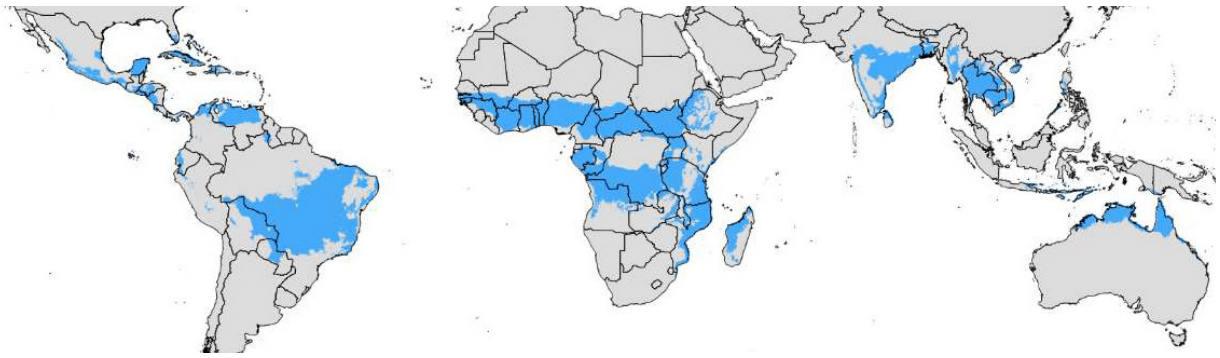


Figure 1 - Darwin shares its wet-dry tropical climate (Köppen-Geiger climate classification 'Aw') with major cities such as Bangkok, Ho Chi Minh City, Mumbai, Accra, Brasilia, Cali, Havana and Cancun.[6]

## Box 1 - Mitigating heat through responses to climate change[7,8,9]

Climate change is increasing temperatures and heat extremes in Darwin, making heat mitigation and adaptation essential for the city to be liveable into the future. The NT Government, City of Darwin and Australian Government are committed to reducing greenhouse gas emissions to tackle climate change. The NT Government's 'Climate Change Response: Towards 2050' Strategy and three-year Action Plan outlines a range of initiatives to reduce emissions and adapt to climate extremes. City of Darwin's Climate Emergency Strategy 2030 identifies emissions reductions and heat-related actions and is the prime environmental strategy to the Greening Darwin Strategy 2030.

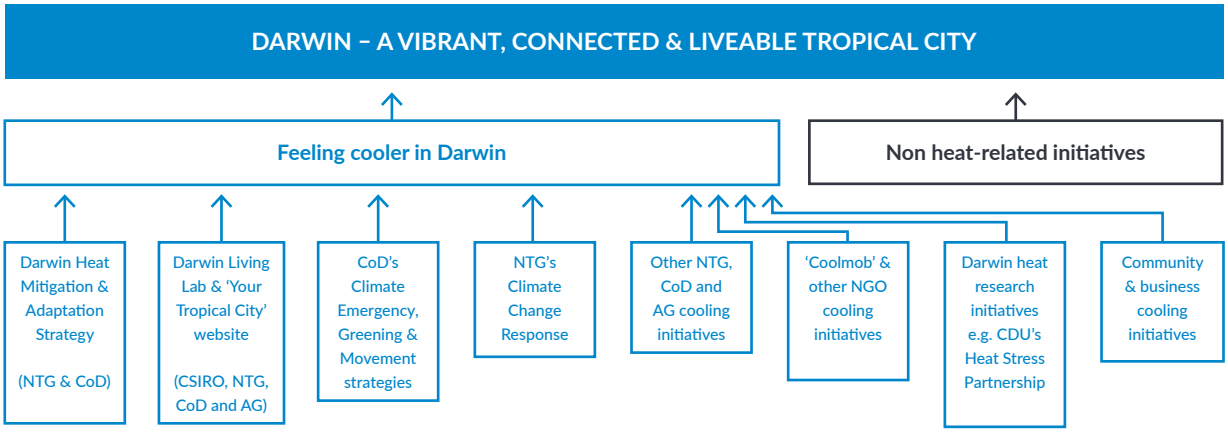




**Figure 2** - The Darwin Heat Mitigation and Adaptation Strategy works with other initiatives to contribute to alleviating heat and in turn to helping maintain Darwin as a vibrant, connected and liveable tropical city.

# 2. DARWIN IS HOT AND IS GETTING HOTTER

**During the months of May to September Darwin is the envy of the rest of Australia, experiencing average maximum temperatures of 31°C, minimums of 21°C and low levels of humidity.[10] However, from October to April temperatures increase and humidity rises. November is Darwin's hottest month, with an average night-time minimum of 25°C and daytime maximum of 34°C which feels more like 42°C. This 'feels like' or apparent temperature better reflects people's thermal comfort[11] because it includes relative humidity which influences how much the body can cool by sweating.**

## Darwin's city centre can be especially hot

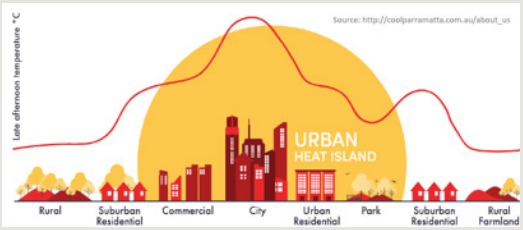
A 2017 study[1, 2] commissioned by the NT Government investigated heat in Darwin's city centre using thermal imagery and measurements of street level air temperature, relative humidity, wind speed and direction, solar radiation and heat flux. The study found:

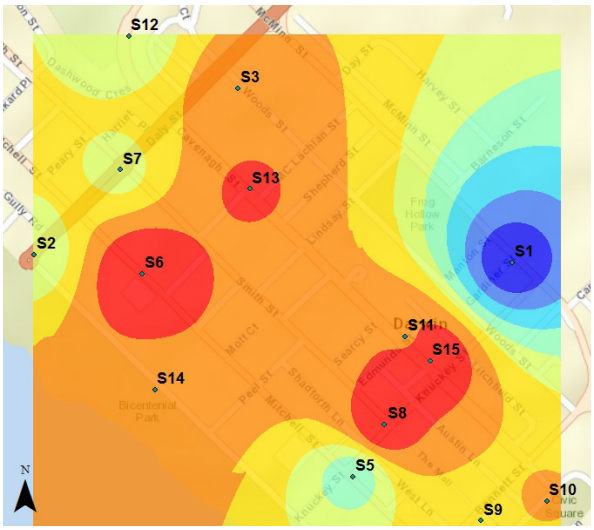
- Darwin city centre is a 'heat island' (Box 2), often having temperatures up to 2-3°C hotter than surrounding suburbs, with this effect most intense at night.
- City temperatures are higher at low wind speeds.
- City temperatures are higher in the central part of the CBD.
- Hot spots include Cavenagh Street, Knuckey Street (especially near Smith St) and Mitchell Street near the Darwin Entertainment Centre.
- Car parks, roofs and streets have surface temperatures above 60°C, whereas the maximum surface temperature of trees is 38°C.

| Surface | Temperature range °C |
|---|---|
| Carparks | 47 - 67 |
| Roofs | 48 - 66 |
| Streets | 55 - 63 |
| Pavements | 49 - 56 |
| Greenery | 32 - 46 |
| Trees | 28 - 38 |

### Box 2 - Cities are hotter than their surrounds

Urban areas often exhibit higher temperatures than surrounding rural areas, an effect known as an **urban heat island**. Numerous factors contribute to an urban heat island, including dense construction, dense populations, and heat from vehicles. Urban overheating negatively impacts thermal comfort, energy consumption and health.[12,13]




**Legend**

**Max UHI intensity-N winds- 2PM**

| | |
|---|---|
| 3.5 - 3.94 | 5 - 5.18 |
| 3.95 - 4.36 | 5.19 - 5.34 |
| 4.37 - 4.71 | 5.35 - 5.54 |
| 4.72 - 4.99 | 5.55 - 5.9 |

Figure 3 - Darwin city centre heat 'hotspots'.

