CLIMATE
COMMISSION

THE CRITICAL DECADE

Queensland climate impacts and opportunities

Summary

Queensland's climate is already changing and is likely to change further in the future, posing significant risks for the state. The next chapter of the climate story is about how Queenslanders, and Australians, can find solutions that minimise the risks of climate change while providing extra benefits for our health, community, economy and environment.

Queensland's agricultural industries are at risk from climate change.

– Agricultural productivity is affected by climate change through: higher temperatures; changes in the amount, intensity, seasonality and variability of rainfall; and changes in the frequency and/or intensity of extreme events such as droughts, bushfires and floods.

– As a result of climate change, beef, sugar and cereal production in Queensland is expected to decline.

– Queensland farmers are accustomed to dealing with a highly variable climate, but in the future, new risk management and adaptation strategies will be even more important as the climate changes.

Queensland's tourism industry is at risk from climate change.

– Tourism is a key industry for Queensland, employing 120,000 people and attracting tourists from around the world. Queensland's tourism industry relies on its unique local attractions including sandy beaches, the Great Barrier Reef, and World Heritage rainforests.

– In the last three months of 2011, visitors to tropical North Queensland spent $735 million. Higher temperatures and changing rainfall will place the rainforests in a highly stressed situation towards the end of the century.

– The Great Barrier Reef is threatened by higher sea surface temperatures and more acidic oceans.

– Queensland's natural environment supports 70% of Australia's native birds, 85% of its mammals and more than 50% of the nation's reptiles and native frogs. Many of Queensland's species and ecosystems are already threatened and climate change poses a serious additional threat to Queensland's unique biodiversity.

Sea-level rise threatens Queenslanders' property and lifestyle.

– Long stretches of sandy beaches in southeast Queensland – the Gold Coast, Moreton Bay, Brisbane and the Sunshine Coast – are threatened by the increased coastal erosion resulting from rising sea levels.

– The Gold Coast has more houses than any other region in Queensland within 110 m of erodible coastline, with more than 4,000 residential buildings at risk.

– Moreton Bay and the Sunshine Coast follow with around 2,000 residential buildings at risk in each region.

Using energy more efficiently can provide new opportunities for Queenslanders.

– Making our cities more sustainable can also make them healthier and more liveable, while reducing energy costs and greenhouse gas emissions.

– Improving the environmental performance of buildings – for instance, by using more energy-efficient lighting, heating, cooling and refrigeration – offers opportunities to save energy costs and provide healthier conditions for workers.

– Many businesses are already cutting energy costs and pursuing new business opportunities, such as using waste products to produce energy. This area will continue to grow with a changing climate.

Queensland is an ideal location for harnessing solar energy.

– Queensland is truly the Sunshine State with some of the world's highest levels of solar exposure.

– Queensland is leading Australia in solar photovoltaic system installation, and has doubled its use of solar energy in less than two years. By July 2012, more than 200,000 Queensland households and businesses had installed solar panels.

– While use of solar energy has grown rapidly, Queensland can take more advantage of its solar resources. Solar photovoltaic systems currently provide around 4% of the state's total electricity generation capacity.

– Around the world, investment in renewable energy is growing strongly and costs are rapidly coming down. In remote areas of Australia the cost of solar electricity is estimated to already be cheaper than retail electricity.

With thanks to the Science Advisory Panel, Dr Paul Marshall, Professor Ove Hoegh-Guldberg, Dr Mark Howden, Mr Alan Pears and Dr Steven Crimp for their comments on the report.

This report draws on the Climate Commission's reports *The Critical Decade: Climate science, risks and responses* and *The Critical Decade: Climate change and health*, and is the Climate Commission's 14th report.

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1. CHANGES IN QUEENSLAND'S CLIMATE

– Queensland has been getting hotter over the past 50 years.

1.1 Temperature

Temperatures are expected to continue rising this century. The average temperature for Queensland has risen by about 1°C since early last century, with most of the warming occurring since the 1950s (BoM, 2012a; Figure 1). The central and southwest regions of the state have experienced the largest increase in average temperature since the 1950s.

While the observed small shift to higher average temperatures may seem modest, sustained warming trends lead to relatively large increases in the number of extreme hot weather events. The average temperature across Australia has risen by 0.9°C since 1910 and has been associated with the number of record hot days more than doubling (CSIRO and BoM, 2007; Figure 2).

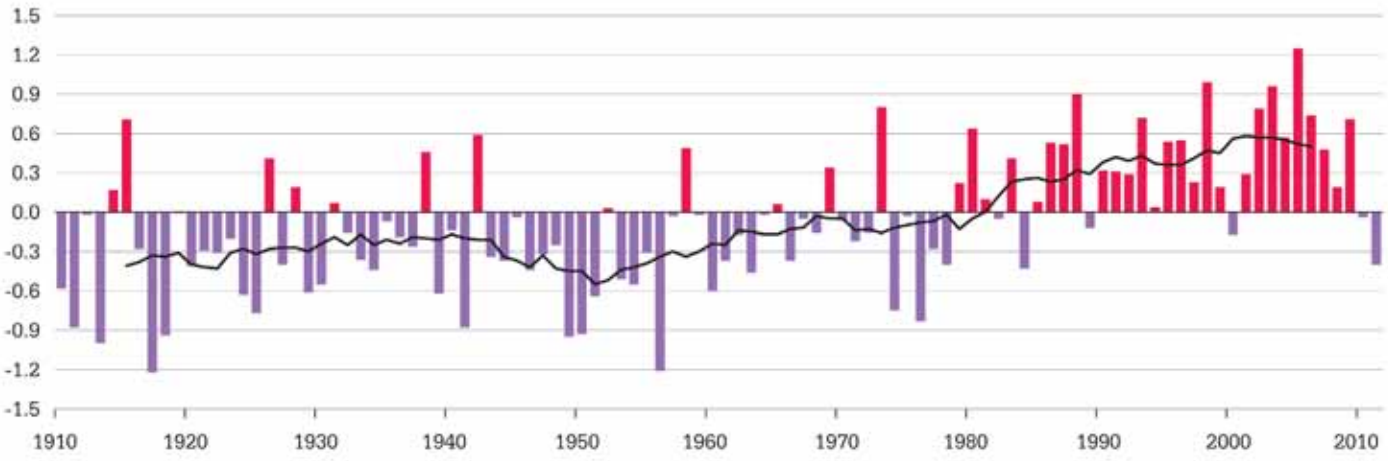


Figure 1. Annual average temperature anomaly for Queensland. The black line indicates the 11 year running average and shows that the average temperature across Queensland has been increasing over the past 60 years. Note: The annual average temperature anomaly is measured as the difference from the long-term (1961–1990) climate average.
Source: BoM (2012a)

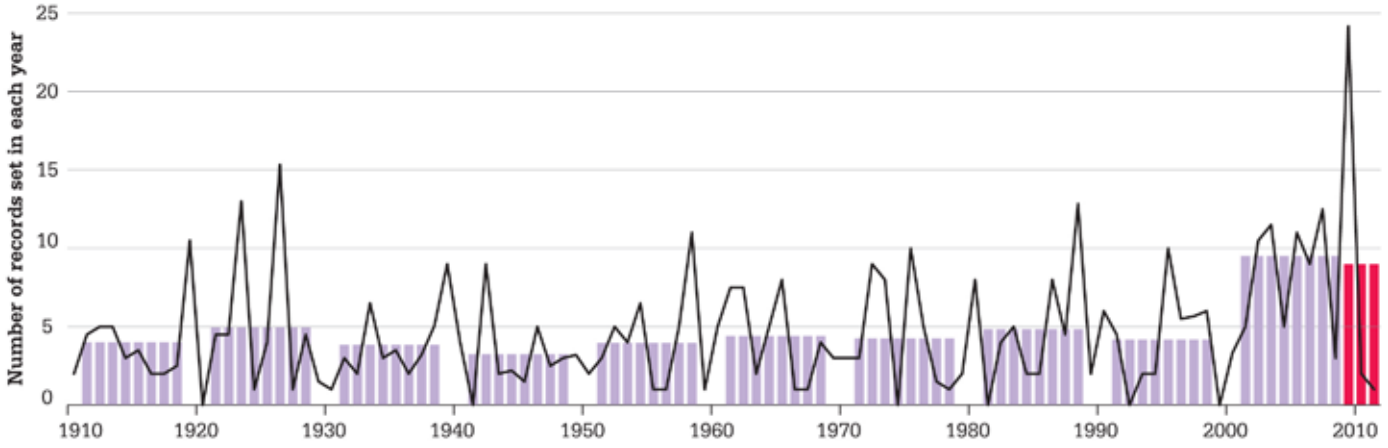


Figure 2. Average number of hottest-day-of-the-month records each year across Australia. Yearly average shown by black line and 10 year average shown by purple bars. The average for the most recent 10-year period (2002–2011) is shown in red.
Source: BoM (2012b)

Average temperatures are expected to continue to rise across Queensland. By 2030, average temperature is expected to have risen by 1°C above the 1961–1990 baseline and by 2070, the increase could be 1 to 5°C, depending on the level of global emissions (CSIRO and BoM, 2007). The temperature rises are very likely to be larger in the inland areas compared to coastal regions.

