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Heatwatch

Extreme heat in the Gold Coast

Increasing extreme heat will have profound impacts on people, industries and ecosystems in Queensland's Gold Coast region. CSIRO and Bureau of Meteorology projections estimate that the average number of days over 35 could increase by up to thirty times without strong climate policies from a current average of one up to 34 days by 2090. Nearly half of summer nights are projected to be above 25 degrees by 2090, a level considered dangerous to human health.

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Summary

The combination of the projected rise in extreme heat as a result of global warming and the high levels of humidity at the Gold Coast present a serious risk to the health and wellbeing of the region's population.

The Gold Coast has historically experienced a relatively pleasant climate with only around one day over 35 degrees per year. However, the amount of these extreme heat days could increase up to a projected 34 days by 2090.

At temperatures above 35 degrees the human body's ability to cool itself reduces, making it a common benchmark temperature for occupational health and safety experts, academic and government agencies.

Over the last year there were 120 days with a relative humidity of 70% or above and 59 days over 80% at 3pm at the Gold Coast. Combined with 70% humidity, conditions over 35 degrees are considered 'dangerous' by government agencies such as the US Government National Oceanic and Atmospheric Administration. Temperatures of 35 degrees combined with 80% humidity are considered "extremely dangerous".

Alarmingly, CSIRO and Bureau of Meteorology (BoM) projections show that unless emissions are substantially reduced, up to nearly half of summer nights could be over 25 degrees by 2090 in the Gold Coast, up from just one night per year now. Nights where the minimum temperature does not fall below 25 degrees are considered an extreme temperature threshold and can have serious health and societal impacts.

The impacts of more extreme heat are already being seen globally with Europe, Russia, India and Pakistan all experiencing heat waves resulting in thousands of deaths.[1,2]

Increased hot days would reduce productivity in key Queensland industries such as agriculture, construction and tourism. The Gold Coast specifically would see its large employment sectors of tourism, services and manufacturing greatly damaged.

Fortunately, these rises in extreme temperatures are not inevitable. CSIRO projections show that if emissions are substantially reduced (for example by increasing Australia's

[1] Wang, Horten (2015) *Tackling climate change: the greatest opportunity for health The Lancet Climate Change and Human Health Commission*, The Lancet, https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)60854-6/fulltext

[2] Hass, et al. (2016) *Heat and Humidity in the City: Neighbourhood Heat Index Variability in a Mid-Sized City in the Southeastern United States,* International Journal of Environmental Research and Public Health.

current emission reduction target), the rises are likely to be far lower. With ambitious emissions reductions, the rise in both hot days and nights could be maintained at close to current levels, helping to retain the Gold Coast's attraction as a tourism hotspot.

Introduction

As the climate warms, the number of extreme temperature days is increasing across Australia. The Gold Coast, although known for its consistent warm weather, has seen the number of extreme temperature days increase slightly in recent years and their frequency is projected to rise dramatically unless greenhouse gas emissions are reduced.

Extreme heat is dangerous for human health, ecosystems and agriculture. At temperatures above 35 degrees, the human body's main cooling mechanism – sweating – is far less effective. Sweating exchanges heat from the body to the atmosphere, but this heat exchange process diminishes significantly beyond 35 degrees and, as a result, body temperature rises. This creates discomfort and a range of health impacts and can ultimately be fatal without intervention.[3]

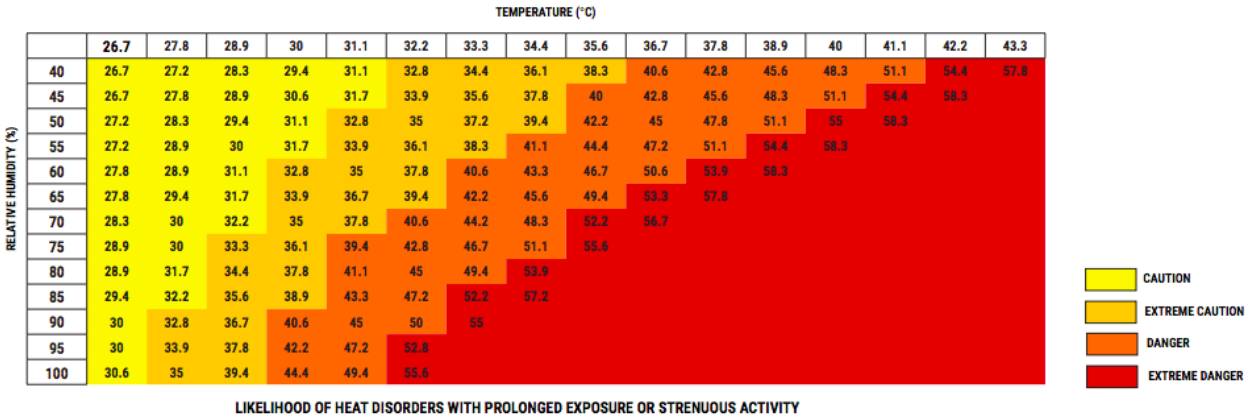
Many regulators and researchers use 35 degrees as an important threshold for safety, work and climatic conditions. 35 degrees is seen as the "limit of high temperature tolerance" by the Occupational Health and Safety Representatives of the Victorian Trades Hall Council; academic researchers have pointed to 35 degrees as a point where substantial productivity is lost. The CSIRO and Bureau of Meteorology therefore publish 35 degree threshold predictions.[4]