The study established that Darwin City is generally hotter than surrounding areas because:

- Dark coloured carparks, roads, pavements and buildings absorb solar radiation and release as heat.
- Heat released from air-conditioning outlets and engines (known as anthropogenic heat) adds to higher ambient temperatures in the city.
- Water temperatures in Darwin Harbour are also relatively high in the build-up and wet seasons so without a large difference between land and sea temperature, sea breezes tend to be limited.
- Wind speeds in the city centre are reduced by buildings and other barriers blocking air flow and trapping warmer air. For example, when the wind speed is 5 metres per second at the airport, the wind speed in the city centre is closer to 0.5 metres per second[1].

## Greater Darwin can be very hot too

Heat mapping[14] of Darwin suburbs and rural areas shows high land surface temperatures where there is a high proportion of built infrastructure such as rooftops, carparks and (often dark coloured) paved surfaces (e.g. industrial areas of Winnellie and Pinelands), and where there are extensive areas of bare ground (e.g. at the airport) (Figure 4). Cooler areas are found near the coast and places with dense tree cover (e.g. rainforest and riverine vegetation), other green vegetation, irrigated playing fields, golf courses and gardens. Other factors influencing this heat profile include distance from coastal breezes and topography.

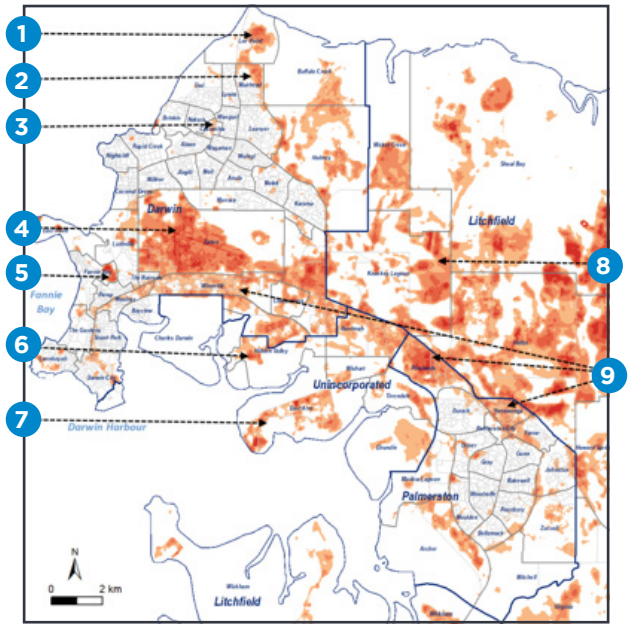



Figure 4 - Suburban and rural features generating high land surface temperatures (LST) based on dry season surface temperatures from satellite imagery[14]

## Global warming is already increasing Darwin temperatures

Between 1910 and 2013, average temperatures in northern Australia increased by ~0.9°C. By 2030 they are projected to rise a further 0.5 to 1.3°C, and by 2090 temperatures are projected to be between 1.3°C (low emissions scenario) and 5.1°C (high emissions scenario) warmer than 2005 temperatures.[15]

The number of days per year with a temperature over 30°C in Darwin has also risen steadily (Figure 5), and Darwin can expect a significant increase in the average number of days per year above 35°C with projected increases from 11 (1981-2010) to 43 by 2030 and to between 111 and 265 days by 2090[16], with the newest evaluations suggesting up to 317 days equal to or above 35°C in anyone one year by 2090 [17]. In 2019, there were 45 days above 35°C, including a record 11 days in a row, already exceeding projections for 2030. In 2019 we experienced the highest daily minimum ever recorded in Darwin, at 30.2°C.

Climate models predict small decreases in relative humidity over the century in northern Australia[18].

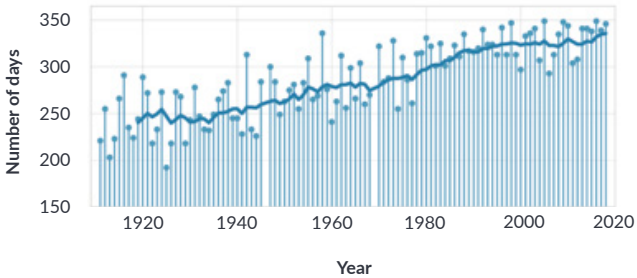



Figure 5 - Darwin is experiencing an increasing number of days above 30°C each year[19]

# 3. WHY WORRY ABOUT A FEW DEGREES?

**Working to reduce the frequency, duration and/or severity of extreme heat impacts as well as supporting people in Darwin to feel cooler, can generate economic, environmental, cultural and social benefits (Figure 6).**

### A more liveable city

Most people don't like feeling too hot and sticky. Darwin's heat and humidity can put people off visiting and is one of the main reasons people choose to leave the Territory.[20,21] It affects the amount of time people want to spend outside which in turn impacts recreation, lifestyle, service and retail experiences and businesses. Working to help people feel cooler in Darwin, and promoting this, will help make Darwin a more enjoyable place to live in and visit. Providing improved thermal comfort can help to attract and retain people and improve the quality of life in Darwin.[22,23]

Rising temperatures and heat extremes have many implications for the Territory beyond those included in this Darwin-focused Heat Mitigation and Adaptation Strategy. Such implications, and actions to respond to them, are described in other publications such as the Northern Territory Government's 'Climate Change Response: Towards 2050' strategy and its supporting documents.

### Better health and wellbeing

Heat exposure kills more people in Australia than all other natural hazards combined[24] and many health risks are linked to extreme or unrelenting heat. In Darwin an increase of just 1°C on hot days with high humidity can see a significant increase in heat-related hospital admissions.[2] In addition to causing physical illnesses, extreme heat negatively affects mood and exacerbates pre-existing mental health conditions, and is linked to increased occupational injuries, violence and suicide rates.[25]

When humidity is combined with high temperatures, health issues such as infections, asthma and poor sleep can also be exacerbated. These heat-health risks affect some sectors of the community more than others. Mitigating heat in Darwin, and helping people to be more prepared for it, will save lives, reduce adverse health outcomes and improve people's sense of well-being in the Top End.


**Figure 6** - Some benefits of mitigating and adapting to heat in Darwin


### Increased productivity and more jobs

Heat and humidity affect the ability of workers to undertake work safely and effectively.[26] This not only impacts individual worker well-being, but reduces productivity at work across Australia by about $7 billion annually.[27] By 2030, heat stress is forecast to decrease productivity in Australia by the equivalent of 10,000 full time jobs annually.[28] Action on heat mitigation and adaptation will improve productivity, create jobs and save businesses money. If we can develop our expertise in heat mitigation products and services, even more opportunities for Darwin businesses will be generated through local demand and exports.

### Reduced electricity use and emissions

A large proportion of Darwin's electricity is used for cooling and this demand increases as temperatures rise. Installing heat mitigation treatments such as reflective surfaces, shading and greenery across the city centre could reduce peak electricity demand by 2% and total cooling load by 7%.[2,29] Although this may seem low, it is large in an international context. In addition to this, fitting office and residential buildings with better insulation and more effective cooling systems offers an opportunity to further reduce electricity use, save money and decrease the heat generated by air conditioners. Reduced electricity use will also reduce any greenhouse gas emissions associated with electricity generation.

