CLIMATE COMMISSION

THE CRITICAL DECADE

New South Wales climate impacts and opportunities

Summary

New South Wales (NSW) is home to over a third of Australians and 31% of the national economy and is highly vulnerable to climate change. Climate change is increasing the risk of hot weather, heatwaves, and bushfires, and changing the patterns of drought and heavy rainfall. A changing climate is costly, putting pressure on human health, agriculture, infrastructure and the natural environment.

NSW is becoming hotter and drier. Record-breaking hot days have more than doubled across Australia since 1960 and heatwaves in the greater Sydney region, especially in the western suburbs, have increased in duration and intensity.

Over the last 40 years much of eastern and southern Australia has become drier. The continuing drying trend increases the risk of longer and harsher droughts. While there will continue to be wet years, the future trend of declining rainfall poses challenges for Sydney's long-term water security.

This long-term increase in hot and dry weather has made NSW more susceptible to bushfires. Very high fire danger days have already become more frequent, and will occur even more often in the coming decades.

Coastal infrastructure in NSW is vulnerable to flooding from sea-level rise. A 1.1m rise by the end of the century could put between 40,000–60,000 houses, 1200 commercial buildings and 250km of highway in NSW at risk of inundation.

This is the critical decade for action. To minimise climate change risks we must begin to decarbonise our economy and move to cleaner energy sources this decade. The longer we wait the more difficult and costly it will be.

NSW is well-placed to capitalise on the global trend towards clean energy. Globally the clean energy sector attracted $263 billion worth of investment in 2011 and is one of the fastest growing sectors in the world. In Australia $5.3 billion was invested in clean energy in 2011. NSW, with a legacy of innovation and achievement in renewable energy development, has significant opportunities.

Professor Will Steffen
Climate Commissioner

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With thanks to the Science Advisory Panel.

1. Temperature

- NSW is becoming hotter
- Heatwaves will become more severe and will likely last longer
- Western Sydney is more vulnerable than coastal locations to extreme heatwaves

Extremes of temperature have significant impacts, including illness and loss of life, and economic costs in transport, agriculture, energy and infrastructure. Extreme high temperatures can trigger costly interruptions to services such as electricity and trains; stress emergency management services; increase hospital admissions for kidney disease, heart attack and other diseases; and drive decreases in agricultural production (Queensland University of Technology, 2010).

A small increase in the average temperature has a big impact on the number of extreme high temperatures experienced. For example, the number of record hot days across Australia has more than doubled since 1960 (**Figure 1**), with an increase in average temperature of only about 0.9°C across the country (CSIRO and BOM, 2007).

Over the period from 1970 to 2011, the number of hot days (days over 35°C) in NSW has increased, in some areas by up to 7.5 days per decade. Coastal Sydney has not shown a significant trend, but for the western suburbs the number of hot days has increased by 60% (see **Figure 3**), owing to both the urban heat island effect (**Box 1**) and the underlying temperature rise due to climate change. Currently, Parramatta experiences 4 times as many hot days as Sydney, up from 3 times as many in the 1970s. The temperature of the hottest day recorded each year has increased across NSW over the past 40 years – in some regions by up to 0.8°C, and warm weather spells (at least four consecutive warm days) have increased in duration over much of the state.