Temperature and humidity are often combined into a heat index figure to provide a simple indicator of the body's ability to cool itself. Of a number of indices available, one of the most important is published by the US Government National Oceanic and Atmospheric Administration (NOAA). As shown in the NOAA heat stress chart in **Error! Reference source not found.** below, the combination of temperatures in the low thirties with high humidity are considered "dangerous" to human health.

[3] Hanna and Tait (2015) *Limitations to thermoregulation and acclimatisation challenges human adaptation to global warming,* Int J Environ Res Public Health, https://academic.oup.com/heapro/article/30/2/239/561863

[4] Victorian Trades Hall Council (2018) *Heat*, http://www.ohsrep.org.au/hazards/workplace-conditions/heat; Singh et al (2015) *Working in Australia's heat: health promotion concerns for health and productivity,* Health Promotion International, https://academic.oup.com/heapro/article/30/2/239/561863; CSIRO and BoM (2015) *Climate change in Australia: Projections for Australia's NRM Regions*, https://www.climatechangeinaustralia.gov.au/en/publications-library/technical-report/

Figure 1. NOAA Heat Stress Index



	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										

Source: http://www.nws.noaa.gov/os/heat/heat_index.shtml

NOAA's heat stress index rises to "Extreme Danger" at temperatures over 35 degrees combine with 80% humidity.

The Gold Coast already experiences humidity of over 70% for a large proportion of the year. From September 2017 to September 2018 there were 120 days, with a relative humidity of 70% or above at 3pm at the Gold Coast, and 59 days over 80% humidity.[5]

A future that combines such high humidity levels with an increase in the frequency of days over 35 degrees represents a serious threat to the wellbeing of the Gold Coast's and Australia's wider population. As well as an increase in heat related deaths and illness, the rise in extreme heat increases irritability and psychological stress.[6] Hot weather affects patterns in domestic violence,[7] interrupts sleep patterns and reduces capacity and willingness to exercise. All carry broad ramifications, such as increased accident risk, sedentary life style induced diabetes and cardio vascular disease.[8,9] Tracking and minimising the way climate change is affecting the number of hot days is of direct interest to the wellbeing of local communities, particularly in hot areas such as the Gold Coast.

[5] BoM (2018) *Daily Weather Observations*, http://www.bom.gov.au/climate/dwo/201710/html/IDCJDW4050.201710.shtml

[6] Queensland Health (2015) *Heatwave Response Plan* https://www.health.qld.gov.au/__data/assets/pdf_file/0032/628268/heatwave-response-plan.pdf

[7] Auliciems and Di Bartolo (1995) *Domestic Violence in a subtropical environment: police calls and weather in Brisbane.* International Journal of Biometeorology 39 (1).

[8] Kjellstrom T et al (2009) *The Direct Impact of Climate Change on Regional Labor Productivity.* Archives of Environmental & Occupational Health 64 (4).

[9] World Health Organisation (2017) *Preventing noncommunicable diseases (NCDs) by reducing environmental risk factors*, http://apps.who.int/iris/bitstream/10665/258796/1/WHO-FWC-EPE-17.01-eng.pdf?ua=1