The number of very hot days is likely to increase further in the future. While the number of hot days is likely to increase modestly in the next few decades, it could increase significantly by the end of the century. Brisbane currently experiences on average around 1 hot day per year (over 35°C). In the Brisbane area this is projected to increase to around 2 days by 2030, 8 days by 2070 and 21 days by 2100 (CSIRO, 2008). Across northern Australia extremely hot weather is expected to occur more frequently. In this region extremely hot days – those that currently occur on average only once in every 20 years – are projected to occur every 2–5 years by mid-century, and every year or two by the end of the century (IPCC, 2012).

1.2 Rainfall

– Rainfall patterns in Queensland are changing, with evidence that some areas are getting drier and some are getting wetter.

Over the past 110 years, Queensland has become slightly wetter apart from the coastal region stretching from the southeast northwards to Townsville (Figure 3). This coastal drying trend has become more obvious over the 1970–2011 period (Figure 3). However, unlike southwest and southeast Australia, where research shows the rainfall declines are at least partly attributed to human-induced climate change, scientists cannot yet say the extent to which observed trends in Queensland are linked to human-induced climate change.

What will future rainfall patterns look like across Queensland? This is a difficult question, as there is not yet consensus among scientists on either the scale or direction of the changes. This is in part due to uncertainty about the response of the El Niño Southern Oscillation and the Interdecadal Pacific Oscillation – two important features of natural variability – to higher temperatures. However, there is some agreement that the tropics are likely to extend further south (Allen et al., 2012; Lucas et al., 2012).

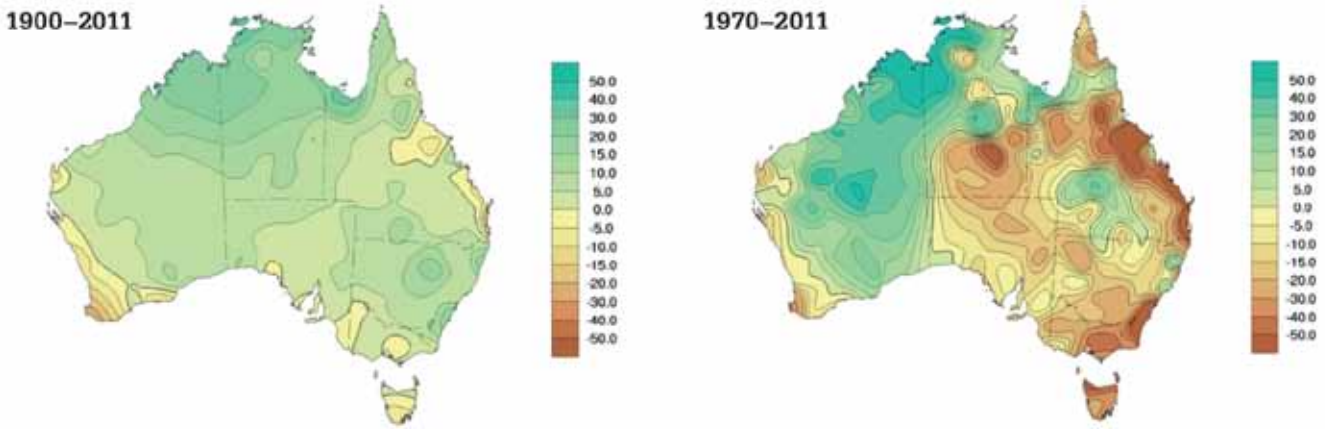


Figure 3. Trend in total yearly rainfall for the periods 1900–2011 and 1970–2011.
Source: BoM (2012c)

Heavy rainfall in Queensland caused widespread flooding, including across many residential areas of Brisbane.
Source: PMBO

Heavy rainfall events are a natural feature of the Queensland climate, as experienced in 2010 and 2011. The extremely wet weather was largely due to the influence of La Niña, a climate phenomenon bringing warmer sea surface temperatures to eastern Australia. Climate change may be a factor due to its influence on rising sea surface temperatures, which influence evaporation rates and the amount of moisture in the atmosphere (Evans and Boyer-Souchet, 2012). Heavy rainfall events may increase across northern Australia throughout the rest of this century but there is a low level of confidence in this projection (IPCC, 2012).

1.3 Tropical cyclones

Tropical cyclones are important extreme events in north Queensland. Rainfall rates and maximum wind speeds that occur during tropical cyclones are likely to increase but the number of cyclones may decrease or remain unchanged (IPCC, 2012). That is, there may be fewer cyclones, but they are likely to be stronger and thus pose a larger risk to people, infrastructure and ecosystems. A southward shift in the starting and finishing locations of tropical cyclones is likely off the Queensland coast. This may result in an increase in tropical cyclones affecting regions of southeast Queensland (Abbs, 2012).

1.4 Sea-level rise

- Global sea level is on track to rise further over this century and beyond, posing challenges for Queensland's coastal towns and cities.
- Sea-level rise is now tracking near the highest levels that scientists have predicted in the past.

Global sea level rose at a rate of 1.7 mm per year over the 20th century. This rate has increased to about 3.2 mm per year over the last two decades. Rates of sea-level rise vary regionally, as has been observed along Queensland's coasts. Depending on the region, the sea level along Queensland's coasts is rising at, or above, the global average.

The observed global sea level is tracking close to the upper range of the Intergovernmental Panel on Climate Change (IPCC) model projections. The IPCC projections for the end of this century, compared to the 1990 baseline, range from about 20 cm to 80 cm but higher levels cannot be ruled out (IPCC, 2007; DCC, 2009). Most experts agree that a rise within the range of 50 cm to 100 cm is most likely by 2100. However, depending on the stability of the major ice sheets in Greenland and the Antarctic, a sea-level rise over 100 cm is a distinct possibility.

2. IMPACTS OF CLIMATE CHANGE ON QUEENSLAND

This section considers issues that matter to all of us: our health, our cities, our biodiversity and industries that rely on the natural environment. Many of the impacts of climate change are often the consequence of multiple aspects of the changing climate system, rather than any single change in isolation, such as the higher sea levels and hotter temperatures described above.

2.1 Human health

- More frequent and/or intense extreme weather events pose risks to human health, both immediately and after the event.
- The geographic region suitable for transmission of mosquito-borne diseases is expected to extend further south.

Changes in climate, particularly increasing temperatures and increasing frequency and/or intensity of extreme weather events, can pose serious risks to human health.

Changes in temperature, rainfall and humidity in Australia may allow mosquito-borne infectious diseases, such as dengue fever and Ross River virus, to become more widespread. The main carrier of dengue fever, the mosquito *Aedes aegypti*, is typically confined to northern Queensland where outbreaks occur almost annually (Ritchie, 2009; Russell et al., 2009). The geographic region suitable for the transmission of dengue is expected to expand southwards along the Queensland coast and into northern NSW over this century, if the climate becomes hotter and wetter (Bambrick et al., 2008; Figure 4).

Hot days and heatwaves put significant pressure on the body, leading to greater incidence of lethargy, heatstroke, organ failure and death. Heat-related mortality in Queensland could increase (Bambrick et al., 2008), even taking into account population changes as well as efforts to reduce greenhouse gas emissions. Children, the elderly, those in heat-exposed jobs (such as construction workers, those on outside mine sites, farmers and emergency service providers) and low-income earners are all at greater risk from heat extremes.

Rising temperatures are likely to make heatwaves more severe. Brisbane has already experienced the impact of very hot days on human health. During the February 2004 heatwave, temperatures on 21 and 22 February peaked at 41.7°C, resulting in a 53% increase in ambulance call-outs (Steffen et al., 2006).

Other extreme weather events such as cyclones, storms, floods, bushfires and droughts also affect human health through injury, disease and death. Thirty-three people died during intense floods in December 2010 and January 2011. The flooding, along with tropical cyclones Anthony and Yasi, caused more than 78% of Queensland to be declared a disaster zone (QFCI, 2012). These events demonstrate the effects that extreme weather events can have on human health and infrastructure.

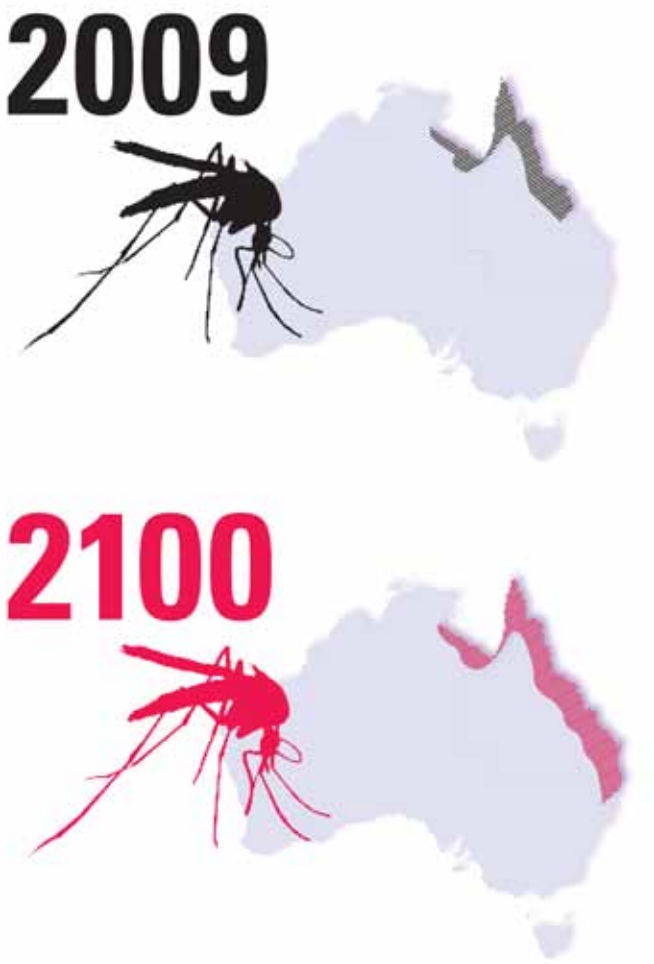


Figure 4. Potential spread of dengue fever by 2100, shown by shaded area.
This diagram is indicative only and is drawn from the in-text references. The actual future distribution of the mosquito carrying dengue fever will be determined by climate as well as other changes, for example, in technology and population.