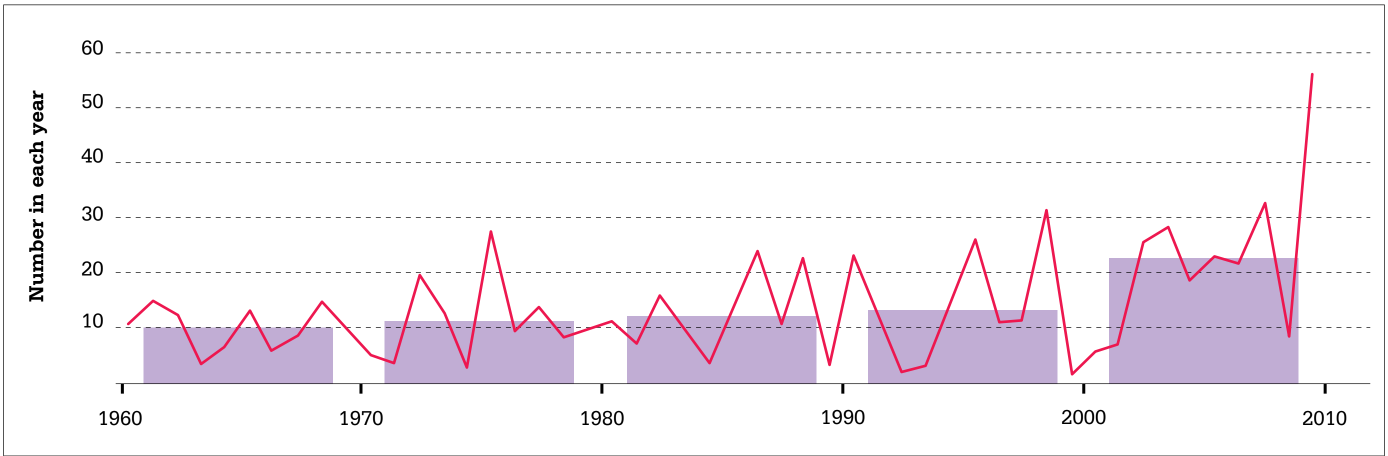
Average temperature across NSW is expected to increase by 0.3–1.5°C by 2030 and by 1.0–5.0°C by 2070 compared to 1990. The upper end of these ranges is projected for the far north of the state only (CSIRO and BOM, 2007). With higher average temperatures, there will be further increases in the number of hot days and heatwaves across the state. Currently in eastern Sydney, there are about 3 days above 35°C a year. By 2030 this is projected to increase to 4–5 days per year, and to 9 days per year by 2070 (**Figure 2**; CSIRO and BOM, 2007). The corresponding expected increases for the western suburbs would be higher if the observed trends shown in **Figure 3** continue.

Figure 2. Number of days over 35 degrees projected for Sydney.

	2008	2030	2070	2100
SYDNEY	3.3	4.4	9	14

Source: Modified from CSIRO, cited in Garnaut, 2008

Figure 1. Average number of record-breaking hot temperatures each year across Australia. Yearly average shown by red line and 10-year average shown by purple bars.



Source: BOM

Box 1. Western Sydney suffers from an urban heat island effect

Urban Heat Island: noun.

An area, such as a city or industrial site, having consistently higher temperatures than surrounding areas because of a greater retention of heat, as by buildings, concrete, and asphalt.

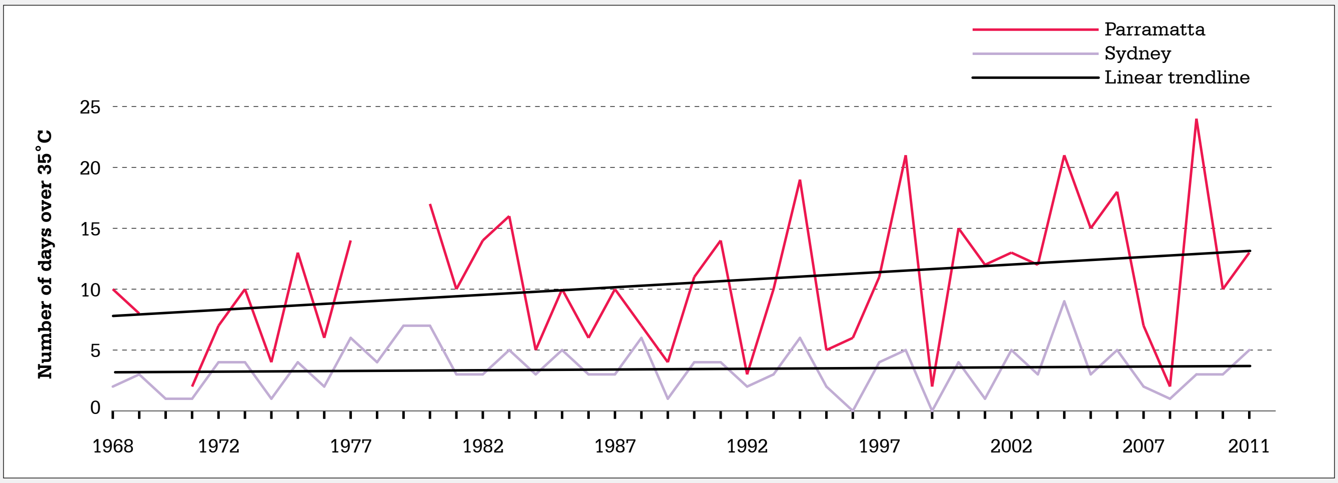
Without the cooling sea breeze off the coast, Western Sydney residents feel the full effect of heatwave conditions.