Hot days at the Gold Coast

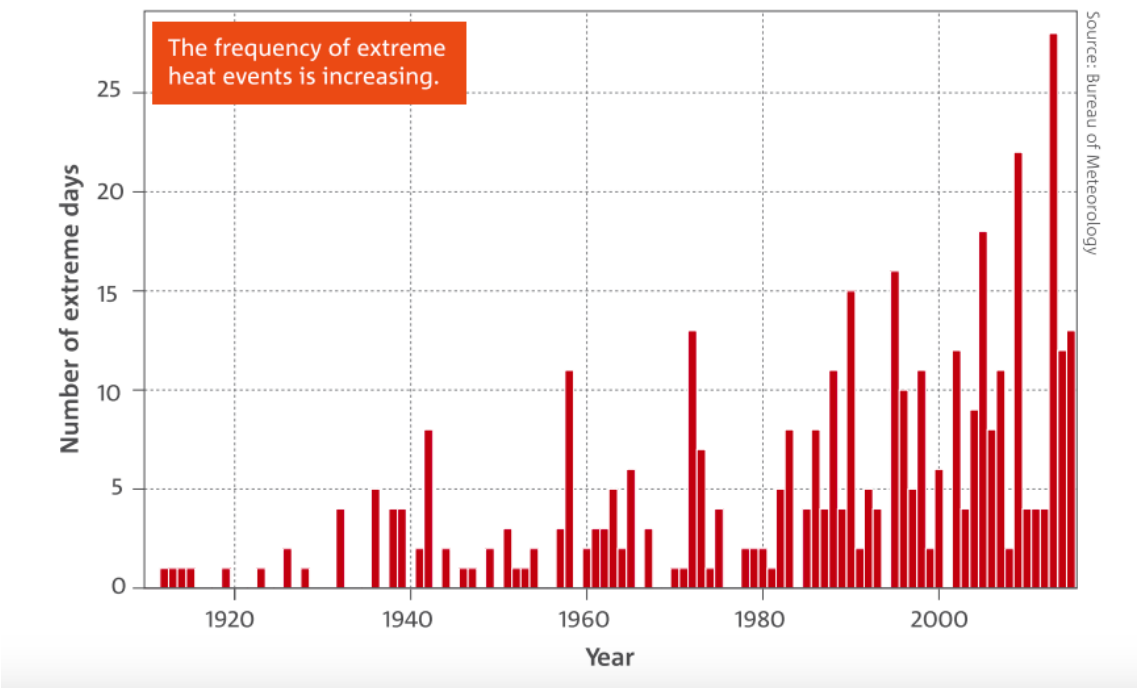
In Australia and globally there has been a clear trend of increasing temperatures and extreme heat events that are attributable to global warming.

The increase in extreme heat events across Australia as a whole is shown in Figure 2 below. This Bureau of Meteorology graph shows the annual number of days exceeding the 99th percentile of each month from 1910–2015.

The Bureau of Meteorology clearly attributes this trend to global warming.

> As the global climate system has warmed, changes have occurred to both the frequency and severity of extreme weather. In Australia, the most obvious change has been an increase in the occurrence of record-breaking heat.[10]

Figure 2: Frequency of extreme heat days, Australia.



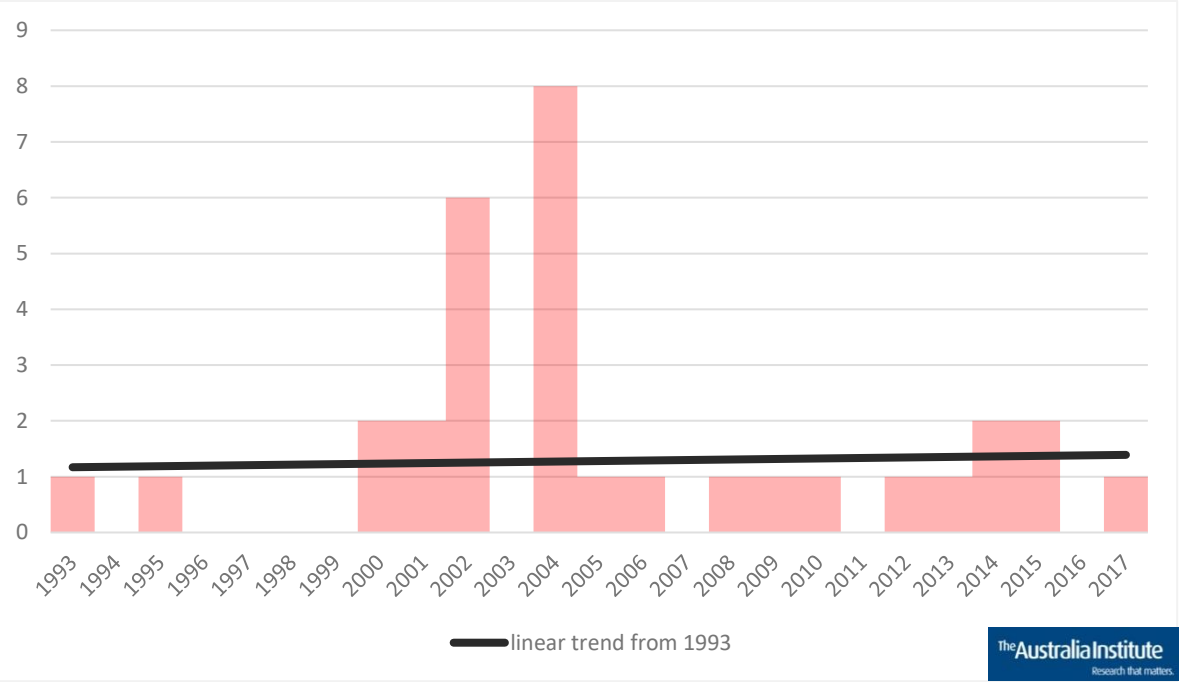
Source: BoM (2016) *State of the Climate*