2.2 Agriculture

– Risks of increasing temperature, changes in rainfall and increasing severity of extreme weather mean that the climate of the future will not be the same as that in the past. The risks to Queensland's agricultural industries from changes in climate include:
  – heat stress for livestock and plants
  – some fruit and vegetable crops no longer being able to be grown where they are now due to less chilling and maturing time
  – salinity related to rising sea levels adversely affecting crops in coastal areas
  – potential increases in rainfall in the north increasing waterlogging in crops like sugar
  – reduced cereal production with increases in temperature or changes in rainfall.

Agriculture contributed more than $14 billion to the Queensland economy in 2011–2012 (DAFF, 2012). Queensland farmers are accustomed to dealing with a highly variable climate, but new risk management and adaptation strategies will be even more important as the climate continues to change.

Future productivity will be affected by climate change through higher temperatures; changes in the amount, intensity, seasonality and variability of rainfall; and changes in the frequency and/or intensity of extreme events such as droughts, floods and bushfires. Agricultural productivity is already sensitive to changes in rainfall amounts and distribution and other climatic extremes. Recent flooding across central, western and southwest Queensland is estimated to have cost primary producers up to $70 million from crop and livestock losses alone (DAFF, 2012).

There may be some limited benefits for agricultural industries from rising atmospheric carbon dioxide (CO_2), as some plants can become more efficient at using water in a high CO_2 environment. However, any benefits are likely to be outweighed by the negative impacts of a changing climate. For example, higher CO_2 concentration means that plant matter is less nutritious (Taub et al., 2008). Even a doubling of CO_2 concentrations in the atmosphere, which would cause dramatic changes to the global climate, is unlikely to offset rainfall declines of greater than 10% of the annual totals (Crimp et al., 2002).

Beef and dairy

Queensland is Australia's largest beef-producing state, supplying nearly 50% of the nation's beef for domestic consumption and export (DEEDI, 2010). Queensland provides about 5% of national milk production (Dairy Australia, 2012).

Modelling by ABARE (2007), based on CSIRO/BoM projections, indicates that beef production in Queensland could decline substantially by 2050 due to climate change. Cattle are likely to suffer heat stress more frequently, especially in feedlots. Animals with heat stress have reduced appetite, produce less milk and milk of lower quality, grow more slowly, and are less likely to breed (QFF, 2008; DEEDI, 2010). Heat stress can also lead to mortality in extreme circumstances. Recent efforts to maximise milk production through selection of larger animals have also served to increase the susceptibility of dairy cows to heat stress. Any decline in rainfall could result in reduced forage production and increased pressure at watering points, leading to land degradation.

Increasing temperatures could also shift the distribution of pests and parasites such as cattle ticks and buffalo fly in a southerly direction, increasing the risk of infection, disease and reduced production (QFF, 2008). Cattle ticks alone have been estimated to cost more than $40 million each year in control measures, and more than $90 million from lost production (McLeod, 1995). Climate change is expected to result in a reduction in tick numbers in the northern parts of the state and an increase in the south, with accompanying impacts on weight gain (White et al., 2003).

Beef cattle in Queensland are likely to suffer heat stress more frequently.

Sugar

The sugar industry contributes more than $1.7 billion per year to the Queensland economy and accounts for over 90% of all sugar produced in Australia (QSL, 2012). Overall, sugar production in Australia is expected to decline as a result of climate change (ABARE, 2007). In the north, potential increases in rainfall may increase waterlogging, limit paddock access and reduce yields and sugar content through reduced sunshine, physical damage, and leaching of nutrients. Crops in coastal areas may be affected by rising water tables and salinity, made worse by rising sea levels (QFF, 2008). There may be limited benefits to sugar production from increasing atmospheric CO_2 and higher temperatures (QFF, 2008; Park et al., 2010). Overall, the story for the sugar industry is that climate change poses significant and damaging risks.

Extreme weather events can have a significant impact on the availability and cost of Queensland fruit and vegetables. The destruction of banana crops after Cyclones Yasi and Larry led to significant increases in banana prices around Australia.

Fruit and vegetables

One third of Australia's fruit and vegetable production comes from Queensland – more than 120 types of fruit and vegetables in total – and the industry employs around 25,000 people (QFF, 2008). Horticultural industries are more sensitive than many other agricultural sectors to climate change, particularly changes to temperature and reduced rainfall (Deuter et al., 2006). As the climate changes, some crops will not be able to be grown where they are grown now. Heat stress, increased irrigation demand, reduced chilling and maturing times, and increased pest and disease problems are likely (QFF, 2008). Rising temperatures will affect yield, quality, and the length of the growing season for crops such as tomatoes and lettuce, although development of more heat-tolerant cultivars may offset some of these impacts (Deuter et al., 2010a; Deuter et al., 2010b).

Cotton

Queensland normally produces about 30% of the nation's cotton crop but drought can cut production dramatically (QFF, 2008). In the Queensland part of the Murray-Darling Basin, any significant reductions in average rainfall in the winter growing period could reduce availability of water for irrigation in spring and summer, resulting in lower production in the region (QFF, 2008). Fibre quality and quantity of both irrigated and dryland cotton is significantly affected by temperature and water availability. Decreases in the number of cold days due to climate change may prove beneficial to cotton production in some regions, but increasingly hot temperatures may also adversely affect production (QFF, 2008).

Winter and summer cereals

Assessments of cereal production by 2030 predict a 7–15% decline as a consequence of climate change (Potgieter et al., 2012). Winter cereals used in intensive livestock industries (e.g. wheat and barley) are worth $2.5 billion to the state´s economy, while other broadacre field crops are estimated to be worth an additional $675 million (DEEDI, 2011). Increased temperatures and changes to seasonal rainfall are expected to have an overall negative impact on cereal production in Queensland.

Fisheries and aquaculture

80% of Australia's prawn farms are located in flat coastal areas of Queensland. Prawn farms are at risk of damage from rising sea levels, increased floods, and increased cyclone intensity (QFF, 2008). Coastal fisheries may be affected directly by rising ocean temperatures and changes in ocean productivity, as well as indirectly by changes in the runoff from land due to altered rainfall (Meynecke and Lee 2011; Munday et al., 2012).

2.3 Coasts at risk

– The risks of coastal flooding and beach erosion will increase for many areas of the Queensland coast.
– Moreton Bay, Mackay, the Gold Coast, the Sunshine Coast, Fraser Coast and Bundaberg local government areas are the most at risk from rises in sea level together with high tides, storm surges and heavy rainfall.

Queenslanders enjoy living close to the ocean – 85% of the state's population (3.8 million people) live near the coast (DERM, 2011b). Rising sea levels pose considerable risk to coastal property, infrastructure and beaches through coastal flooding and erosion (Figure 5).

As described in Section 1.4, experts agree that global sea level is likely to rise 50–100 cm by 2100 compared to 2010. Even at the lower end, a 50 cm increase in sea level would contribute to a significant increase in the frequency of coastal flooding (Figure 6).

Coastal flooding occurs during extreme weather events such as storms, which can drive a surge of seawater onto vulnerable coastal areas. These storm surges, when combined with a high tide, rising sea level and heavy rainfall on coastal catchments, increase the risk of flooding to property, infrastructure and beaches. North Queensland, in particular, is vulnerable to coastal flooding, as more intense tropical cyclones could drive very large storm surges as well as heavy rainfall. Flooding caused by a combination of a high tide, a storm surge and rising sea-level is often called a 'high sea-level event'.