Urban centres are hotter than their rural surrounds because dark roofs, car parks, paved areas and bitumen roads absorb and keep heat in the area (**Figure 4**). Lack of shade and high density buildings trapping heat increase the effect. This is intensified in areas like Western Sydney that miss out on the relief brought by cooling sea breezes.

Analysis of temperature records over the last 40 years shows that Western Sydney has seen a rise in annual temperatures above that experienced in coastal parts of the city. Residents of Blacktown, Richmond, Camden, Liverpool and Parramatta have all experienced this effect: the gap between coastal and Western Sydney temperatures has widened, and the number of extreme hot days has increased in the west (**Figure 3**). Assuming no changes in the sea breeze in future, the current trends are very likely to continue as the average temperature across the region increases further in the coming decades.

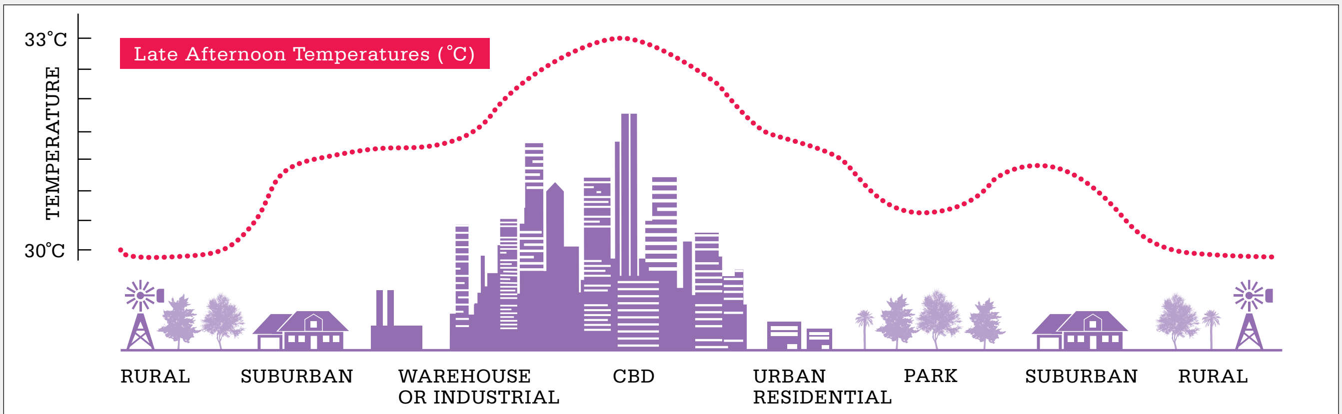
Some people are more vulnerable than others to the impacts of heat extremes. Children and people who are elderly, work in heat-exposed jobs or have low incomes are at greater risk. The dangers can be aggrevated by infrastructure failures (see section 4 on health).

Figure 3. Number of days over 35°C in Parramatta and Sydney, from 1970 to 2011.



Source: BOM, 2012b. Historical data obtained from Observatory Hill Station (Reference Climate Station, Sydney Cove) and North Masons Drive Station (Parramatta). Gaps are due to missing data points for those years.

Figure 4. The urban heat island effect. The average annual air temperature in cities (more than one million people) may be 1 to 3°C hotter than surrounding areas.



Source: Modified from US EPA, 2008 and NASA, 1999

Box 2. Heat records continue to be set

2009 was the hottest year on record in NSW. Three extreme heat events occurred in that year: a heatwave in late January/early February in southwest NSW, extreme winter heat in August in northern NSW and an unusually extended and intense heatwave across all of NSW in November (**Table 1**; BOM, 2010).

The highest temperature recorded in NSW in 2009 was at Menindee, at 46.8°C (National Climate Centre, 2009).

During the November 2009 heatwave, temperatures were 4.6°C above the average for that time of year; the largest monthly variation ever recorded for an Australian state. Many heat records were set, with 71% of NSW setting maximum temperature records. For example, the monthly maximum temperature average in Bathurst was 7.8°C above normal (National Climate Centre, 2009).

As average temperatures rise with climate change, there is likely to be an increase in the number of hot and very hot days, and in extreme heat events like those in 2009. While there will continue to be hotter and colder years, the overall trend is increasing temperatures.