The Bureau of Meteorology has temperature records from Gold Coast Seaway starting in 1993. While the relatively short timeframe of these records mean that trends should

[10] BoM (2016) *State of the Climate,* http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf

be viewed with caution, the number of days over 35 degrees in each year is shown in Figure 3 below.

Figure 3: Average annual number of days over 35 degrees at Gold Coast 1993-2017



Source: Bureau of Meteorology (n.d.) *Climate data online,* http://www.bom.gov.au/climate/data/index.shtml

Table 1 below demonstrates that although the average number of days recorded the weather station has remained relatively consistent, there has been an upwards trend.

Table 1: Average number of days per year above 35 degrees

Years	Average days over 35 degrees
1993–1997	0.4
1998–2002	2.0
2003–2007	2.0
2008–2012	0.8
2013–2017	1.2

Source: Bureau of Meteorology (n.d.) *Climate data online,* http://www.bom.gov.au/climate/data/index.shtml

Projected increases in days over 35 degrees

The number of days over 35 degrees at the Gold Coast is expected to increase dramatically in the coming decades if global emissions continue to rise according to CSIRO and BoM climate modelling.

The CSIRO use eight climate models to project temperature extremes into the future. All climate models use different methods for understanding the complex climate system, and as such provide a range of projections. The models used by the CSIRO are selected on the basis of how well they simulate the current climate.[11]

Our analyses in Figures 4 and 5 use all eight climate models selected by the CSIRO, and present the full range of their projected increases in days over the various temperature thresholds according to two different emissions scenarios. Figures 4 and 5 also mark the average of the projections, as well as the highest and lowest ones.

The two scenarios the projections are based on are from the United Nations Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (RCPs), which are two of four scenarios of various levels of concentrations of greenhouse gases in the atmosphere.

The historical data used to make projections by the CSIRO–BoM models is not that of the stations shown in Figure 4, but is instead a time-series from the Australian Water Availability Project (AWAP) where the average temperature was compiled in 5x5km spatial grids between 1981–2010.[12]