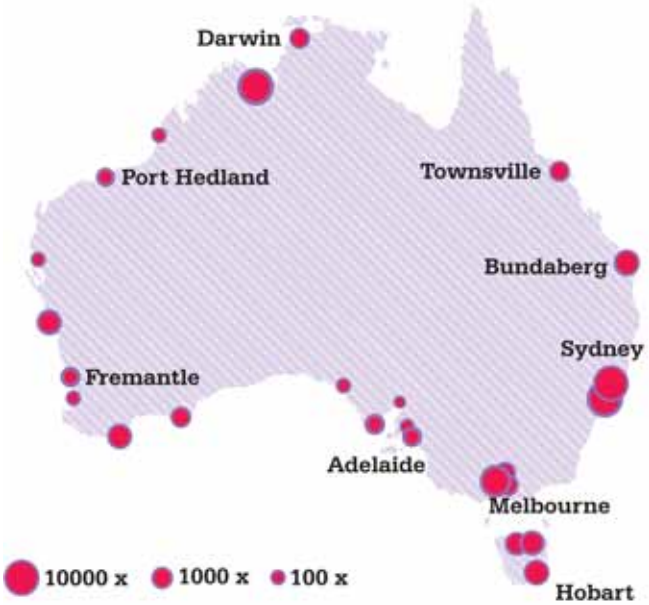


Figure 6. Estimated increase in the frequency of high sea-level events from a rise of 50 cm in sea level. Such a seemingly modest rise in sea level will lead to a very large increase in the frequency of coastal flooding. For example, a thousand-fold increase in high sea-level events means that flooding that currently occurs only once in 100 years would occur almost every month.
Source: ACE CRC 2008

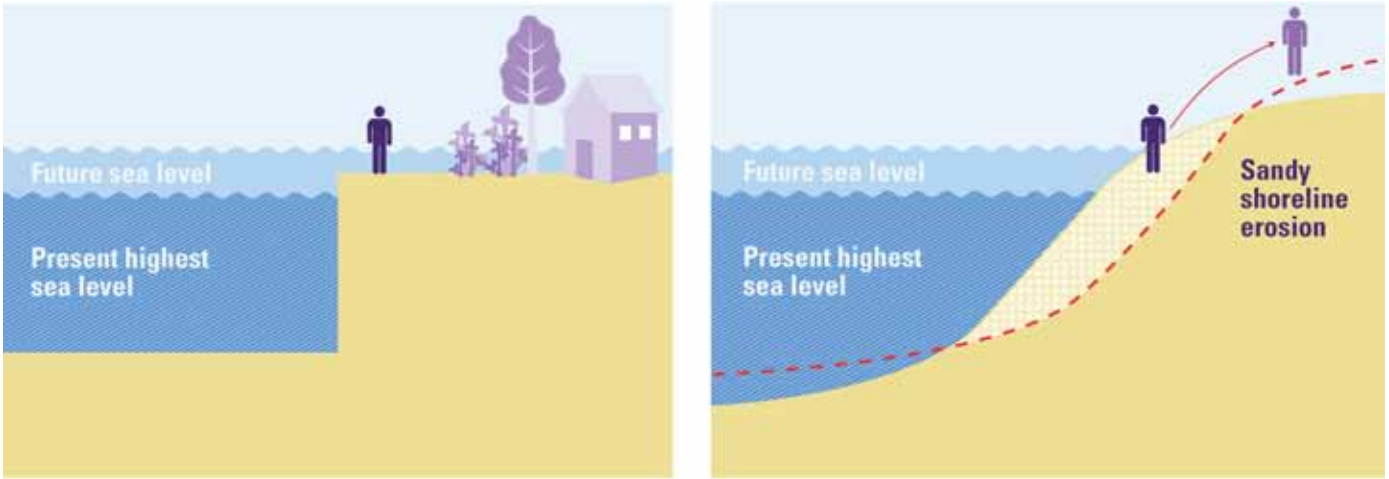
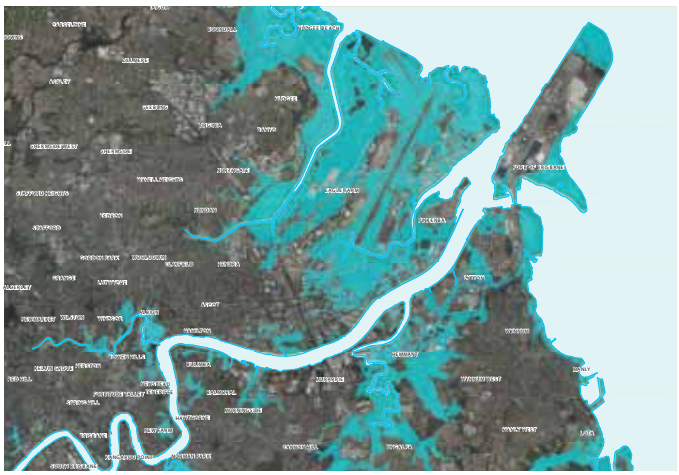


Figure 5. There are two main impacts of sea level rise: flooding and erosion.
Source: modified from ACE CRC



Major airports, including Brisbane airport (above) and Cairns airport are vulnerable to sea-level rise and storm surge (OCC, 2010). Coastal flooding can also cause significant damage to infrastructure such as roads, water supply and sewerage.
Source: DCCEE (2010)

At the high end of climate change projections, sea level could rise by 110 cm over this century compared to 1990. This level would threaten up to 1,400 existing commercial buildings in Queensland, with a replacement value of $10 – $15 billion, and up to 1,800 light industrial buildings, with a value of $1.3 – $2 billion (DCCEE, 2011). An estimated 35,900 to 56,900 existing residential buildings in Queensland may also be at risk of flooding from sea-level rise (DCC, 2009). Storm surges were not included in this assessment, and it is likely a higher number of properties would have been identified at risk if it had been (DERM, 2011b). Local government areas with the highest number of properties at risk from a 110 cm sea-level rise and a high tide include Moreton Bay, Mackay, the Gold Coast, the Sunshine Coast, Fraser Coast and Bundaberg (DCC, 2009).

High sea-level events can also contribute to the erosion of coastlines and eventual coastal retreat. Erosion can cause the loss of iconic beaches and damage property and infrastructure. There are around 15,200 residential buildings within 110 m of erodible coastline in Queensland (DCC, 2009).

The heavily populated coastal regions of southeast Queensland – the Gold Coast, Moreton Bay, Brisbane and the Sunshine Coast – are a magnet for tourism and development, with the gross tourism value of the Gold Coast beaches alone estimated to be between $106 and $319 million in 2006 (DERM, 2011b). After the Gold Coast (Box 4), Moreton Bay and the Sunshine Coast have 2,250 and 1,850 residential buildings respectively within 110 m of erodible coastline (DCC, 2009).

Box 1. Torres Strait Islands

Many Torres Strait Islands are already vulnerable to flooding, but rising sea levels will worsen this vulnerability. Around 7,000 people live on 18 of the 274 small islands between northern Cape York and the coast of Papua New Guinea (AHREOC, 2008). Many of the islands are already very low-lying and exposed to the impacts of storm surges, king tides and flooding, particularly the islands of Boigu and Saibai where average height of communities is already below highest astronomical tide (the highest tide under average conditions; TSRA, 2010).

Sea level in the Torres Strait region has been rising at double the global average, at approximately 6 mm per year (Suppiah et al. 2011). An increase in average sea level will result in increased frequency and severity of high sea-level events.

Major flooding events in 2005, 2006 and 2009 affected roads, residential buildings, cultural sites and community gardens and affected the function of waste treatment facilities (Green, 2006; Green et al., 2008; J. Rainbird, pers comm. 13 September 2012). Although these flooding events have not been linked directly to climate change, they demonstrate a window to the future as the average sea level continues to rise (Green et al., 2008).

Torres Strait communities are particularly vulnerable because the remoteness and small size of the islands can make recovery from storm events difficult, and because of the social and economic disadvantages faced by many islanders (DCC, 2009; TSRA, 2010).

Large sea-level rises could completely inundate some Torres Strait islands (TSRA, 2010), forcing communities to relocate to islands with higher ground or to mainland Australia (AHREOC, 2008). Forced relocation would cause a variety of social, cultural and economic difficulties because the Torres Strait Islanders' culture relies heavily on connection with country (Green, 2006).

Inundation at Saibai Island, Torres Strait in 2010.

2.4 Plants and animals

– Heat and extreme weather events threaten the survival, breeding and regeneration cycles of many plants and animals.
– Climate change will increase the risk of extinction for many of Queensland's species.
– Many of Queensland's iconic natural ecosystems such as the Great Barrier Reef and World Heritage tropical rainforests will become increasingly threatened as the climate continues to change rapidly.

Queensland is host to around 1,386 different ecosystems that support 70% of Australia's native birds, 85% of its mammals and just over half of the nation's reptiles and native frogs. (DEHP, 2012a). Many of these species are only found in Queensland (DERM, 2011c). Many of Queensland's species and ecosystems are already threatened – more than 200 of its ecosystems are currently listed as endangered and more than 500 as vulnerable (DERM, 2010). Climate change poses a serious additional threat to Queensland's unique biodiversity.

Biodiversity has many benefits, such as regulating the quality and flow of freshwater, maintaining soil fertility, and preventing erosion. Healthy ecosystems benefit people and economically important sectors including agriculture and tourism (MEA, 2005).

The responses of animals and plants can provide a readily visible indication of a changing climate (Box 2). Many birds and insects in Queensland are now found at more southerly locations or at higher elevations because they have migrated toward cooler temperatures (e.g. Chambers et al., 2005). Aspects of animal and plant life cycles, such as migrations and flowering, are also changing in response to a hotter climate (Steffen et al., 2009).

Plants and animals in the high altitude areas of the Wet Tropics World Heritage Area are especially vulnerable to climate change. Many species in this region are already at the limits of their range and face high risks of extinction from temperature rise and potential reductions in rainfall (Shoo et al., 2011).