# 4. WHAT DIFFERENCE CAN WE MAKE, AND HOW?

The NT Government and City of Darwin recognise the need to 'Act', 'Adapt' and 'Innovate' to feel cooler in Darwin – **act** now to mitigate heat with the knowledge that we have, **adapt** to the heat impacts that can't be mitigated and **innovate** to develop new approaches to heat mitigation and adaptation tailored to the wet-dry tropics. The Strategy sets three overarching goals for these drivers (Figure 7). Participation by Darwin businesses and the community will be essential to achieving these goals by 2030 and help position Darwin as a more vibrant, connected and liveable tropical city.

**Act – Darwin's buildings, streetscapes and urban environments are geared to cool, and thermal comfort in priority public places is improved.**

We want to plan, design, build and plant with heat mitigation as a priority. We want to increase the area of cooling vegetation and shade, and decrease the area of heat absorbing paved surfaces, as well as trial innovations to capitalise on the cooling benefits of breezes and water.

**Adapt – Darwin residents, visitors and businesses are prepared for heat, and heat related illness is minimised.**

We aim to increase awareness and understanding of the effects of heat so that the community, as well as businesses and government, are better prepared for periods of extreme heat, reducing heat related illnesses and mortality. Being better prepared for and adapted to heat also means we can make the most of the outdoor opportunities that Darwin has to offer.

**Innovate – Darwin becomes a leader in heat mitigation and adaptation in the wet-dry tropics.**

We want Darwin to lead the way in heat mitigation and adaptation in the wet-dry tropics. If all levels of government, industry, academia and the community, including Larrakia people, work together to identify, test and implement their ideas we can develop new opportunities for how we respond to Darwin's hot and humid climate, and share these with other cities.

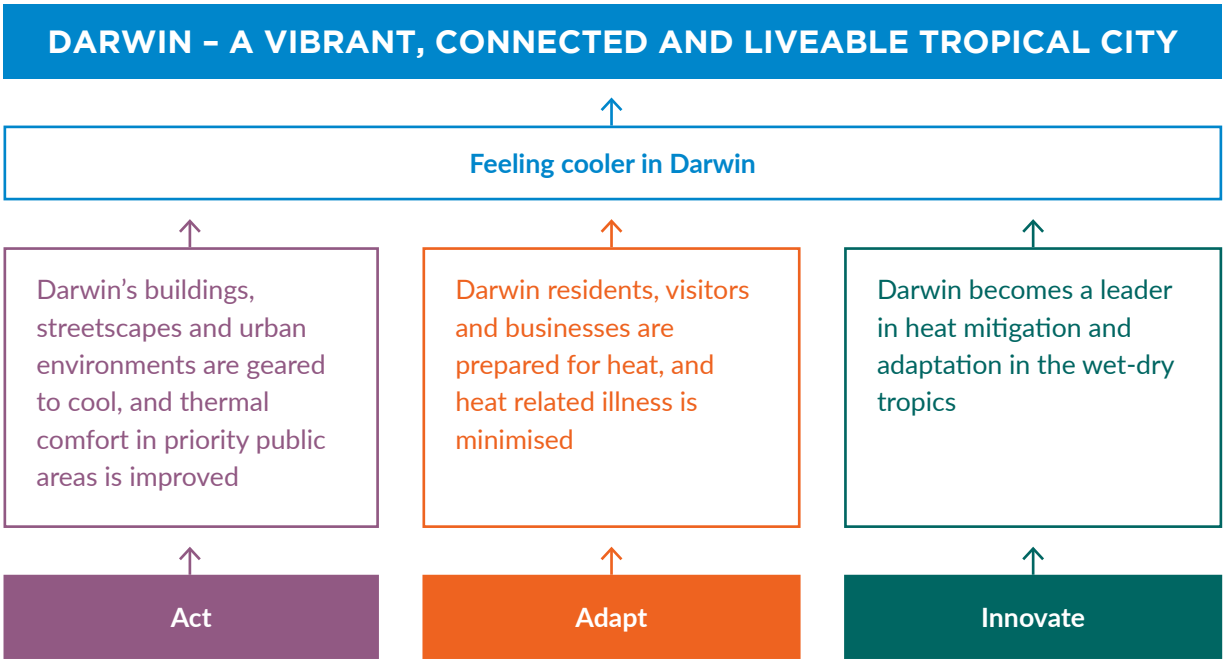



Figure 7 - Strategy logic hierarchy

# 5. ACT - DARWIN'S BUILDINGS, STREETSCAPES AND URBAN ENVIRONMENTS ARE GEARED TO COOL

**Darwin has many opportunities to better mitigate heat – for example, tree canopy cover is low compared to other Australian cities,[30] about a third of the city is unshaded bitumen[2] and many buildings could be more sensitive to our climate[31] – and we can immediately adopt strategies to enhance the city and suburbs for cooling (Figure 8).**

## 5.1. Plan and design for heat mitigation

Good planning and design to maximise cooling is particularly important in wet-dry tropical cities such as Darwin which face a combination of temperature, humidity and seasonal water challenges. Construction codes, design standards and planning scheme requirements, guidelines and area plans need to consider heat-mitigating factors such as capturing breezes and minimising absorbed solar radiation; as well as recognise the influence of nearby buildings, topography, green spaces and other features on microclimates.

In Darwin, planning and designing to facilitate airflow through the alignment and position of streets, structures and green spaces has a particularly important influence on thermal comfort by removing accumulated heat and directly cooling pedestrians.

Planning and design that incorporates street trees, parks and tracts of trees with dense canopies can help cool urban and suburban areas even when there is very little wind, and provide amenity and biodiversity benefits.

Water sensitive urban design can also provide a mechanism to reduce temperatures through retaining soil moisture and cooling via evapotranspiration.[32]

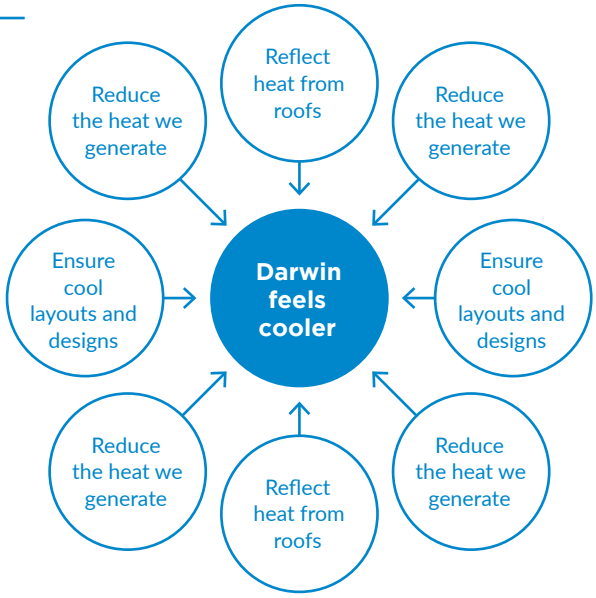



**Figure 8** - Approaches that can contribute to heat mitigation in Darwin

### Box 3 - Suburbs can be geared to cool through good planning and design

In new developments, street orientations along with green space size, style and position can increase exposure to cooling breezes, blocks can be staggered to help airflow, houses set back several metres from the street and gaps between houses wide enough to maximise cross ventilation and shade tree plantings. Dwelling design can include passive cooling features such as parallel windows in living areas for cross air flow, large roof eaves and covered outdoor areas, and planting space for shade trees. In some areas duplexes with shared walls and double storey house designs that increase room for greenery may also assist cooling. Guidelines for the Darwin suburb of Breezes Muirhead demonstrate an effective design for cooling.[33]

Planning and design that reduces the area of bitumen and other heat-absorbing surfaces will help Darwin feel cooler - for example, undertaking regulation and policy reform and encouraging multi-storey or under-ground carparks can reduce the area of exposed carpark.