Table 1. A selection of temperature records broken in NSW during 2009: hottest temperature, hottest November temperature and length of hot periods.

Location	Temperature (November)	Previous record (November)	Year of previous record	
Sydney airport	27.2	26.7	1968	
Parramatta	28.6	28.4	2002	
Bankstown	28.6	28.1	1968	
Location	**Temperature**	**Previous record**	**Year of previous record**	
Dubbo	43.4	43.3	1944	
Prospect reservoir	42	41.6	2002	
Bowral	38	37.1	1997	
Location	**Temperature threshold**	**Number of days above threshold**	**Previous record**	**Year of previous record**
Bathurst	30	16	15	1982
Dubbo	35	12	11	1922
Wagga	35	11	7	1982

Source: BOM, 2011

2. Bushfires

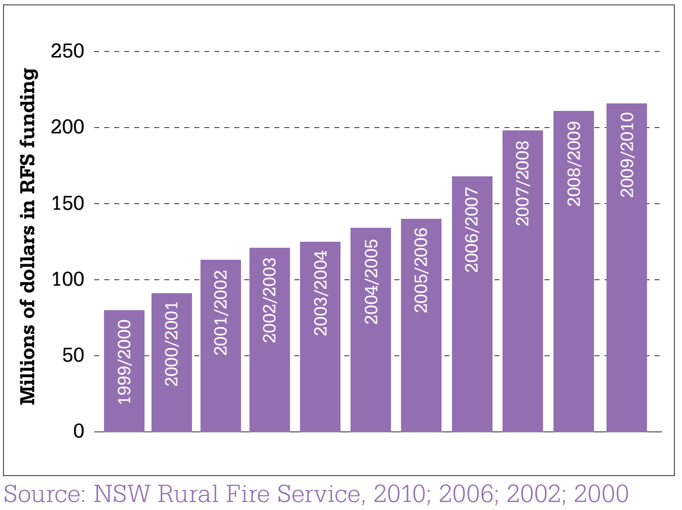
- Long-term increases in hot and dry weather have made NSW more susceptible to bushfires
- 'Very high' fire danger days have become more frequent and will become even more frequent in future

Higher average temperatures also have significant implications for extreme temperature-related events such as bushfires. NSW has already experienced an increase in extreme fire weather associated with the increased frequency and intensity of extreme heat and drought since the early 1970s (Clarke et al., 2011; **Figure 6**).

The conditions for large and intense fires – low humidity, high winds and extreme high temperatures, which contributed to the 1994 and 2001 Black Christmas fires and the 2003 southeast NSW/Australian Capital Territory fires – are likely to become more common by mid-century. Climate projections suggest that the numbers of 'very high' fire danger days in southeast Australia could increase by as much as 23% by 2020 and up to 70% by 2050 (Lucas et al., 2007).

Bushfires cause loss of property, livelihoods, biodiversity and human lives (**Box 3**). The safety of fire-fighters is at risk, with sleep deprivation, heat, and carbon monoxide exposure dangerous to health (Aisbett, 2012). There are also costs associated with suppressing and preventing fires – funding to the NSW Rural Fire Service has doubled in the past 10 years in recognition of the increased threat (NSW Rural Fire Service, 2003; **Figure 5**).

Figure 5. Funding to the Rural Fire Service from 1999/2000 to 2009/2010.



Source: NSW Rural Fire Service, 2010; 2006; 2002; 2000

Figure 6. A 2009 fire at Morton National Park.

Source: Dave Cunningham

Box 3. 2001/2002 NSW bushfire season

From December 2001 to mid-January 2002, NSW experienced a fire season of considerable intensity. Contributing factors were the very high temperatures (up to 45°C), low humidity and very strong winds, with 20 consecutive days without rain.

There were 450 fires in total, concentrated in bushland around Sydney. More than 29,000 personnel were involved in fighting the fires, including fire fighters called in from every state in Australia and from New Zealand (NSW Rural Fire Service, 2002; Joint Select Committee on Bushfires, 2002).

The losses were significant: approximately 754,000 hectares of land were burnt by fires, 7,000 head of livestock killed, and 109 homes destroyed (Joint Select Committee on Bushfires, 2002).