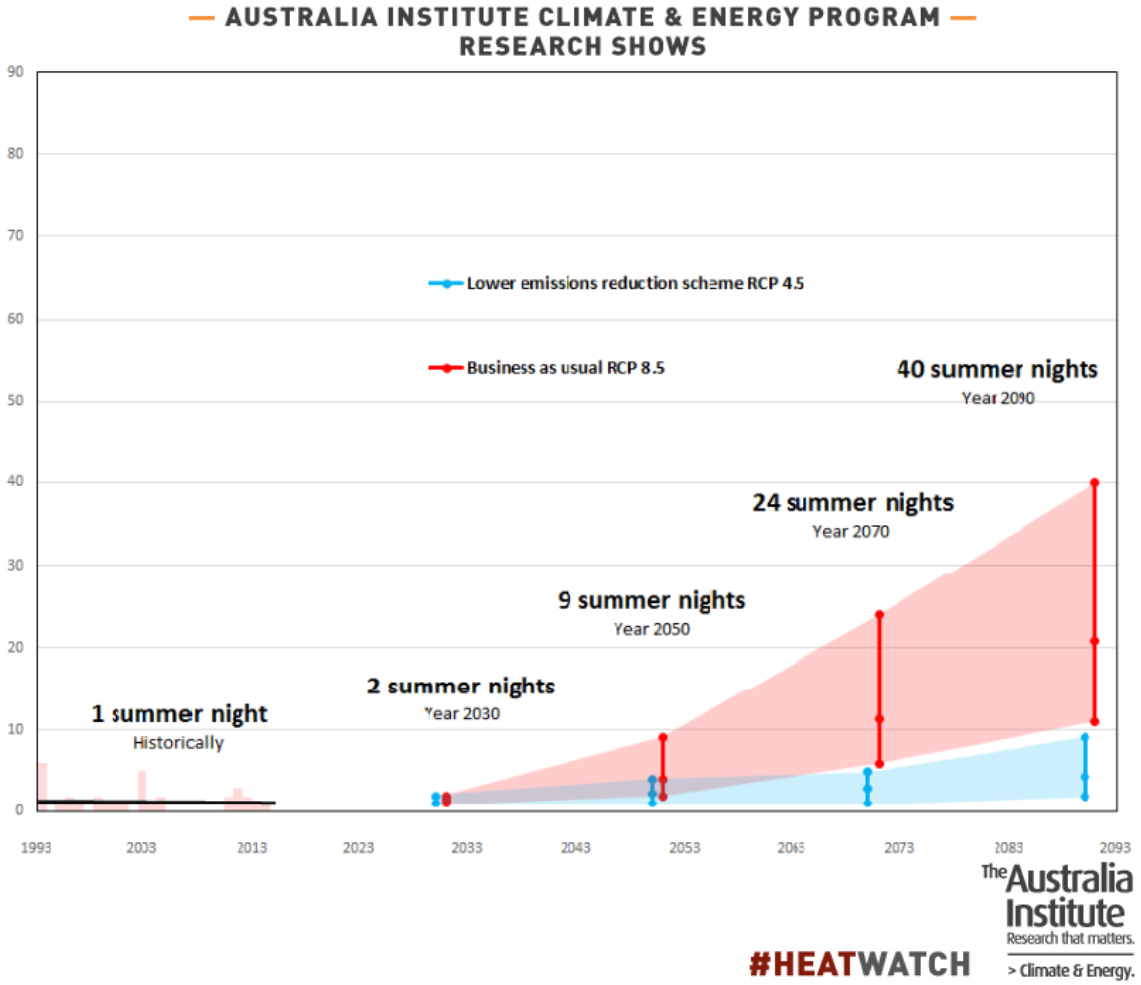
These models, and the projections built off them, observed only one day a year over 35 degrees historically which is consistent with the average at Gold Coast Seaway station since 1993.

Figure 4 below lays out the CSIRO predictions to 2090 of the two scenarios:

[11] CSIRO (n.d.) *Modelling choices and methodology,* Climate Change in Australia, https://www.climatechangeinaustralia.gov.au/en/climate-projections/about/modelling-choices-and-methodology/

[12] CSIRO and Bureau of Meteorology (2015) *Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report*, CSIRO and Bureau of Meteorology.

Figure 4: Forecast annual number of days over 35 degrees the Gold Coast



Source: CSIRO and Bureau of Meteorology (2015*) Climate projections: Climate threshold calculator*, https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/threshold-calculator/

Figure 4 displays the scenario 'RCP 8.5', which is the highest of the four scenarios of global emissions outlined by the IPCC in their 2014 Fifth Assessment Report. It reflects the business as usual (BAU) scenario, which most closely resembles the current global trajectory as emissions continue to increase and insufficient action is taken.[13]

Under the BAU scenario of greenhouse emissions, the CSIRO projects that the Gold Coast could experience as many as nine days over 35 degrees per year in 2050, and 34 days per year by 2090. This would be a near thirtyfold increase from the BoM average of one day from 1993–2017. The range of the eight climate model projections under BAU is shaded in red.

[13] Le Quere et al (2017) *Global carbon budget 2017,* Earth Syst Sci Data 8.

Figure 4 also shows the projected number of days over 35 degrees under the RCP 4.5 scenario where strong emission reduction is achieved. The RCP 4.5 pathways require decisive reductions in emissions. If this is achieved, the average of the CSIRO climate models expects the number of days over 35 degrees per year to be lower than in a BAU trajectory – staying at 3.6 days over 35 degrees per year in 2050, 4.1 days per year in 2070, and 5.3 days per year in 2090. While this still has significant inherent risk, substantial additional harm could be avoided. The range of the eight climate model projections that assume a substantial reduction in emissions (under RCP 4.5) is shaded in blue.