## 5.2. Build, retrofit and plant for heat mitigation

Heat mitigation technologies and treatments such as shade structures, vegetation and water features are well-used across the world, and locally in Darwin to improve thermal comfort. Other treatments such as reflective and permeable materials are becoming more prevalent as technologies evolve and temperatures increase.[4,34,35]

Modelling commissioned by the NT Government assessed the effectiveness and cost of five treatment types to mitigate heat in Darwin's city centre (Box 4). The modelling shows that, relative to a 2017 baseline scenario, new heat mitigation treatments in the city centre can decrease local outdoor air temperatures by up to 6.5°C, and whole of city centre air temperatures by up to 2.8°C. Results also show that these heat mitigation treatments can decrease the surface temperatures of roofs, car parks and streets by 25°C locally and by 15°C across the city centre.

### Box 4 - Heat mitigation treatments modelled for Darwin

**Cool carparks, roads and pavements** - Darwin's carparks, streets and pavements absorb solar radiation and radiate heat. Cooler surface temperatures can be achieved by using lighter coloured or reflective materials but care is needed to avoid unwanted glare and simply reflecting solar radiation onto other surfaces.

**Increase trees and greenery** - Vegetation can play a key role in cooling urban temperatures through shade and evapotranspiration. Greenery includes:

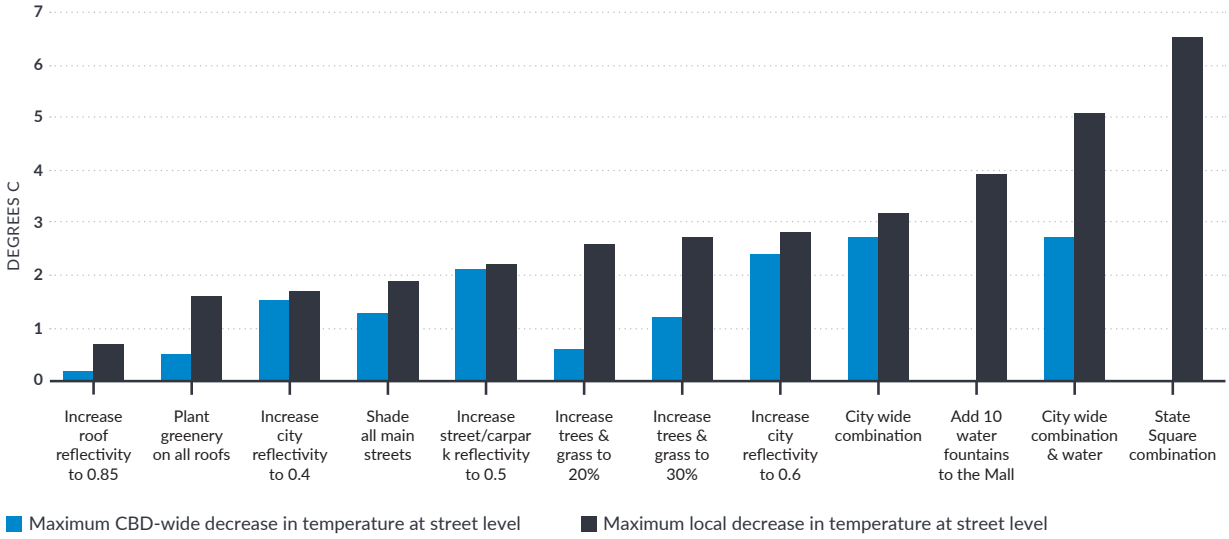
- *Street trees* - Trees planted along streets and in city car parks reduce exposure to solar radiation and provide shade for pedestrians, buildings and vehicles.
- *Green roofs* - Green rooftop gardens prevent roofs absorbing heat and therefore reduce air-conditioning needs but have limited effect on thermal comfort at street level.
- *Parks and green spaces* - Tracts of trees with dense canopies can help to cool nearby urban areas even when there is very little wind because cooler air from these green spaces is drawn to hotter urban areas by rising air currents that generate breezes. Green grass areas have less capacity than trees to mitigate heat, but can provide relief from hot bitumen.

**Construct shade** - Shade from buildings, balconies, awnings, shade sails and other built structures creates cooler microclimates by reducing the amount of solar radiation from reaching street level. Built shade structures are more effective if they are constructed from light-coloured materials and allow breezes to penetrate.

**Reflect heat from roofs** - Increasing the reflectivity of rooftops to redirect rather than absorb solar radiation can mitigate urban heat. Reflectivity can be increased by painting roofs a lighter colour, using light-coloured roofing materials, applying a heat-reflective coating, or using specialised roofing materials such as reflective roof tiles or cool membranes. Care is needed to avoid glare and solar radiation reflecting onto taller buildings.

**Integrate water** - Fountains and other water features can reduce temperatures through evaporative cooling but can use large amounts of water and benefits may be minimal when there is high humidity. Increasing tree cover and the reflective surface of carparks and other pavements offers the best investment for reducing temperatures across the city centre (noting that care is needed to ensure reflective surfaces don't create unintended glare or reflected solar radiation).

**Modelling results show the range of temperature decrease (city wide and local) in degrees Celsius by treatment type[1]**




More specifically, the modelling shows that the scenarios combining several heat mitigation treatments generate the best reductions in air temperatures both locally and across the city centre. Looking at individual treatments, increasing solar reflectivity at street level and increasing greenery generate the highest reductions in local maximum temperatures. The intensive use of water fountains also drops local temperatures. Reflective roofs show less ability to reduce temperatures in the city at street level.

As well as improving thermal comfort outdoors, building design, retrofitting and plantings can improve thermal comfort inside buildings. Building design and shading that limits the accumulation of heat in sun-exposed walls can reduce the amount of heat that buildings radiate internally, especially at night. Building materials and designs can also work to facilitate internal air flow and promote 'passive cooling' (cooling without air-conditioning).

## 5.3. Reduce the heat we generate

Air-conditioning systems, internal combustion engines, refrigeration systems and many other man-made devices release hot air and increase urban heat in Darwin. Fortunately many strategies are available to reduce these 'anthropogenic' heat sources. For example, the heat generated by cars, trucks and other vehicles can be reduced if more people chose to walk, ride or use public transport. The heat generated by air conditioners can be reduced by using more effective systems (e.g. district cooling for larger buildings), using smart sensors and improving thermal performance of buildings while still encouraging passive cooling.

As well as reducing 'waste' heat, increasing energy efficiency and ensuring construction materials and building design are geared for cooling (Box 5) helps to keep air-conditioning costs down and are crucial for making cooling available to everyone including those with limited means.

### Box 5 - Construction and energy efficiency codes

The National Construction Code sets out minimum performance requirements for the design and construction of buildings and other structures, and allows for the variations in climate and other conditions throughout Australia. Requirements include sustainability measures such as thermal performance and energy efficiency.

The Nationwide House Energy Rating Scheme (NatHERS) is a star rating system that rates the energy efficiency of a home (out of 10) based on its design. In the Northern Territory houses are currently required to meet a 5 star rating. For apartments, each sole occupancy unit needs to have an energy rating of not less than 3 stars, and the average rating across all sole occupancy units not less than 3.5 stars.