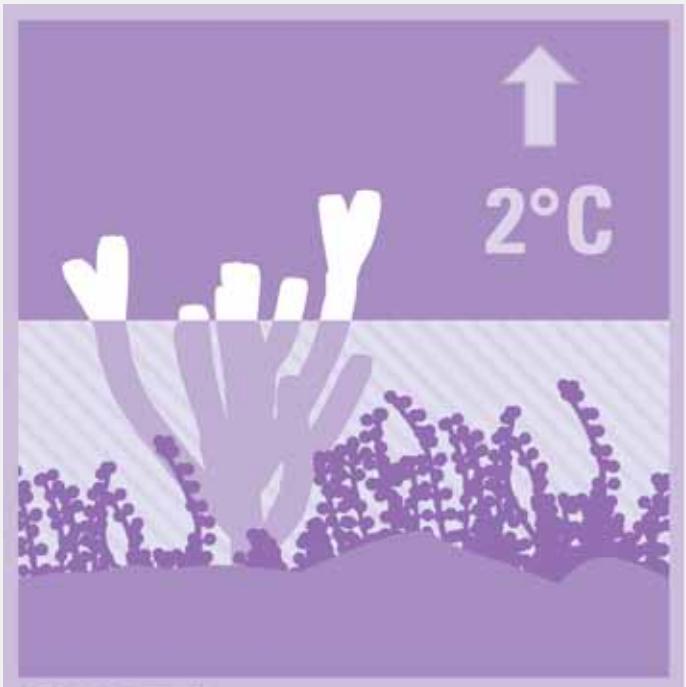
Queensland's fire-prone tropical savannas, grasslands and dry eucalypt forests provide habitat for many plants and animals, and are also at risk as the climate warms further. Bushfires are expected to become more frequent and more intense, affecting the ability of species and ecosystems to bounce back from fire damage.

Queensland's marine systems are among the most diverse in the world (Box 3). Moreton Bay in southeast Queensland is one of the largest estuarine bays in Australia, covering 3,400 square kilometres. The marine park contains an enormous variety of habitats including coral reefs, mangroves, sandy beaches, saltmarshes and seagrass beds. These systems are vulnerable to rising sea level, especially in areas where urban development prevents them taking hold in new areas inland (Lovelock et al., 2011; Traill et al., 2011).

Many species and natural ecosystems are already stressed as a result of human pressures such as land clearing, urban development and introduced species, making it harder for them to respond to the changing climate. Reducing these human pressures can make these systems more resilient to the stress of climate change. One strategy, aimed at assisting species to change their distribution in response to climate change, is to connect areas of suitable habitat. For example, the Great Eastern Ranges Initiative aims to link and protect ecosystems from the Victorian Highlands to the Atherton Ranges, allowing species to migrate and respond to climate change.

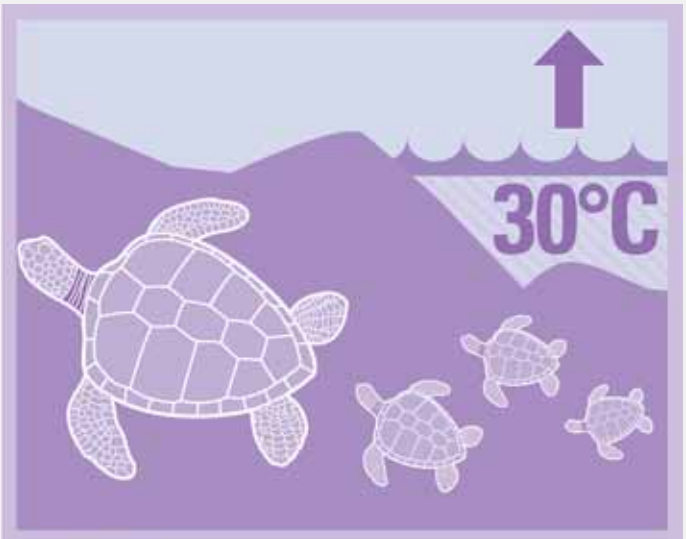
If the Queensland climate becomes hotter and drier, it is likely reduce the habitat suitable for koalas, in addition to habitat pressures from human activities (Adams-Hosking et al., 2011). Rising concentrations of atmospheric CO_2 could also affect leaf-eating animals like koalas because the plants they live on become less nutritious as CO_2 increases (Kanowski, 2001). Koalas suffer greatly during drought with populations in southwest Queensland declining by an estimated 80% between 1995 and 2009 (Seabrook et al., 2011).
Source: Flikr/Tom Tarrant

Box 2. Examples of some key species impacts in Queensland



CORAL REEFS

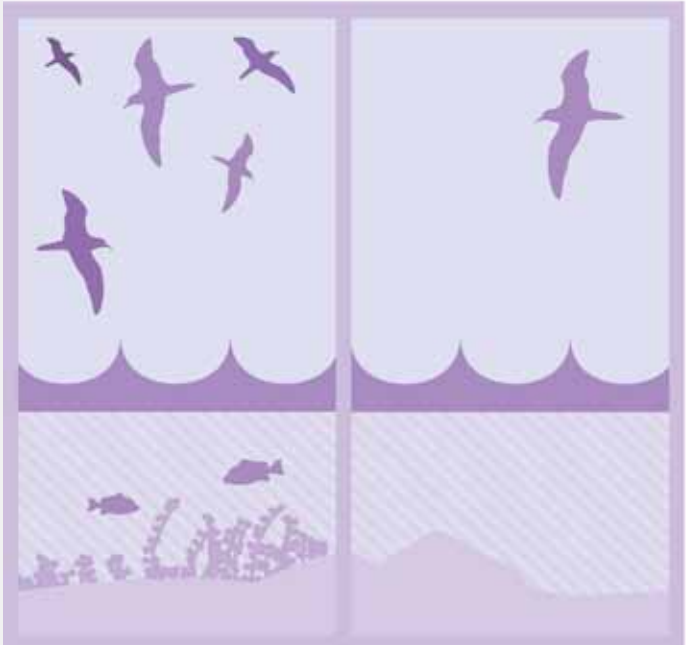
Sea temperatures **1–2°C above normal** can cause **mass coral bleaching**.



TURTLES

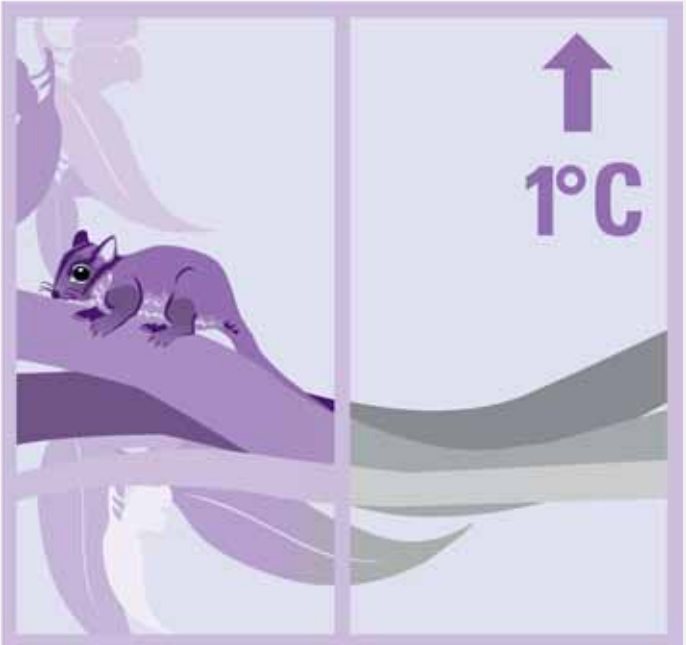
The sex of turtles is determined by the temperatures of the nest – at about **30°C only female turtles are born**, endangering future successful breeding.

Nest sites may also be affected by any increase in intensity of tropical cyclones, and rising sea level could **flood important nesting beaches** (Fuentes et al., 2011; GBRMPA, 2009).



SEABIRDS

Some seabirds have **failed to breed at all** in years where sea temperatures have been high, due to the reduced availability of fish (Smithers et al., 2003).



WET TROPICS

Animals such as the mahogany glider and lemur-like ringtail possum could **lose a large portion of climatically-suitable habitat**. (DSEWPAC, 2006)

Box 3. Climate change and the Great Barrier Reef

The Great Barrier Reef (GBR) is the world's largest continuous reef system (over 2,200 km long, and 375,000 square kilometres in area), and comprises more than 2,900 individual reefs. The GBR is one of the most biologically diverse ecosystems in the world and is a globally-important breeding ground for seabirds and other marine vertebrates such as turtles and whales (GBRMPA, 2009). The reef is vital to Australia's tourism and fishing industries, attracting five million visitors to the region in 2008–2009 (Stoeckl et al., 2011). In 2006–2007, the GBR was estimated to contribute $5.4 billion to the Australian economy, and provided more than 50,000 jobs (Access Economics, 2008). The GBR also provides protective services to coastal communities valued at more than $10 billion (Oxford Economics, 2009).

Climate change poses multiple, serious threats to the GBR (Johnson & Marshall, 2007). Sea temperatures only 1–2°C above the average summer maximum (based on the period 1985–93, excluding 1991–92) can cause mass coral bleaching (loss of symbiotic algae) (Hoegh-Guldberg et al., 2007) and lower their growth rate (De'Ath et al., 2009). If high temperatures (2–3°C above normal) are prolonged or persistent (more than eight weeks) bleached corals will die in increasing numbers. Before 1979 there were no records of bleaching on the GBR but since that time at least nine bleaching episodes have occurred (Anthony and Marshall, 2012). Ocean temperatures in the region have warmed by over 0.45°C since 1980 with the highest temperatures ever recorded occurring in the summer of 2010 (Lough et al., 2012). With the current rate of warming, reefs could suffer a chronically high level of bleaching by the mid to late part of this century (Anthony and Marshall, 2012).