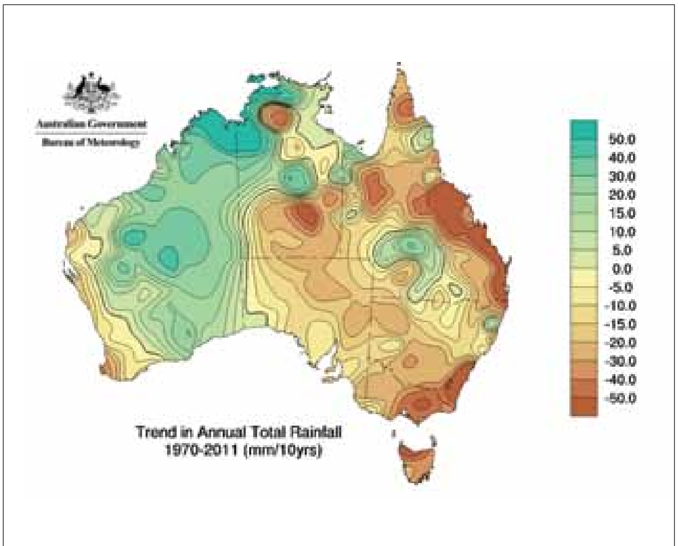
3. Rainfall and drought

- Rainfall patterns have changed across NSW over the past 40 years
- The well-known climatic pattern of severe droughts and flooding rains will continue into the future, modified by longer-term trends in climate
- Climate change cannot be ruled out as a factor in recent heavy rainfall events

Rainfall patterns are changing, bringing both risks and opportunities. Despite difficulties in projecting long-term trends, there are some large-scale patterns that are becoming clearer. As summarised in the recent Climate Commission report (2012) 'The science behind Australia's wet, cool summer':

> "The quintessential Australian climatic pattern of severe droughts and flooding rains will continue into the future. Across the south, heavy rainfall events will still occur, and high summer rainfall events will continue to be a feature of the climate. However, on average, the south of the continent will likely be drier in the future compared with the early to mid twentieth century, particularly in the cool months of the year."

Figure 7. Trend in annual total rainfall (mm/10 years) for the 1970–2011 period.



Source: Bureau of Meteorology

Figure 8. Extended dry periods have risks for water supplies and agriculture.

Drought

Most of NSW has experienced an overall drying trend over the past 40 years, with the trend more pronounced in the southeast of the state (**Figure 7**).

The 1997–2009 dry period provides a recent example of the risks that extended dry periods bring for the water supplies of Sydney and many other cities and towns in NSW. The period was the driest 13-year period in southeast Australia in the last 110 years of climate records (SEACI, 2010; **Figure 8)**. Although 2010/2011 have been wet years, water security is likely to be an on-going issue of critical importance for NSW (Steffen et al. 2012).

The drought from 1997 to 2009 exposed the vulnerability of Sydney's urban water supplies to extended drought, and led to permanent changes in the way water is supplied and used in Sydney, the Illawarra, and the Blue Mountains. From October 2003, increasingly severe water restrictions were introduced as dam levels dropped below 40% (Sydney Water, 2012). In 2009, the NSW Government introduced new, permanent water efficiency rules in recognition of Sydney's highly variable climate and growing population (NSW OW, 2012a).

The impact of the drought was felt acutely in Goulburn, where dam levels fell to 12% during 2007. Serious consideration was given to the expensive option of trucking in water (Goulburn Mulwaree Council, 2012). After the drought ended, Goulburn also introduced permanent water saving rules, as well as guaranteeing its water supply by building an emergency pipeline to connect to Sydney's water supply (Goulburn Mulwaree Council, 2012).

Agriculture is also affected by changes in water availability. For example, without effective global action to reduce emissions, irrigated agriculture in the Murray-Darling Basin could decline about 50% by 2050 (Garnaut, 2008). However, many Australian farmers have shown considerable adaptive capacity in dealing with present-day climate variability and with the observed trends over the past 40 years – changing what they plant and when they plant, and changing the ways they manage livestock. These skills will be tested in future as patterns of drought and rainfall continue to shift in ways that are difficult to predict.

Rainfall

As well as a decline in annual rainfall across nearly all of NSW over the past 40 years, the number of wet days per year has declined across the state. However, as for temperature, the changes in rainfall are most acutely felt in the extremes – the flooding rains that punctuate the extended dry periods.