## 5.4. Current work and future action

**Goal: Darwin's buildings, streetscapes and urban environments are geared to cool, and thermal comfort in priority public places is improved.**

### Current 'cooling' work by partners

- Implementing greening and shading initiatives, including the Civic and State Square Masterplan, State Square Art Gallery and the Cavenagh and Daly street beautification projects, to create cooler spaces for people (NTG, CoD).
- Requiring light coloured roofs on new NT Government owned buildings and energy efficient building envelope designs (NTG).
- Amendment to NT Planning Scheme has been introduced to encourage vertical greening, underground carparking and end-of-trip facilities.
- The introduction of Energy Efficiency requirements for non-residential buildings (Section J of the National Construction Code (NCC)) is currently being considered, with cost/benefit analysis undertaken.
- DIPL has mandated implementation of NCC Section J minimum energy efficiency requirements for government-funded projects over a set threshold; has simplified minimum sustainability design standards for all other new building works; and is committed to projects to showcase leading-edge design for sustainability beyond NCC Section J.
- The NT Planning Commission is continuing consultation for the Designing Better project which is seeking to implement a suite of recommendations to amend the Northern Territory Planning Scheme 2020. Designing Better aims to deliver higher quality building design that:
  - responds to context and celebrates local and regional differences;
  - responds to the varied and often extreme climate of the Northern Territory through quality design of the built form;
  - embraces innovation through flexible, best practice design solutions; and
  - creates great places that provide meaningful, vibrant and livable spaces for people.
- Installing environmental sensors to monitor temperatures, humidity and other environmental factors and monitoring the Cavenagh Street heat mitigation treatments (Box 7) to guide future works (NTG, CoD).
- Finalising the Climate Emergency Discussion Paper and Draft Strategy, draft Greening Darwin and Movement strategies (CoD).
- Developing the 'Your Tropical City' website (DLL, NTG, CoD).
- Identifying potential new developments and sharing relevant heat mitigation approaches to encourage incorporation into new builds (DLL).

### Future action

| Action | Detail | Who | Timing |
|---|---|---|---|
| 1. Identify and implement a suite of incentives and mechanisms to encourage developers, property owners, residents and others to mitigate heat. | Investigate development incentives, business/home improvement schemes, low cost loans, partnering programs etc., and how to best implement. | CMC<br>CoD<br>DIPL<br>DLL | Identify 2021-22<br>Implement 2023-2030 |

| Action | Detail | Who | Timing |
|---|---|---|---|
| 2. Review and support planning initiatives and construction standards, codes and regulations to achieve better heat mitigation. | For example, review City of Darwin and NT Government policies and planning controls, adopt codes and guidelines that emphasise heat mitigation and encourage passive cooling solutions. | CoD DIPL | Review 2021-22<br>Implement 2023-2030<br>Support 2021-30 |
| 3. Promote information on how Darwin communities and businesses can act now to build, retrofit and plant (shade trees) to mitigate heat. | Proactively communicate existing information and resources such as those outlined in Box 6. | DLL<br>CoD<br>CMC | 2021-2030 |
| 4. Include heat mitigation measures during redevelopment of public areas adjacent to new and priority existing government buildings and other assets. | Recognise the benefit of heat-mitigating design features in priority public places in Darwin. | DIPL<br>CoD | 2021-2030 |
| 5. Develop targets and support action towards increasing tree canopy cover. | Includes:<br>• Finalise and implement the draft Greening Darwin Strategy.<br>• Trial how to best increase greenery in building envelope and street verges on private and public land.<br>• Identify and prioritise tree species resilient to climate change impacts and that maximise cooling benefits.<br>• Understand community perspectives and needs around increasing greenery.<br>• Pilot an environmental-economic account to value Darwin's green space. | CoD<br>DLL | Set targets 2021-2022<br>Support 2021-30 |
| 6. Reduce the area of heat-absorbing surfaces such as bitumen carparks. | Includes:<br>• Review controls relating to car parking shortfall contribution plans and shading requirements.<br>• Trial surfaces that better mitigate heat e.g. lighter and/or permeable materials.<br>• Incentivise temporary shading in bare vacant blocks. | CoD | Review 2021-23<br>Trial 2021-25<br>Implement 2021-2030 |

| Action | Detail | Who | Timing |
|---|---|---|---|
| 7. Increase shade by encouraging the installation of permanent and temporary shade structures in Darwin. | For example use actions '1' and '2' above to promote the use of awnings, shutters, shade sails, shading between buildings and vertical blades if positioning produces shade. | CoD<br>DIPL | 2021-2030 |
| 8. Increase shade by allowing roofs, balconies below a specified height and green walls/planters to project into the public domain. | For example, review controls and amend where necessary to support new and retrofitted structures over road reserves. | CoD<br>DIPL | 2021-22<br>Implement 2023-30 |
| 9. Encourage the installation of cool building technologies for public and private apartments and mixed-use housing development in commercial and central business zones during replacement or new construction. | Consider use of landscaping to reduce the amount of heat absorbed by buildings through techniques such as green walls, living walls or vertical gardens. | NT Planning Commission[36] | 2021 -2030 |
| 10. Investigate and trial water sensitive urban designs that will help greening initiatives and mitigate heat. | Identify design elements to pilot, possibly linked with a 'cool precinct' initiative (Section 7). | DLL<br>CoD<br>DIPL | Investigate 2021-23<br>Trial 2023-26 |

## Box 6 - Information on how you can mitigate heat in Darwin:

| Resource | Organisation | Website |
|---|---|---|
| Your Tropical City | DLL | yourtropicalcity.com.au/ |
| Coolmob | Environment Centre NT | coolmob.org/ |
| Designing Better | NT Planning Commission | planningcommission.nt.gov.au/projects/designing-better |
| Your Home | Australian Government | yourhome.gov.au/ |
| Darwin Living Lab | CSIRO DLL | research.csiro.au/darwinlivinglab/publications |
| Guide to Urban Cooling Strategies | Low Carbon Living CRC | lowcarbonlivingcrc.com.au/resources/crc-publications/crclcl-project-reports/guide-urban-cooling-strategies |
| Urban Heat Mitigation Index and Tool | University of NSW | uhimitigationindex.be.unsw.edu.au/mitigation/index.html<br>uhimitigationindex.be.unsw.edu.au/uhitool/index.html |

| Action | Detail | Who | Timing |
|---|---|---|---|
| 11. Support energy efficiency measures that reduce anthropogenic heat in the city and help with cooling affordability. | For example, continue to support national energy efficiency improvement measures. | DIPL<br>CoD | 2021-2030 |
| 12. Support initiatives to promote 'cooler' transport and cool routes for active and micro-mobility transport. | Includes supporting cycling, scooting and ensuring that key travel routes are shaded. | CoD DIPL | 2021-2030 |


## Box 7 - Cavenagh Street redevelopment[37]

Cavenagh Street, in the centre of Darwin, is a cutting-edge experimental 'street cooling' project. This street was a city hotspot that generated high temperatures and impacted thermal comfort levels across the city. To put heat mitigation theory into practice, several treatments were implemented along this street as part of the Darwin City Deal:

A 55 m long shade structure was built using stringybark timber supplied by the Gumatj Corporation from East Arnhem Land. Rangoon Creeper and Orange Trumpet vines are growing over the structure to provide shade.

Light-coloured and heat-reflective road surface treatments were installed to reduce pavement surface temperatures.

29 trees have been planted in especially designed tree pits and median beds to provide shade.

The treatments are monitored by several sensors - data will allow us to assess the effectiveness of the heat mitigation treatments and use the results to inform future work.