The reef is vital to Australia's tourism and fishing industries.
Source: Great Barrier Reef Marine Park Authority

Higher average temperatures will cause increasing amounts of coral bleaching in the Great Barrier Reef.
Source: Great Barrier Reef Marine Park Authority

In addition to the impacts of warming waters, corals and other marine organisms are likely to be affected by ocean acidification. The world's oceans are approximately 30% more acidic than in pre-industrial times due to their absorption of CO_2 from the atmosphere (Howard et al., 2012). Acidification is expected to reduce the rate of reef growth and makes corals and other organisms more fragile. Further serious impacts from rising sea levels, increasing coral diseases and physical damage from any intensification in tropical cyclones are also expected (Veron et al., 2009). The GBR has been affected by five severe tropical cyclones between 2005 and 2011, with Cyclone Yasi being the largest tropical storm system in recorded history to cross the GBR (Anthony and Marshall, 2012).

The ability of coral reefs to adapt to global warming is a matter of contention. While laboratory experiments suggest that some adaptation is possible, the rate of climate change is likely to be too rapid for most coral reef organisms to keep pace and for the critical goods and services provided by the Great Barrier Reef ecosystem to be maintained (Hoegh-Guldberg, 2012). This means that substantial negative impacts are likely not only for reef biodiversity but for the tourism and fishing industries that the reef supports.

Management actions to increase resilience of coral reef systems include protecting herbivorous fish (who play important ecological roles), as well as top predators, reducing coastal sediment and nutrient runoff (Brodie et al., 2012), and minimising other human disturbances by increasing marine protected areas (Hughes et al., 2007; Veron et al., 2009; Wooldridge et al., 2012). Management initiatives such as the Reef Water Quality Protection Plan, Reef Rescue, and the Representative Areas Program (which expanded totally protected areas on the GBR from 4.6% to over 33%) are strategies to improve the ability of coral reefs to endure the rising pressure from rapid climate change.

Box 4. Tourism in Queensland

DAINTREE (WET TROPICS) WORLD HERITAGE

Higher temperatures and changing rainfall will place the rainforest in a highly stressed situation towards the end of the century (Liddell, 2010).

Many species in this region are already at the limits of their range and face **high increased risks of extinction.**

46% of tourists visiting Australia come to Queensland (TA, 2012).

18 million overnight visitors come to Queensland every year (QG, 2012b).

Tourism contributes **$17.7 billion** to the Queensland economy – or about 7% of Queensland's Gross State Product (TQ, 2012b).

Tourism directly and indirectly employs **120,000** Queenslanders (QG, 2012a).

Domestic visitor expenditure during 2011/12 rose **18%** (TQ, 2012a).

GREAT BARRIER REEF MARINE PARK

Visitors to tropical North Queensland spent around **$6.2 billion** in the year ending March 2012 (TQ, 2012d).

'The health of the Reef and the sustainability of its tourism industry are inextricably linked' (GBRMPA, 2011).

The quality of many reef sites has been affected by coral bleaching (GBRMPA, 2011).

GOLD COAST

International visitors to the Gold Coast in 2011/12 spent a total of **$833 million** (TQ, 2012c).

Sandy beaches under threat from erosion caused by rising sea levels.

4,750 Gold Coast residential buildings are within 110 m of erodible coastline.

Preparing for the impacts of climate change can build resilience in the tourism industry. For example, on the Gold Coast sand is pumped onto beaches to support the tourist experience. However, these responses have costs; Gold Coast City Council spends between $2.5 and $3.5 million replenishing sand stocks each year (Westthorp, 2012).

Acting on climate change by reducing greenhouse gas emissions is critical to limit the impacts. Box 6 has examples of how tourist destinations and operators are already playing their part by reducing emissions.

3. OPPORTUNITIES

With the impacts and risks clearly set out by scientists across the globe, the next chapter of the climate story is about finding solutions that minimise the risks of climate change while providing extra benefits for our health, community, economy and environment.

Harnessing renewable and clean energy and using resources more efficiently will create business opportunities and help some businesses save money and improve productivity. This is not to deny that there will be costs in the short run for some industries and communities, and that the rate of economic growth will be slowed. Short-term costs of transition have been found to be outweighed by the costs to the economy of a changing climate and also increasing costs the longer action is delayed (Stern, 2007; Garnaut, 2008).

Many of the opportunities in tackling climate change are less well understood than the costs, which have often been the centre of discussions. This report illustrates some of the opportunities that are particularly relevant to Queensland.

As Australia moves to reduce greenhouse gas emissions, levels of investment, employment and income are likely to continue to grow strongly. However, the types and locations of jobs may change and there will be a premium on innovation and flexibility. Fortunately, Australia has demonstrated that it can deal well with business challenges – pressure on profits provides a strong incentive to rethink business models and firms are more likely to be innovative (Dolman and Gruen, 2012). For example, 252 of Australia's top energy-consuming businesses have already saved more than $800 million in annual energy costs with a range of energy efficiency measures (DRET, 2012).

Periods of economic and technological change tend to mean that some operations and industries will diminish, while other firms and industries grow. While the structural changes associated with tackling climate risks should not be taken lightly, they are not likely to be as significant as other pressures for change – arising from a sustained strong exchange rate, strong demand for resources and agricultural exports, and the impact of the information technology and communication revolution.

3.1 Renewable energy

- Queensland has abundant renewable resources, including solar resources that are among the best in the world.
- Use of solar energy in Queensland has doubled in less than two years.

Investment in clean energy is growing globally. In 2011, US$257 billion was invested in renewable energy worldwide (Frankfurt School UNEP Centre, 2012). This represents growth of 6.5% from 2010, a level that outpaces growth in the overall global economy for the same period (PET, 2012). In Australia, $4.9 billion was invested in clean energy in 2011, mostly in solar projects (PET, 2012). In Queensland, $2.7 billion was invested in renewable energy over the 2009–2011 period, mostly for small-scale solar installations (Queensland Government, 2012a).

The clean energy industry employed about 8,000 full-time equivalent staff in construction, operations and maintenance across Australia in 2010 (CEC, 2011a). Of this total, 22% of jobs were in Queensland, mainly in biomass energy facilities (CEC, 2011a). In comparison, the rest of the Australian electricity supply industry directly employed around 48,000 workers (ABARES, 2011).

Solar

Queensland has some of the world's highest levels of solar exposure and low levels of solar variability, making it an ideal location for solar energy generation (Queensland Government, 2010; Parsons Brinckerhoff, 2010). Solar photovoltaic (PV) electricity generation represents about 4%* of total generation capacity in Queensland.

Solar Photovoltaic (PV)

Solar PV electricity generation is increasingly popular among households and businesses in Queensland (Figure 7). The state has the largest installed solar PV capacity in Australia, at over 475 megawatts (MW), and the most installations – more than 209,000 as at 30 June 2012 (Wills, 2012). Use of solar energy in Queensland has doubled in less than two years (Queensland Government, 2012b). Current projections show that the yearly contribution of rooftop solar PV to Queensland's energy mix is likely to double over the next 10 years and in a high uptake scenario may even quadruple (AEMO, 2012a).

* Based on available data. Percentage figure calculated using solar PV capacity at 30 June 2012 (Wills, 2012) and Queensland's total expected generation capacity of 12,200 MW for summer 2012 (AEMO, 2012b).

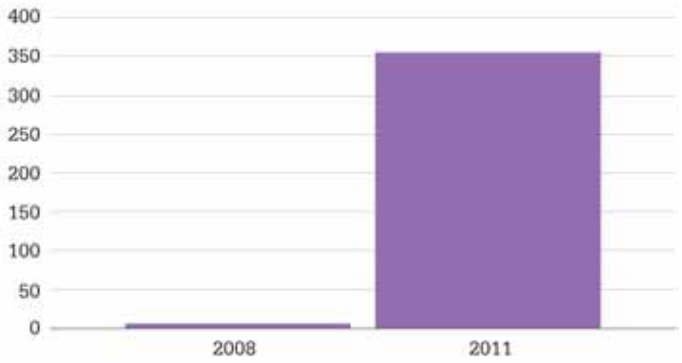


Figure 7. Installed solar PV capacity (MW) in Queensland, 2008 and 2011.
Source: Queensland Government, 2012b

While the vast majority of solar PV installations have been small-scale, there have also been some medium- and large-scale installations. For example, the University of Queensland hosts Australia's largest PV array. The 1.22 MW PV system at the St Lucia campus is about 25% larger than any other rooftop system in Australia and covers four buildings (UQ Solar, 2012). The PV system will meet approximately 6% of the annual electricity needs of the campus, the equivalent of taking 335 cars off the road, and will avoid about 1,750 tonnes of greenhouse gas emissions each year (UQ Solar, 2012).

Solar PV is also being used in sporting stadiums. The Gold Coast's Metricon Stadium is the first in Australia with a 'solar halo' as part of the roof. The stadium won the 2011 EcoGeneration award for an outstanding large-scale clean energy project (Metricon Stadium, 2012). The system provides 215 kilowatts (kW), or around 20%, of the stadium's total electricity (Metricon, 2012). The Townsville RSL stadium has a rooftop solar PV system with capacity of 335 kW, enough to supply around two-thirds of the stadium's daytime power use (Townsville Queensland Solar City, 2008).

The Gold Coast's Metricon Stadium 'solar halo' provides 20% of the stadium's electricity needs.

University of Queensland's ground-mounted Concentrating PV array, which tracks the sun across the sky each day.