The 2010–2011 La Niña period set records across Australia for the amount of rainfall received. Heavy rainfall contributes to flooding events. Floods over the past two years have affected most of the state, with many regions experiencing damage and disruption, including road closures, power outages and evacuations (**Figure 9**). With the projection that, on average, the intensity of precipitation events is expected to increase with a hotter climate (IPCC, 2007), the risk of damage and disruption is likely to increase in the future, which emphasises the need for effective preparation measures.

Figure 9. Floods can cause major damage to important infrastructure, such as roads and bridges.

Source: Jo Caldwell

The start of 2012 saw widespread heavy rainfall across the state. Several regions experienced record high daily rainfalls and more than 75% of the state was affected by flood warnings (BOM, 2012c). Natural disaster zones were declared in 87 regions (NSW Farmers, 2012) and over ten thousand people were evacuated from their homes.

As well as the humanitarian concerns of people being cut off from health services and from fresh food and water, there were economic costs for urban areas and farmers. For example, tens of thousands of head of sheep and cattle were moved out of floodwaters to higher ground and helicopters were used to drop fodder to stranded animals. Thousands of head of livestock were lost and surviving animals that have been exposed to floodwater may suffer poor health as a result (Walker, 2010).

In the Griffith, Hillston, Deniliquin and Finley areas, dairies, vineyards, and summer crops such as rice, sorghum and maize were inundated. Waterlogged plants were rapidly damaged and were exposed to a range of toxins and pollutants from runoff. Waterlogged conditions encourage the spread of plant diseases, and soil quality may be affected for a long time after the water is gone, affecting future crops (DPI, 2012).

The Commission's recent report (2012) 'The science behind Australia's wet, cool summer' discussed the possible link between the heavy rainfall of 2010–2011 and climate change:

> "Climate change cannot be ruled out as a factor in recent heavy rainfall events. The Sea Surface Temperatures (SSTs) around northern Australia during the spring and early summer of 2010–2011 were the highest on record. This has very likely contributed to the exceptionally heavy rainfall over much of Australia in the last two years. La Niña events bring high SSTs to the seas around northern Australia, but warming over the past century has also contributed to the recent record high SSTs."

A future climate with potentially more frequent and intense rainfall events will have significant effects on our cities, roads and infrastructure. The effects we have seen of intense rainfall events are instructive in planning for future risks (**Box 4**).

4. Human health

- More extreme heatwaves increase the risk of heat related deaths and hospital admissions
- Respiratory disorders will worsen as air quality deteriorates
- More extreme weather events create higher risks of loss of life, illness and mental ill-health

Adverse impacts on health that can be attributed to climate change have already been observed globally and in Australia. These include illness or death related to heat, air pollution, water and vector-borne diseases, and mental health problems (Kjellstrom and Weaver, 2009).

Box 4. Single storm event causes major disruption in Sydney

Extreme rainfall events can cause damage and disruption in exceptionally short periods of time.

On 8 March 2012, Sydney experienced the wettest March day in over 25 years. A single major storm event caused severe flash flooding, with nearly 110mm measured at Observatory Hill over the course of the day, of which over 40mm fell between 7:30 and 8:30am – right in the middle of the morning traffic peak (BOM, 2012d).

The flooding caused many road closures and traffic chaos. There were more than a thousand road incidents, and travel delays of 2½ to 3 hours were experienced.

Public transport was severely affected; some rail lines and train stations were closed due to flooding and delays occurred on seven of the 16 rail lines (SMH, 2012). Bus routes were affected by road closures, ferries were cancelled, and there were flight delays and diversions (SBS, 2012; **Figure 10**).

Power was lost to 2000 homes and businesses, and many people were evacuated from their homes. The State Emergency Service conducted 19 flood rescues (SBS, 2012).

The economic costs include damage to infrastructure, public and private buildings, people's homes and assets, lost productivity due to people missing work, and loss of business. Early estimates of the damages alone are in excess of half a billion dollars for this single day (Gay, 2012).

Figure 10. Extreme rainfall in Sydney on 8 March 2012 affected roads, public transport, power and had significant costs.

Source: Fairfax Syndication

Periods of extreme hot weather can lead to an increase in mortality, especially in the elderly (Kjellstrom and Weaver, 2009). A study of emergency hospital admissions in five regions in NSW – Sydney East and West, Illawarra, Gosford-Wyong and Newcastle – showed that on extremely hot days there was an increase in heat related injuries such as dehydration. Those with existing conditions such as cardiac and respiratory diseases, and mental health problems, are more susceptible to heat-related injury and death (Khalaj et al., 2010). Workers at risk from exposure to extreme heat include those who work outdoors, such as construction workers and builders; maintenance workers; farmers and emergency and essential service providers (Hanna et al., 2011).