# 6. ADAPT – DARWIN RESIDENTS, VISITORS AND BUSINESSES ARE PREPARED FOR HEAT

**Even with the best mitigation treatments in place, Darwin's heat is dangerous at times and with more severe extremes predicted, it's critical that we adapt our behaviours and responses to become more resilient to heat.**

## 6.1. Implement heat health warnings

Heat health warning systems have been established in many cities around the world but are less common in cities in the wet-dry tropics where it can be difficult to determine and predict times of dangerous heat. Heat health warnings need to trigger communication processes and associated heat heath activity to help residents prepare for and respond to extreme heat events. These need to be customised for local meteorological and demographic conditions and may include early advisories and alerts, emergency public health measures, and guidance for businesses and community organisations.

Different indicators of heat identify different places and times as dangerous. The Bureau of Meteorology defines a heatwave as 'three or more days of high maximum and minimum temperatures that are unusual for that location'.

Other countries include both temperature and humidity in their warning systems since the amount of moisture in the air is important in human thermoregulation (e.g. Canada's Humidex and the United States' Heat Index, Figure 9). Labour-intensive occupations including the military use wet-bulb globe temperature thresholds to identify heat risk since this indicator was developed to mitigate heat risk during physical exertion. Choosing the right warning measure for Darwin will help safeguard community members, especially those who are vulnerable.

Currently the NT Department of Health issues 'Health Alerts' for dangerous heat conditions based on the Bureau of Meteorology's heatwave definition. The department is developing communication processes for publicising these alerts and investigating a notification process to alert particular community groups of extreme heat conditions.

LIKELIHOOD OF HEAT DISORDERS WITH PROLONGED EXPOSURE OR STRENUOUS ACTIVITY

| RELATIVE HUMIDITY (%) \ TEMPERATURE (°C) | 26.7 | 27.8 | 28.9 | 30 | 31.1 | 32.2 | 33.3 | 34.4 | 35.6 | 36.7 | 37.8 | 38.9 | 40 | 41.1 | 42.2 | 43.3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 26.7 | 27.2 | 28.3 | 29.4 | 31.1 | 32.8 | 34.4 | 36.1 | 38.3 | 40.6 | 42.8 | 45.6 | 48.3 | 51.1 | 54.4 | 57.8 |
| 45 | 26.7 | 27.8 | 28.9 | 30.6 | 31.7 | 33.9 | 35.6 | 37.8 | 40 | 42.8 | 45.6 | 48.3 | 51.1 | 54.4 | 58.3 | |
| 50 | 27.2 | 28.3 | 29.4 | 31.1 | 32.8 | 35 | 37.2 | 39.4 | 42.2 | 45 | 47.8 | 51.1 | 55 | 58.3 | | |
| 55 | 27.2 | 28.9 | 30 | 31.7 | 33.9 | 36.1 | 38.3 | 41.1 | 44.4 | 47.2 | 51.1 | 54.4 | 58.3 | | | |
| 60 | 27.8 | 28.9 | 31.1 | 32.8 | 35 | 37.8 | 40.6 | 43.3 | 46.7 | 50.6 | 53.9 | 58.3 | | | | |
| 65 | 27.8 | 29.4 | 31.7 | 33.9 | 36.7 | 39.4 | 42.2 | 45.6 | 49.4 | 53.3 | 57.8 | | | | | |
| 70 | 28.3 | 30 | 32.2 | 35 | 37.8 | 40.6 | 44.2 | 48.3 | 52.2 | 56.7 | | | | | | |
| 75 | 28.9 | 30 | 33.3 | 36.1 | 39.4 | 42.8 | 46.7 | 51.1 | 55.6 | | | | | | | |
| 80 | 28.9 | 31.7 | 34.4 | 37.8 | 41.1 | 45 | 49.4 | 53.9 | | | | | | | | |
| 85 | 29.4 | 32.2 | 35.6 | 38.9 | 43.3 | 47.2 | 52.2 | 57.2 | | | | | | | | |
| 90 | 30 | 32.8 | 36.7 | 40.6 | 45 | 50 | 55 | | | | | | | | | |
| 95 | 30 | 33.9 | 37.8 | 42.2 | 47.2 | 52.8 | | | | | | | | | | |
| 100 | 30.6 | 35 | 39.4 | 44.4 | 49.4 | 55.6 | | | | | | | | | | |

CAUTION | EXTREME CAUTION | DANGER | EXTREME DANGER

Figure 9 - Example of a temperature and humidity alert matrix[38]

## 6.2. Increase resilience to heat

Although most people can take basic measures to help to reduce heat exposure and associated risks such as keeping hydrated and seeking refuge in cool places, we need more considered preparations to successfully adapt to heat. The NT's Climate Change Response: Towards 2050 Action Plan proposes a suite of actions to achieve this and the CoD's Climate Emergency Discussion Paper and Draft Strategy adds to these. Examples of where preparation may be particularly important include:

### People vulnerable to heat and humidity

Certain groups in the community are more sensitive to heat and humidity than others, with the ability to shed heat often compromised in people who are elderly, very young, lack mobility or unable to adequately care for themselves. People with limited means are more likely to be exposed to high temperature conditions for prolonged periods if costs restrict their ability to cool their homes or invest in adaptation strategies. Homeless people and people without adequate shelter may be particularly vulnerable to heat exposure.[39]

### Outdoor workers and operations

Ongoing research, including Charles Darwin University's Heat Stress Research Partnership,[40] is assisting outdoor workers such as construction workers, emergency workers and defence personnel to work more safely and productively in the heat. NT Worksafe[41] strategies for people working in heat include:

- limiting the numbers of continuous hours exposed to extreme heat/humidity through rotations, working at cooler times of day and having extra breaks in a cool area
- wearing light, heat-protective clothing, drinking adequate water, and using fans, shade or coolers to reduce temperatures.

### Sports clubs

Organisations overseeing sports and other outdoor activities have a responsibility to keep participants safe, especially when heat conditions are risky. Possible actions include:

- developing and implementing heat related policies, including scheduling activities at cooler times, and addressing when it is too hot to train or play
- communicating information about heat stress symptoms and treatments
- ensuring participants drink enough water and that water bottles can be easily refilled.

### Schools

Children in Darwin can be exposed to high heat and humidity in physical education classes, during breaks and in travelling to and from school. Schools make decisions around heat and student wellbeing day to day, however to prepare for days of more extreme heat, individual school management plans and an overall heat risk policy could be beneficial. Considerations include:

- reducing heat-related risks for students during breaks
- evaluating and modifying teaching and play spaces and their times of use
- identifying when it's too hot to hold physical education classes outside
- clarifying parent and teacher expectations during heat events.

## 6.3. Current work and future action

**Goal: Darwin residents and visitors are prepared for heat and heat related illnesses are reduced.**

### Current 'cooling' work by partners

- Issuing heat health warnings when extreme heat conditions are forecast
- Communicating information on heat stress and treatments through websites e.g.
  - https://nt.gov.au/wellbeing/health-conditions-treatments/heat-stress
  - https://securent.nt.gov.au/prepare-for-an-emergency/heatwave
  - https://worksafe.nt.gov.au/forms-and-resources/bulletins/working-in-heat
- Implementing safe workplace practices to prevent heat stress
- Installing sports oval lighting to enable night competition to decrease heat stress risks
- Progressing related initiatives described in the NT's Climate Change Response and CoD's Climate Emergency Discussion Paper and Draft Strategy
- DLL working with Larrakia to understand biodiversity values and monitor changes to guide adaptation in a changing climate.