Globally, the cost of producing solar PV cells has dropped 75% in the past four years and 45% in the past 12 months (BNEF, 2012). Electricity generated from solar PV panels has been estimated to already be cheaper than retail electricity prices in some areas of Australia and is projected to be competitively priced in the next few years (Bazilian et al., 2012; BNEF, 2012). Solar PV (along with wind) could be the cheapest form of power in Australia by 2030 (BREE, 2012). The "challenge is to elegantly transition solar energy from a highly promising and previously expensive option to a highly competitive player" in the electricity industry (Bazilian et al., 2012).

Concentrated Solar Thermal (CST)

There is also potential for large-scale solar power generation in Queensland (Queensland Government, 2010; Queensland Government, 2012b; Parsons Brinckerhoff, 2010).

Queensland receives significant direct (as opposed to diffuse) sunlight, making concentrated solar thermal (CST) an efficient method to generate electricity. CST uses mirrors to reflect sunlight into a small area to heat fluids or salts. These heated fluids then drive an engine (usually a steam turbine) which converts the energy into electricity.

Queensland experiences levels of radiation that compare favourably with existing solar thermal generation sites in the United States and Spain (Queensland Government, 2010; Figure 8). Queensland also experiences low variability in solar radiation throughout the year, which is most favourable for setting up a CST plant (Parsons Brinckerhoff, 2010).

CST can lower the emissions-intensity of existing fossil-fuel power plants, and provide power during daytime peak loads and baseload power when combined with thermal storage. The primary challenges of using CST include identifying the best locations with access to main transmission lines and the current high cost of the electricity produced (ASI, 2012). However, costs per unit of energy are expected to decline as the technology is adopted more widely (Lovegrove et al., 2012).

CST is already being developed on a commercial scale in Queensland. The 44 MW Kogan Creek Solar Boost Project, currently being constructed, will be the largest solar integration project in the world (CS Energy, 2012). The project will provide a solar thermal addition to the existing 750 MW coal-fired Kogan Creek Power Station to pre-heat steam for the boilers, increasing efficiency, capacity and life expectancy (CS Energy, 2012). At peak solar conditions, the project will be able to supply up to 44,000 megawatt hours (MWh) of electricity each year (CS Energy, 2012).

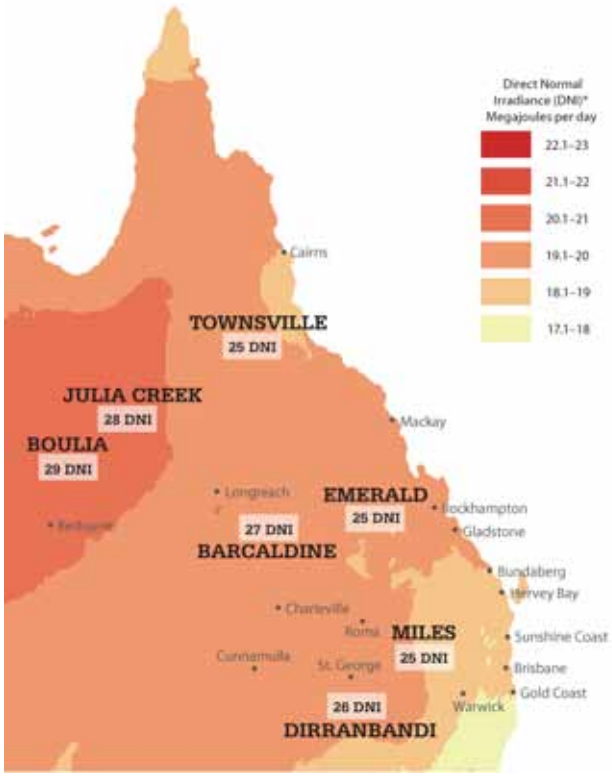


Figure 8. Queensland receives high levels of direct solar radiation (measured as DNI), with many locations higher than existing CST sites around the world.

Typical levels of DNI for locations at Nevada USA and Andasol I, Spain (locations of operating CST plants) are 24.1MJ/m²/day and 20.71MJ/m²/day respectively.

Concentrated solar thermal uses mirrors to reflect sunlight into a small area and heat fluids or salts.

Solar hot water

Solar energy can also be used to heat water. A solar hot water system is cost effective in comparison to a conventional electric hot water system and produces minimal greenhouse gas emissions (CEC, 2011a). For example, a solar hot water system can reduce typical household water heating emissions by between 60 and 90% depending on the location (CEC, 2011b).

Around 14% of Queensland households have solar hot water systems. This has increased significantly in recent years (Queensland Government, 2012b).

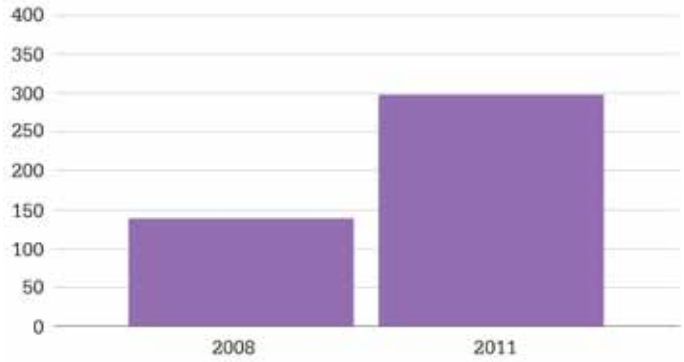


Figure 9. Installed solar hot water capacity (MW) in Queensland, 2008 and 2011.
Source: Queensland Government, 2012b

Bioenergy

Queensland's installed capacity for producing electricity from waste products totals 429 MW, which is about 55% of the total capacity across Australia (CEC, 2011a). Sugar cane waste (bagasse) is the main source, with some additional generation from landfill (Box 5) and sewage methane gas. There are 44 biomass plants with capacity of more than 100 kW operating in Queensland (CEC, 2011a and Queensland Government, 2012a).

Tully Sugar Mill is one of the largest biomass energy producers in the state (Queensland Government, 2012a). The mill generates 99.5% of its total annual energy usage by firing steam boilers with waste material from sugar production (Tully Sugar, 2012). It also exports 10 MW of electricity to the Queensland electricity grid (Tully Sugar, 2012).

Racecourse Mill, operated by Mackay Sugar, is powered through sugar cane waste bagasse. The energy generated at the mill also powers a sugar refinery. In 2007, the bagasse storage area capacity was increased from 70,000 to 96,000 tonnes. The expansion saved $759,000 each year (with a pay-back period of 2.14 years), and 21,850 tonnes of greenhouse gas emissions. A further 38 MW of bagasse energy generation capacity is now under construction at the mill (Mackay Sugar Limited, 2012).

Waste from sugar mills can be used to produce electricity.

Box 5. Energy from waste

Thiess Services currently owns and operates Swanbank renewable energy and waste management facility, a landfill site made up of 250ha of former coal mines in Ipswich. As one of the largest landfill sites in Australia, Swanbank accepts 500,000 tonnes of waste each year (Thiess Services, 2012).

The site has a pilot plant of an innovative decomposition process using organic waste to produce 'biogas' (gas from renewable sources). The process significantly accelerates the production of biogas. The gas is fed through the Swanbank site gas collection system, and piped to a neighbouring coal-fired power station, where it produces approximately 56,000 MW hours of electricity each year. This represents a reduction of around 147,000 tonnes of greenhouse gas emissions each year (Thiess Services, 2012).

This photo shows three of the biocells at the Swanbank Renewable Energy Facility. Two contain organic waste and one contains leachates (liquid waste); the gas produced from the decay of this matter is collected by the pipes on the left of the photo.
Source: Swanbank Renewable Energy Facility

3.2 Business

– Large, medium and small businesses are already saving money and reducing greenhouse gas emissions by becoming more efficient
– Buildings can be designed to minimise energy costs and greenhouse gas emissions.

The transition to an economy with lower greenhouse gas emissions provides opportunities for Queensland businesses to use clean energy and become more efficient. In addition to saving money through reduced electricity bills, other benefits can include better product quality, improved employee health and safety, and competitive advantages (Box 6).

Australia's largest energy-using companies in the mining sector have identified net financial benefits of $257.3 million a year from energy savings projects, more than any other business sector. Coal mining companies reported the highest financial benefits per unit of energy saved, at $41.08 per gigajoule (DRET 2012). The areas with potential for energy savings identified by mining companies included staff operation, maintenance procedures, energy measurement, process control and retro-fitting with more efficient or new technologies.

The River Quay building in Brisbane's South Bank demonstrates a number of passive design features.
Source: Gollings Photography Pty Ltd

Business practices

There are many ways that businesses can save money and reduce greenhouse gas emissions. For example, production systems may be upgraded, energy-efficient technology may be installed, and energy use can be better monitored and controlled.

Businesses around Queensland are already reducing their costs and greenhouse gas emissions. For example:

– PAC Foundry in Maryborough, one of Australia's largest foundries, saves more than $100,000 each year and has reduced its greenhouse gas emissions by upgrading its manufacturing processes. The foundry replaced its original 1978 furnace and installed a new sand-handling system (Ecobiz, 2008). In addition to saving energy, product quality is higher and occupational safety has improved (The Compass, 2005).
– The Currumbin RSL Club on the Gold Coast has reduced energy use by 13% (the equivalent of 19 households) waste removal by up to 70% and greenhouse gas emissions by 4% (the equivalent of 20 cars) since 2010 (DEHP, 2012). The club's energy, water and waste initiatives have saved around $55,000 and all initiatives have had a payback period of less than two years (Currumbin RSL, 2012). Savings measures included energy-efficient lighting and a more efficient hot water system. (Currumbin RSL, 2012).
– By reducing its energy and water use the Noosa Aquatic Centre on the Sunshine Coast is avoiding 215 tonnes of greenhouse gas emissions and saving approximately $52,086 annually (DEHP, 2011). The centre has installed a water recycling unit and variable-speed drives to reduce the energy required to operate the pool pumps (DEHP, 2011). In addition, pool water is pre-heated by a solar heating system (DEHP, 2011).