Urban Heat Island effect at the Gold Coast

Highly urbanised areas create an environment that is divergent from the surrounding rural areas. Research has found that due to urban structures like skyscrapers - along with roads, pavements, roofs and diminished vegetation cover – cities becomes warmer as more heat is absorbed in the materials during day and and then relased at night, which increases night-time temperatures.[14]

This creates an Urban Heat Island effect (UHI) not just on these surfaces but also in the atmosphere. This is more prominent during summer as temperatures rise. During the daytime, UHI causes exposed surfaces like roofs to heat to temperatures up to 50 degrees hotter than the air while rural areas remain closer to the atmospheric temperatures, creating an 'island' effect in cities.[15]

It is at night though when UHI has its most negative influence on atmospheric heat extremes. Heat absorbed in urban structures during the day is slowly released after sunset compared to heat in vegetated areas. This produces much higher temperature shifts in the air overnight than in equivalent rural areas.[16] On a clear calm night, the US Environmental Protection Agency states that the temperature difference can be as high as 12 degrees between urban and rural areas.[17]

The overnight effects of UHI are consistent across climate zones and scenarios. Coastal cities like the Gold Coast suffer from UHI despite sea breeze.[18] Studies also raise the concern that night temperature extremes carry the higher risks of mortality as people are unable to recover from daytime heat stress.[19]

[14] Sharifi and Soltani (2017) *Daily variation of urban heat island effect and its correlations to urban greenery: A case study of Adelaide,* Frontiers of Architectural Research 6.
[15] United States Environmental Protection Agency, *Learn About Heat Islands,* https://www.epa.gov/heat-islands/learn-about-heat-islands
[16] Argueso et al. (2015) *Effects of City Expansion on Heat Stress under Climate Change Conditions,* PLoS ONE 10.
[17] United States Environmental Protection Agency, *Learn About Heat Islands,* https://www.epa.gov/heat-islands/learn-about-heat-islands
[18] Santamouris et al. (2017) *Urban Heat Island and Overheating Characteristics in Sydney, Australia – an analysis of multiyear measurements,* Sustainability 9.
[19] Zhao et al. (2018) *Interactions between urban heat islands and heat waves,* Environmental Research Letters 13.

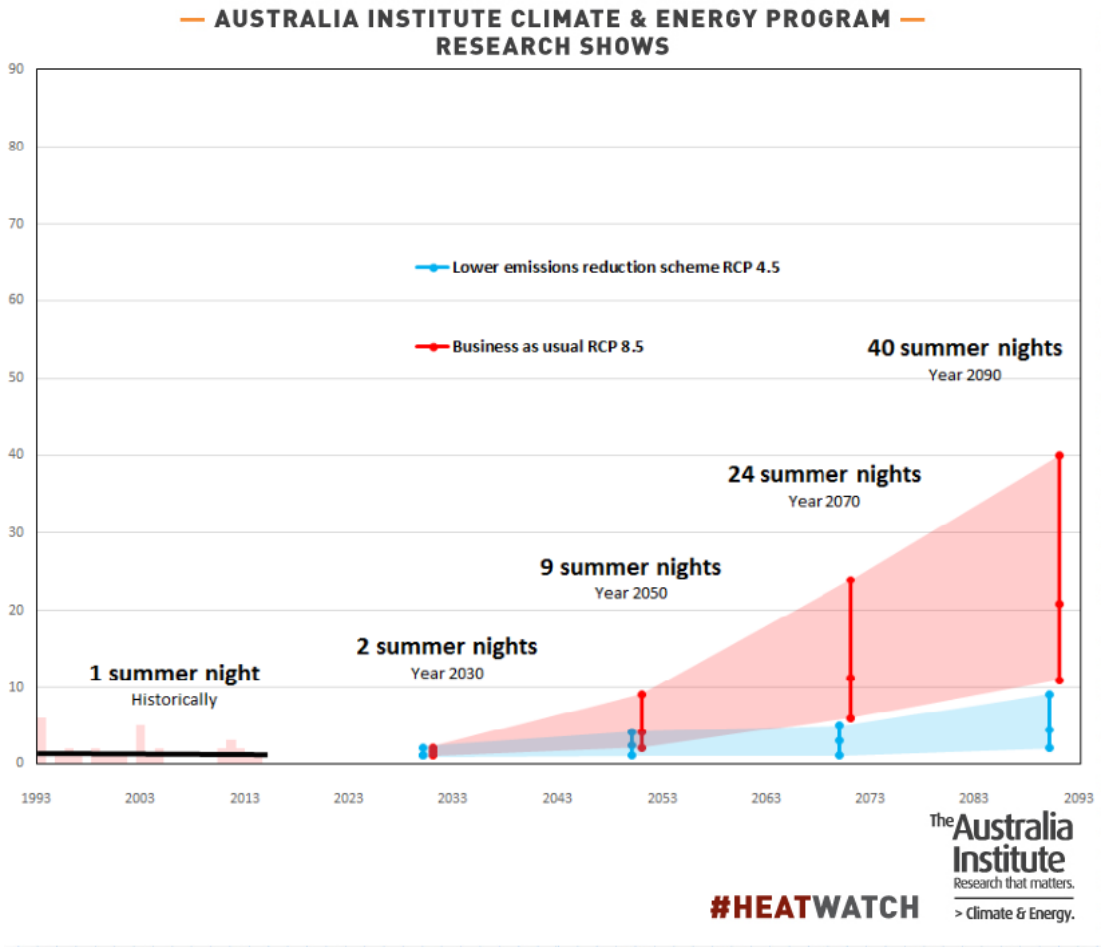
Projected extreme heat over summer nights with UHI