### Future actions

| Action | Detail | Who | Timing |
|---|---|---|---|
| 13. Develop and promote communication products, tools and resources to assist the Darwin community to live and work safely in very hot and humid conditions. | This includes promoting:<br>• heat mitigation treatments and associated incentive schemes and regulations<br>• heat-health information tailored to workplaces, schools etc.<br>• preparation for heat extremes in a similar way to preparation for cyclones. | DoH and relevant agencies, Secure NT, CoD and DEPWS | Develop 2021-23<br>Promote 2022-30 |
| 14. Share Indigenous knowledge of ways to manage heat stress in the local climate with the broader Darwin population. | Work with Larrakia people and, through story-telling, identify actions based on shared experiences of adaptation to the ever-changing environment. | DLL<br>CoD | 2021-25 |
| 15. Continue to participate in the development of a National Heatwave Warning Framework to ensure an appropriate formal heat-health warning system for Darwin. | Includes:<br>• Identify an appropriate warning indicator and alert scales.<br>• Develop and implement a communications process to ensure it is effectively communicated across business and the community. | DoH<br>BoM<br>CMC | Establish 2021-23<br>Implement 2024-2030 |

| Action | Detail | Who | Timing |
|---|---|---|---|
| 16. Develop and implement a plan(s) associated with the alert system that identifies and supports people who are especially vulnerable to heat stress in Darwin. | This will link with the longer term adaptation plans being developed under the NTG Climate Change Action Plan and CoD Climate Emergency Discussion Paper and Draft Strategy. | DoH<br>CoD | Develop 2022-24<br>Implement 2025 ongoing |
| 17. Ensure adequate public heat relief measures are available in Darwin, with particular attention to vulnerable populations. | Includes, for example, drinking water stations, adequate shade and refuges such as shopping centres, swimming pools and libraries. | CoD<br>DoH | 2021-30 |
| 18. Explore and trial methods to better prevent heat stress for people working or undertaking physical activities outdoors. | For example, progress digital apps that link environmental conditions to symptoms of heat stress, allowing personalised alerts and guidance on actions. | CoD<br>DLL | Explore 2021-23<br>Trial 2023+ |
| 19. Implement heat adaptation-related actions in the NT Government's Climate Change Response: Towards 2050 Action Plan. | This includes the actions below:<br>• Identify and prioritise key risks to industry associated with climate change, including work health and safety concerns (2.2.1).<br>• Identify and prioritise NT Government's infrastructure, assets and services at risk from impacts associated with climate change (2.3.2) and deliver adaptation frameworks (2.3.3).<br>• Work with community services to develop climate change risk adaptation and response frameworks (2.5.2). | DEPWS and other relevant agencies | 2021-23 |
| 20. Finalise and implement heat adaptation-related actions in the CoD's Climate Emergency Discussion Paper and Draft Strategy. | | CoD | 2021 to finalise with ongoing implementation |
| 21. Identify, learn from and promote actions that improve heat-related liveability in Darwin. | | DLL | 2021-30 |
| 22. Analyse temperature and humidity data from the city centre and suburbs and report on trends to inform adaptation strategies. | | DLL<br>CoD | 2021-30 |

# 7. INNOVATE - DARWIN BECOMES A LEADER IN HEAT MITIGATION AND ADAPTATION

**Around the world, entrepreneurs, businesses, governments, researchers and others have, and continue to, develop innovative heat mitigation and adaptation treatments for cities and communities. Unfortunately, much of the international work doesn't translate well to Darwin's context because of our challenging wet-dry tropical climate. In response, the Darwin Living Lab is drawing on CSIRO's extensive partnerships and international networks to learn from and to evaluate the potential of these experiences for Darwin. The Lab and partners are also hosting symposiums, webinars and other exchanges to share international, national and local knowledge, and facilitate the collaboration needed to test ideas through real world experiments in Darwin.**

**This work provides an exciting opportunity to establish Darwin as a centre of expertise in tropical heat mitigation and adaptation. To fully develop a meaningful level of expertise, Darwin's citizens, businesses and institutions will need to evaluate and be open to innovative ideas as well as apply known technologies in new contexts and different ways.**

**With half of the world's population predicted to reside in tropical countries by 2050[42] heat mitigation experts from Darwin could be very well placed to share their knowledge with other global tropical regions.**

## 7.1. Innovate to mitigate heat

There is enormous scope for innovation to help people feel cooler in Darwin and elsewhere, and for the Northern Territory to be known for its work in mitigating heat. Building this reputation will require us to answer at least some of the following questions:

- What heat mitigation treatments - ranging from adaptations of existing approaches to cutting edge technology - are yet to be discovered as suitable for Darwin?
- Around the world what mechanisms to encourage uptake of heat mitigation treatments have been especially successful and why?
- How can heat mitigation measures best be co-located with priority public areas and attractions such as markets, cafes, playgrounds and events?
- How can we plan where trees are planted to get the most benefit for cooling as we increase the area of tree canopy in Darwin?
- Can we cost effectively and safely install cooling stations such as misters and fans across the city and suburbs?
- Which of our research and development strengths could we build on to advance heat mitigation?
- What products and services can be developed in Darwin and transferred to other countries?

Some ideas for innovation are outlined in Boxes 8 and 9, and the Darwin Living Lab is investigating a range of other opportunities.

## Box 8 - How other cities encourage cooling – some examples

**Tropical Urbanism in Cairns** – the Cairns Planning Scheme requires landscaping and tropical design elements that promote cooling, such as a minimum of 50% shading to the external surface of buildings. The Cairns Regional Council has also developed incentives (e.g. permitting higher commercial buildings on condition that developers incorporate enhanced setbacks, separations, shade structures and/or landscaping) and guidelines such as 'Sustainable Tropical Building Design - Guidelines for Commercial Buildings' and 'Cool Homes'.
https://www.cairns.qld.gov.au/building-planning-business/building/tropical-building

**The Seattle Green Factor** – Development standards for certain areas in the city require landscaping that meets a minimum Green Factor score. Developers choose from a 'menu' of credit points for landscape features such as streetscape plantings, deep soil zones, permeable paving and native plants to increase the amount of, and improve the quality of, landscaping for a range of benefits including cooling.
http://www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/seattle-green-factor

**Cooling Singapore** – here the National Research Foundation funds a multi-institute initiative implementing more than 80 measures to cool the city, including green parking lots, shaded bicycle lanes, building height variations, well-ventilated walkways, smart shading devices, and materials that change colour, shape and density according to temperature, humidity or light.
https://www.coolingsingapore.sg/

**Other examples** – Roofs: New York City's Cool Roofs Program has cooled >500,000 sq metres of rooftop with reflective paint and material. In Europe, the European Cool Roofs Council is a non-profit, member-funded association that is researching and promoting the use of cool roof products and overseeing an accreditation scheme. Layout: In Guiyang, China, authorities have aligned green belts, water bodies and transport routes to allow cooling winds to blow through the city. Greenery: Many cities around the world are investing in urban forests to increase tree canopy cover and vegetation for cooling. In Australia, Melbourne and Sydney have major urban tree programs underway, Launceston has increased its greenery the most recently (9% between 2016 and 2020) and Cairns is our greenest city with over 80% green cover.[29]

## 7.2. Innovate to adapt to heat

Innovation is needed to assist people and businesses in Darwin and elsewhere adapt to heat and humidity, and to make the best of hot and humid conditions. Questions to investigate here could include:

- What tools, clothing, materials and practices will help people adapt to heat in the wet-dry tropics and how can we best promote these?
- What can we learn from custodians of traditional Aboriginal knowledge, especially Larrakia custodians, to improve local and visitor capacity to acclimatise to heat?
- Which Darwin demographic copes best with hot and humid conditions and why?
- How can we innovatively help those vulnerable to heat in Darwin?
- To what extent could solar powered air-conditioning be used in the Top End?
- How can we build on our strengths in heat-related health, and export these services and products to other countries?
- Can we use our investments in heat mitigation and adaptation to help change negative perceptions about hot conditions in Darwin and to help promote 'feeling cooler'?
- How can Darwin better position itself to benefit from its heat and humidity, for example to promote itself as a hub for elite sports training, specialised defence training opportunities, outdoor worker health and safety training, and more?