Noosa Aquatic Centre has reduced greenhouse gas emissions and costs by having more efficient pool pumping and using solar water heating.

Built environment

Inefficient cooling, lighting and refrigeration in commercial and residential buildings results in significant greenhouse gas emissions and wasted money. There are many ways to design buildings for the efficient use of electricity. Examples of innovative buildings in Queensland include:

– The Green Square South Tower has attained a rating of 6 stars, the highest awarded under the National Australian Built Environment Rating System (NABERS). The building features a number of automated systems to regulate air temperature as well as lighting to minimise emissions, supporting the council's goal of reducing greenhouse gas emissions by 50% before 2026 (NABERS, 2012).

– Rio Tinto moved into the most energy efficient building in Brisbane, 123 Albert St, in 2011. The building features a trigeneration system (generates electricity, heating and cooling at the same time) which reduces the building's peak electricity consumption by 25 per cent and a chilled beam electricity system (Dexus, 2012). The building has a 6-star Green Star rating and a 5 Star NABERS Energy Rating (Dexus, 2012).

– The iseek Data Centre in Brisbane has a Targeted Power Usage Effectiveness rating of 1.3, making it the most energy-efficient data centre in Australia (iseek, 2012). The building provides state-of-the-art facilities and sets a new industry standard for green data centres in Australia (PCA, 2012).

– The River Quay building in Brisbane's South Bank has recently won two design awards for sustainable design. The building's features include glazed walls to maximise natural lighting, bi-fold doors to maximise natural ventilation, glass that minimises heat loads and very efficient air conditioning (South Bank Corporation, 2012).

Residential houses can be designed to significantly reduce air conditioning demands by considering orientation, cross ventilation, capturing prevailing breezes and placement of living areas. Heating and cooling generally use around 40% of household electricity; and this cost can be almost eliminated with smart design. There are also many opportunities to improve efficiency in existing homes including using efficient appliances and low-energy lights, protecting the west side of the house from afternoon summer sun, and using blinds or curtains to keep the heat out or in depending on the season (see Stockland, 2012 for more suggestions).

Box 6. Sustainability initiatives in the Queensland tourism industry

Many destinations and operators in Queensland are already acting to reduce their energy use and greenhouse gas emissions. For example, 88% of Tourism Queensland operators have installed energy saving light bulbs and 69% have purchased energy saving appliances (TQ, 2010).

The Sheraton Noosa Heads Resort and Spa hotel on the Sunshine Coast has a target of reducing energy use by 30% before 2020 (Starwood, 2012). Actions taken to date to help meet the target include installing solar heating for the outdoor spa, LED lights and variable speed fans (saving $24,000 per year), reducing daily room cleaning (saving $68,000 each year), and waste composting (saving $80,000 each year in reduced council rates) (Phillips, 2011).

Some tourism destinations in Queensland are beginning to use climate action as a selling point. Pumpkin Island, situated within the Great Barrier Reef Marine Reserve, is certified as a Climate Action Leader, an initiative set up by Sustainable Tourism Australia. The island has implemented initiatives including using only solar and wind energy and LED lighting (Pumpkin Island, 2012).

Pumpkin Island is one example of sustainability initiatives undertaken in the Queensland tourism industry.
Source: Adam Gormley

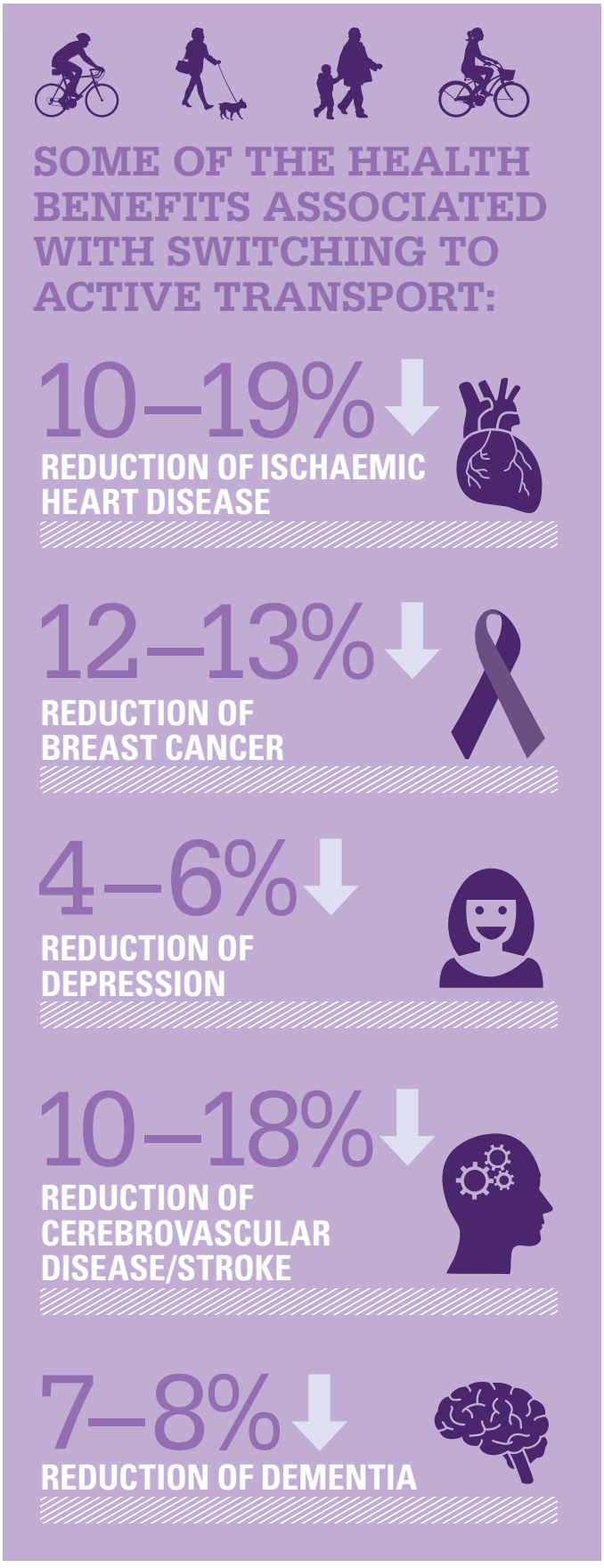
3.3 Transport

– Increasing the use of public and active transport can ease congestion and reduce greenhouse gas emissions.
– Increasing the use of active transport such as walking and cycling offers opportunities to improve public health and air quality.

Transport currently accounts for 13% of Queensland's greenhouse gas emissions, with private cars accounting for a large proportion of this total (DERM, 2011a). Transport emissions are 70% higher than in 1990, reflecting the state's growing population (DERM, 2011a). Cars produce more than six times the greenhouse gas emissions of buses and trains in peak periods of travel to the city (Garnaut, 2008).

In southeast Queensland's growing population centres, there are opportunities to further develop transport systems to reduce greenhouse gas emissions and meet travel needs. Brisbane's current travel patterns rely heavily on fossil-fuelled transport (BCC, 2007). Current estimates suggest that approximately 600,000 more people will need to use Brisbane's transport system before 2026. This growth in demand for public transport provides an opportunity to encourage more sustainable choices. Brisbane City Council has identified the need for delivery of infrastructure, behaviour change programs and service improvements to help reduce emissions from transport (BCC, 2008).

A shift to using public and active (walking and bicycle) transport will reduce greenhouse gas emissions while improving air quality and reducing congestion (IAPT, 2012). Cycling and walking projects provide high value for money, with the health gains returning a benefit to cost ratio of 5:1 (De Hartog, 2010). Communities and suburbs that are designed to facilitate active and public transport can reduce household costs (WHO, 2011), reduce social isolation and improve social capital as well as improve health and wellbeing (Chapman, 2008).



Public transport

Existing public transport options in Brisbane include trains, buses and ferries. Brisbane has about 25 km of dedicated busways with more than 20 stations moving about 70 million people in and out of the CBD each year (BMTMC, 2012).

Brisbane City Council has introduced an electronic ticket system allowing travellers to move between bus, train and ferry services; the system reached two million users in June 2011. The city's high-frequency bus services have also been integrated with a new public bike hire scheme.

Through increasing bus services, the council provided more than 147,000 additional bus trips in 2010/11, replacing an average of 23 cars for each trip and avoiding around 135,000 tonnes of emissions (BCC, 2011b).

Public transport, such as buses, can reduce emissions while also improving air quality and reducing traffic congestion.
Source: Flickr/thefunkyman

Brisbane's public bike hire scheme is an example of initiatives to increase active transport – reducing emissions and improving health.
Source: Brisbane City Council

Active transport

Brisbane has 760 km of on- and off-road bikeways (BCC, 2008). The council plans to promote more cycling and has set a target of 1,700 new kilometres of bikeway networks by 2026 (BCC, 2011a).

Brisbane's public bike hire scheme provides 150 bike hire stations across the city centre. The scheme has experienced strong growth, and there were 18,874 trips in May 2012 (CityCycle, 2012).

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