Due to UHI and its effects on atmospheric heat over night, the number of hot days at the Gold Coast will be accompanied by an even greater increase in the frequency of extreme summer nights. Part of this more rapid warming at night is characteristic of the climate system however as night-time temperatures are more sensitive to a build up of greenhouse gases.[20]

The BoM classifies nights with extreme heat as those with minimum temperatures of 25 degrees. A further indication of the projected distribution of extreme heat nights into the future can be gained from examining the CSIRO and BoM datasets. The CSIRO AWAP summer projections are based off December–February having 90.25 days – and for the Gold Coast the historical average is under one summer night with a minimum temperature of 25 degrees between 1981–2010 as shown in Figure 5:

[20] Davy et al. (2016) *Diurnal asymmetry to the observed global warming*. *International Journal of Climatology*.

Figure 5: CSIRO–BoM projections of frequency of summer nights over 25 degrees



Source: CSIRO and Bureau of Meteorology (2015) *Climate projections: Climate threshold calculator*, https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/threshold-calculator/

Figure 5 demonstrates the dramatic projected increase in the frequency of extreme heat nights in summer in the highly urbanised areas of the Gold Coast region.

Under a BAU scenario on greenhouse emissions, the CSIRO and BoM estimate that the Gold Coast could experience as high as one in ten summer nights over 25 degrees by 2050, under one in four by 2070 and 44% – nearly half – of summer nights in extreme heat by 2090.

Under a RCP 4.5 pathway with significant emissions reduction, the amount of these extreme heat nights would not reach anywhere near the peak of the BAU scenario. Even under the highest projections, the RCP 4.5 scenario tops out below the lowest projection of BAU at five days by 2070, and nine by 2090. The average of these climate models also predicts under five extreme heat nights a summer by 2090, avoiding substantial harm to the people of the Gold Coast.

The high incidence of extreme summer nights combined with the significant increase in projected heat days can lead to a a climate that's very dangerous to human health and wellbeing.

Health and productivity impacts of extreme heat

The impact of extreme heat on human health, particularly over extended periods of time, is severe. Although people living in hot areas do acclimatise to help cope with extreme temperatures, there are limits.[21] A large increase in days over 35 and nights over 25 degrees will push past those limits.

The health impacts of increasing extreme heat can include both direct heat illnesses such as heat exhaustion and indirect illnesses such as heart failure and even death.

WorkSafe Queensland lists a range of illnesses arising directly from extreme temperatures from mild cramps, rashes, and dehydration to severe injuries such as heat stroke, exhaustion and even death if treatment is delayed.[22] As climate change worsens this can be expected to put more vulnerable people at increasingly greater risk.

The groups most vulnerable to heat impacts include the elderly, the very young, and those with pre-existing health conditions. Illnesses such as angina, kidney disease, and diabetes are at higher risk of being triggered or exacerbated when people are unable to maintain a safe body temperature.[23]

People suffering from mental disorders are also vulnerable. This vulnerability to extreme heat can result from altered behavioral responses to high temperatures or the impact of medications.

As stated earlier, irritability and psychological stress also increase in heat. When hot days are combined with hot nights, heat load and stress carries over and the body has no opportunity to cool down and recover. Studies show that there is an association between the mortality of not just stroke patients but also the general population and

[21] Hanna and Tait (2015) *Limitations to thermoregulation and acclimatisation challenges human adaptation to global warming,* Int J Environ Res Public Health 12.

[22] WorkSafe Queensland (n.d.) *Health effects,* https://www.worksafe.qld.gov.au/injury-prevention-safety/hazardous-exposures/heat-stress/health-effects

[23] Hanna et al. (2016) *The silent killer: Climate Change and the Health Impacts of Extreme Heat,* The Climate Council, https://research-management.mq.edu.au/ws/portalfiles/portal/72578140/72578105.pdf

high night temperatures.[24,25] The 'synergistic effect' of night humidity, increased temperatures, and UHI in heatwaves has been estimated in some studies to double general mortality risk by the end of the century under RCP 8.5.[26] Often underated, major heatwaves have caused more deaths in the last century in Australia than bushfires, cyclones, earthquakes, floods and severe storms put together put together.[27]

Extreme heat nights also cause increased insomnia and lack of rest. This is exacerbated by the higher relative humidity at overnight time. As sleep is vital for healthy human functioning, a deficit means more susceptibility to disease, obesity, chronic illness and harm to our psychological and cognitive functioning.[28]

Productivity decreases significantly under these stresses as people are affected with the consequences of extreme heat. Workplace safety and the ability to work declines. This can also be displayed in economic terms as costs rise to account for the lack of labour productivity and changes needed in workplaces.[29]

As the Gold Coast is reliant on the services, tourism, manufacturing, construction and retail industries for employment, this would have detrimental impacts to the region.