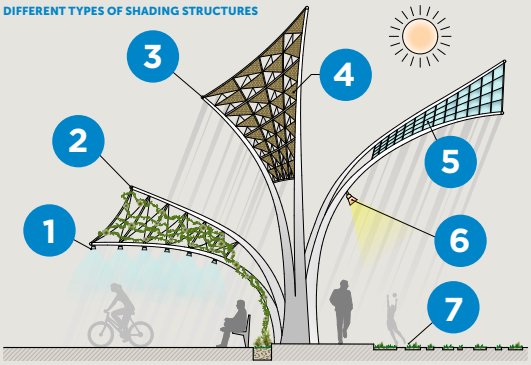
## Box 9 - Heat mitigation ideas to investigate for Darwin

**CONCEPT – Combine heat mitigation treatments with public art.**

For example - control building heat by constructing a 'second skin' that limits solar heat gain and is an attractive art piece. The skin could be semi-permanent, and able to be relocated if neighbouring land is developed. A kinetic screen sculpture that responds to wind can add an additional layer of visual interest and changeability. The installation could be monitored to assess its heat mitigating efficiency.[43,44]

**CONCEPT– Build cooling stations to improve pedestrian comfort especially in the build-up.**

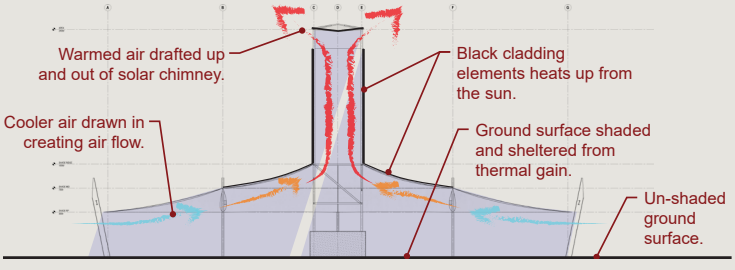
For example – install a series of shade structures, misters and/or solar-powered fans to create shade and coolness in hot busy places such as shopping centre carparks, outdoor sporting facilities, city street corners, and outside schools and hospitals. The cooling stations could be permanent or mobile, record temperature and incorporate smart sensors to power off fans and misters when not in use. Ideally stations would be place specific and co-designed with locals, especially those vulnerable to heat stress.[45]




1. Integrated misting fans pointing to pedestrians
2. Pergolas covered with vegetation
3. Structures oriented in different angles to provide shading in different areas throughout the day
4. Light-coloured shading devices with fractal figures to cut off incident radiation and increase light penetration
5. Translucent PV panels integrated to shading structures to provide solar protection, increase light penetration and produce energy
6. Street lights powered by solar energy
7. Vegetated and semi-vegetated ground combined with shading devices to reduce surface temperatures

**CONCEPT - Create an innovative public benefit heat mitigation test piece that is highly visible, able to be relocated and able to be reproduced at a range of scales.**

For example - construct a central chimney element with dark cladding that heats up during the day to create a temperature and pressure differential that induces passive air movement, a key factor for improving human comfort in wet/dry tropical environments. The structure could be designed as relocatable (e.g. with above ground footings, modular assembly, removable canvas skirt) and used for example for outdoor dining from food vendors, for market stalls or for car parking in city heat hotspots.[46]



## 7.3. Current work and future action

**Goal: Darwin becomes a leader in heat mitigation and adaptation in the wet-dry tropics.**

### Current 'cooling' work by partners

- Hosting symposiums and webinars and connecting with other countries, especially those in the wet-dry tropics, to share innovations (see the Darwin Living Lab website for more information https://research.csiro.au/darwinlivinglab/)
- Delivering 'Switching on Darwin', innovative city-scale smart infrastructure, including smart sensors collecting data such as temperature, humidity and wind speed across the city and suburbs.

### Future actions

| Action | Detail | Who | Timing |
|---|---|---|---|
| 23. Undertake a series of initial projects to establish platforms and baselines for innovation in heat mitigation and adaption. | This includes:<br>• mapping where community aspirations, science and local capital works programs converge<br>• developing a digital city 'twin' to help monitor, assist and explore urban cooling and greening actions<br>• sharing knowledge on how Indigenous biodiversity knowledge can inform urban greening<br>• refining UAVs to capture thermal data for mapping heat and urban microclimates. | DLL | 2021-23 |
| 24. Host symposiums, think tanks and webinars to catalyse and develop new ideas for heat mitigation and adaptation. | Foster and showcase an innovation community focused on heat mitigation. | DLL<br>CMC | 2021-2030 |
| 25. Identify, develop and test innovative heat mitigation and adaptation approaches for Darwin. | For example this could include:<br>• Create experiences to demonstrate future heat impacts in Darwin and potential outcomes of efforts to mitigate heat.<br>• Identify and promote heat-related examples of sustainable, best practice tropical urban living.<br>• Scope an app to plan pedestrian and active travel using the most shaded or 'cool' route. | DLL<br>CoD<br>CMC | 2021-2030 |

| Action | Detail | Who | Timing |
|---|---|---|---|
| 26. Investigate and implement innovative opportunities to display best practice and cutting-edge heat mitigation and climate sensitive design. | Incorporate best practice heat mitigation in future precinct redevelopments or significant capital works projects; for example, under-grounding car parks and creating cool green spaces. | CMC<br>CoD<br>DLL<br>DIPL | Investigate 2021-23<br>Implement 2023-30 |
| 27. Partner with research organisations, especially those based in Darwin, to continue to improve heat mitigation and adaptation in Darwin. | Identify expertise and capacity at Charles Darwin University and develop research plans to guide DLL collaborations. | DLL | 2021-2030 |
| 28. Exchange heat mitigation and adaptation knowledge with other cities, especially those with similar climates. | Build on existing relationships and establish new ones; establish a regular communication forum. | DLL<br>CMC | 2021-2030 |
| 29. Explore opportunities to deliver heat mitigation and adaptation products and services nationally and internationally. | Pathways to be developed through existing and expanding national and international networks. | DLL<br>CMC | 2023-2030 |
| 30. Establish and implement an awards program to recognise excellence and innovation in heat mitigation and adaptation. | This initiative is under discussion between partners. | CMC<br>CoD<br>DLL | Establish 2021-22<br>Implement 2023-2030 |

# 8. REVIEW AND GOVERNANCE

The Darwin Heat Mitigation and Adaptation Strategy will be reviewed every three years to ensure an adaptive and responsive approach to helping people feel cooler in Darwin. The review will include:

- an evaluation of the extent to which actions have been implemented and desired goals achieved
- consideration of new innovations in heat mitigation and adaptation
- learnings from the monitoring and evaluation of trials in Darwin
- consideration of any updated climate change modelling for northern Australia
- recommendations for the next three year period.

Reviews will link with the 'Tracking Darwin' project, a Darwin Living Lab initiative to monitor and evaluate improvements in heat mitigation, liveability and sustainability across Darwin. The monitoring and evaluation undertaken by the Darwin Living Lab will promote continual learning and improvement among the delivery partners of this strategy.

Because the Strategy is a deliverable under the Darwin City Deal, it will be progressed and overseen through City Deal mechanisms. City Deal partners will establish appropriate governance arrangements to ensure that the Strategy's heat mitigation and adaption efforts and outcomes grow Darwin as a vibrant, connected and liveable tropical city.

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