[24] Murage et al. (2017) *Effect of night-time temperatures on cause and age-specific mortality in London,* Environmental Epidemiology 1.
[25] Roye (2017) *The effects of hot nights on mortality in Barcelona, Spain,* International Journal of Biometeorology 61.
[26] Zhao et al. (2018) *Interactions between urban heat islands and heat waves,* Environmental Research Letters 13.
[27] Hanna et al. (2016) *The silent killer: Climate Change and the Health Impacts of Extreme Heat,* The Climate Council
[28] Obradovich et al. (2017) *Nighttime temperature and human sleep loss in a changing climate,* Science Advances 3.
[29] Climate Council (2014) *Heatwaves: Hotter, Longer, More Often,* https://www.climatecouncil.org.au/uploads/9901f6614a2cac7b2b888f55b4dff9cc.pdf

Extreme heat impacts on infrastructure

The effects of extreme heat on infrastructure essential to the Gold Coast is also projected to be significant:

- Power and transmission infrastructure around the Gold Coast region would be affected by higher sustained temperatures. Levels of peak demand during heat would also rise as people use air conditioning to escape the day and night stress. This would affect the ability of generation to meet demand and increase the incidence of blackouts due to load shedding.
- General water demand would rise while supply would fall, leading to water stress.
- Medical facilities would be under increased strain because of the rise of detrimental health effects.
- Transport infrastructure would fail more frequently. Bridges, roads, concrete structures and rail lines would all be susceptible to damage from cracking and buckling under stress.
- The effects of heat damage, cracking and buckling would also affect the theme park industry's rides and attractions – a key attraction in the Gold Coast.
- Homes, businesses, power generators, and public infrastructure would all be under the increased threat of bushfires caused by drier and hotter conditions.[30]

The financial losses and economic cost that result from the effects of these failures and disruptions would affect everyone and every aspect of the Gold Coast region.

[30] Climate Council (2014) *Heatwaves: Hotter, Longer, More Often,* https://www.climatecouncil.org.au/uploads/9901f6614a2cac7b2b888f55b4dff9cc.pdf

Conclusion

An increase in days and nights of temperature extremes will have severe impacts on human health, including increased rates of heat-related deaths.

Given the vulnerability of the Gold Coast and the rest of the Queensland to climate change, strong emissions reduction policies are in the region and state's interests.

Fortunately Queensland is in a strong position to implement and benefit from strong climate and energy emissions reduction policies. Queensland is blessed with an abundant solar resource. This presents it with the opportunity to make large reductions in power sector emissions and a particular opportunity for solar rich areas like the Gold Coast to benefit from the regional development and employment opportunities of renewable energy.

Increasing gas and coal exports is incompatible with Australia's carbon budget and commitments under the Paris Agreement to limit warming to less than 2 degrees above pre-industrial levels. It has been calculated that two thirds of existing fossil fuel reserves need to remain in the ground in order to have even a 50% chance of avoiding 2 degrees of warming.[31]

The recent IPCC Special Report on Global Warming found that keeping warming below 1.5 degrees will be necessary to avoid many devastating impacts, and that to do so the world will need to reach net zero emissions by 2040, or 2055 at the latest. [32]

Australia is one of the highest per capita emitters in the world. Queensland's large and expanding coal and gas export activities are internationally significant and are throwing fuel on the fire, increasing extreme temperatures in a way that will have a devastating impact on the Gold Coast region.

There is an urgent need for adaptation measures to cope with increasing extreme heat in many parts of Australia, including the Gold Coast. However, without strong global action on climate change, temperature increases will reach levels beyond most adaptation responses. As a major emitter, it is important that Queensland and Australia as a whole play our part in achieving these ambitious and essential emissions reductions.

[31] McGlade and Ekins (2015) *The geographical distribution of fossil fuels unused when limiting global warming to 2 °C*, https://www.nature.com/articles/nature14016

[32] IPCC (2018) *Global Warming of 1.5 °C,* http://www.ipcc.ch/report/sr15/