Climate change is likely to lead to increases in certain types of air pollutants as well as air-borne allergens like pollen and mould spores (Hughes and McMichael, 2011). These have serious effects on people who suffer from respiratory illnesses, such as asthma, hay fever and lung cancer as well as affecting those suffering from other conditions such as heart disease. The current health cost of Sydney's air pollution is estimated to be $1 billion to $8.4 billion each year (Spickett et al., 2011). A study of the Sydney region by CSIRO showed that higher ozone levels (which contribute to smog) associated with an increase in hot days, could result in a 40% increase in hospital admissions over the years 2020–2030, and a 200% increase over the years 2050–2060 (Cope, 2008).

Changes in climate- and weather-related extreme events and natural disasters can increase stress and influence mental health, as described in the recent Climate Commission report (2011), 'The Critical Decade: Climate change and health':

> "…the results of one study in New South Wales found that a decrease in annual rainfall by about 300mm would lead to increase in the suicide rate by about 8% of the long-term average suicide rate (Nicholls et al., 2006). …In metropolitan South Australia, admissions for mental, behavioural and cognitive disorders have been found to increase by around 7% during heatwaves (Hansen et al., 2008a; Nitschke et al., 2007)."

Increased frequency and intensity of extreme events such as storms and floods will also have significant flow-on health impacts. Extended electricity outages can cause food to spoil due to improper refrigeration, or be contaminated due to inadequate cooking, leading to illness (Kjellstrom and Weaver, 2009). Water and sewerage infrastructure can be damaged, potentially increasing risks to water quality (**Box 5**; DECCW, 2010a).

Droughts can also cause water quality problems; less water in dams increases pollutant concentrations, and higher water temperatures encourage growth of toxic blue-green algae (Kjellstrom and Weaver, 2009). Increasing algal blooms due to prolonged drought pose a risk to water quality in the Sydney catchment areas (NSW OW, 2010).

Figure 11. Many residents in the Hunter region were evacuated during severe storms and flooding, including health care patients.

Source: Fairfax Syndication

Box 5. 2007 Hunter region storms and the impact on health

In 2007, storms and associated floods in the Hunter region caused 10 deaths and 6,000 evacuations (**Figure 11**). Flooding and power outages affected 105,000 homes, 207 drinking water supplies, 2,600 septic tanks and 1,200 food premises. The public health risk associated with water quality and quantity prompted daily health briefings for four weeks after the storm, and residents were urged to boil all water before consumption (Cretikos et al., 2007).

As well as an increase in hospital admissions due to storm-related injuries and illnesses, electricity outages and flooding also directly affected the health system. Twenty-nine people were admitted to New England hospitals because their oxygen, dialysis, intravenous and other therapies were interrupted by power outage. Three health care facilities had to relocate patients due to power outages and flooding and 12 hospitals and 50 private nursing homes had to rely on on-site electricity generation. Over 10,000 vaccine doses had to be replaced in general practices due to refrigeration failure (Cretikos et al., 2007).

5. Sea-level rise

– 85% of Australians live near the coast and nearly all our major cities are on the coast, making Australia highly vulnerable to sea-level rise
– Coastal flooding will increase as the sea level rises
– Coastal infrastructure in NSW is vulnerable to rising sea levels
– Many NSW beaches are under threat from increased erosion

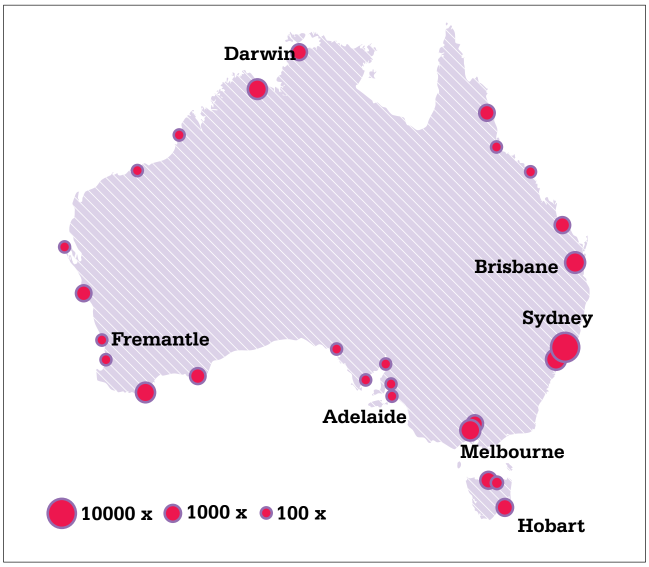
The densely populated coastal areas of NSW face significant risks from sea-level rise – to property, infrastructure and beaches. There are three ways that buildings and infrastructure are at risk from sea level rise:

1. Storm-related flooding that causes inundation events
2. More regular flooding from higher sea levels associated with high tides
3. Erosion of the land on which buildings and infrastructure are built.

Storm surge flooding

The impacts of sea-level rise are felt most acutely during severe storm events. When combined with a storm surge and high tide, even small rises in sea level can result in very large increases in the frequency of coastal flooding (ACE CRC, 2008; Church et al., 2006). Around Sydney, flooding that is currently considered a 1-in-100 year event could occur every few months with a sea-level rise of 0.5m (**Figure 12**).

Figure 12. Estimated increase in the frequency of high sea-level events caused by a sea-level rise of 50cm.



Source: ACE CRC 2008

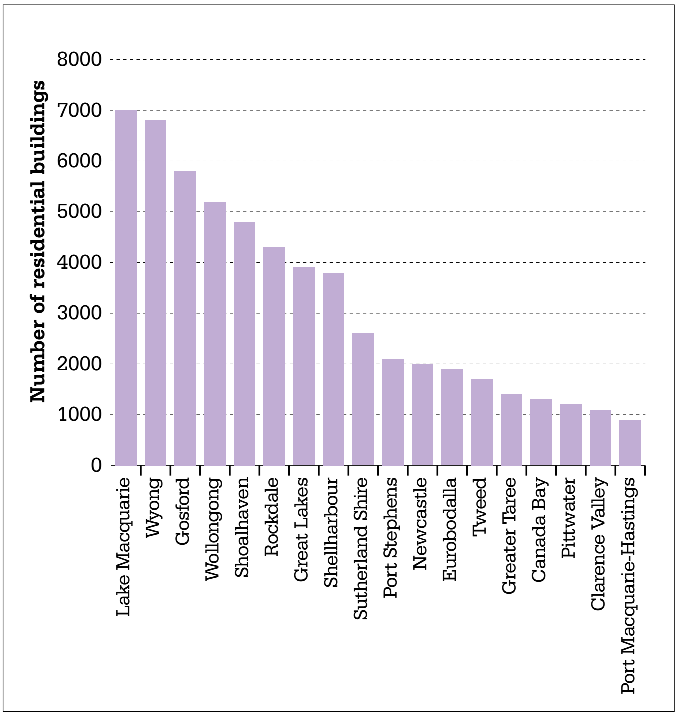
More regular flooding

Average global sea levels have risen by about 20cm since the late 1800s. For NSW (including Sydney) sea levels along the southern coast have risen slightly more than the global average, while for the northern coasts the rise has been about the global average or slightly less (CSIRO and BOM, 2012).

Global average sea level is projected to rise by up to 80cm by 2100 compared to 1990 levels (IPCC, 2007). Larger rises cannot be ruled out due to uncertainties about how fast ice-sheets can melt or disintegrate. Observed sea-level rise is currently tracking close to the worst case scenario, the upper limit of climate model projections. This suggests that a global sea level rise by 2100 of about 0.5m is likely and that a rise of 1.0m is a significant risk.

A 1.1m rise in sea level (modelled by the Australian Government to assess the highest likely risk) could put between 40,000–60,000 houses in NSW – the highest of any state in Australia – with a value of up to $18.7 billion, at risk of flooding towards the end of this century (**Figure 13 and 15**; DCC, 2009). Up to 20% of all houses in the Rockdale, Great Lakes and Shellharbour local government areas could be at risk under this scenario.

Figure 13. Number of residential buildings at risk in NSW local councils (lowest estimate), from a sea-level rise of 1.1m.



Source: DCC 2009

Figure 14. Erosion of coastal walkway at Scotts Head, NSW.

Source: Hannah Angus

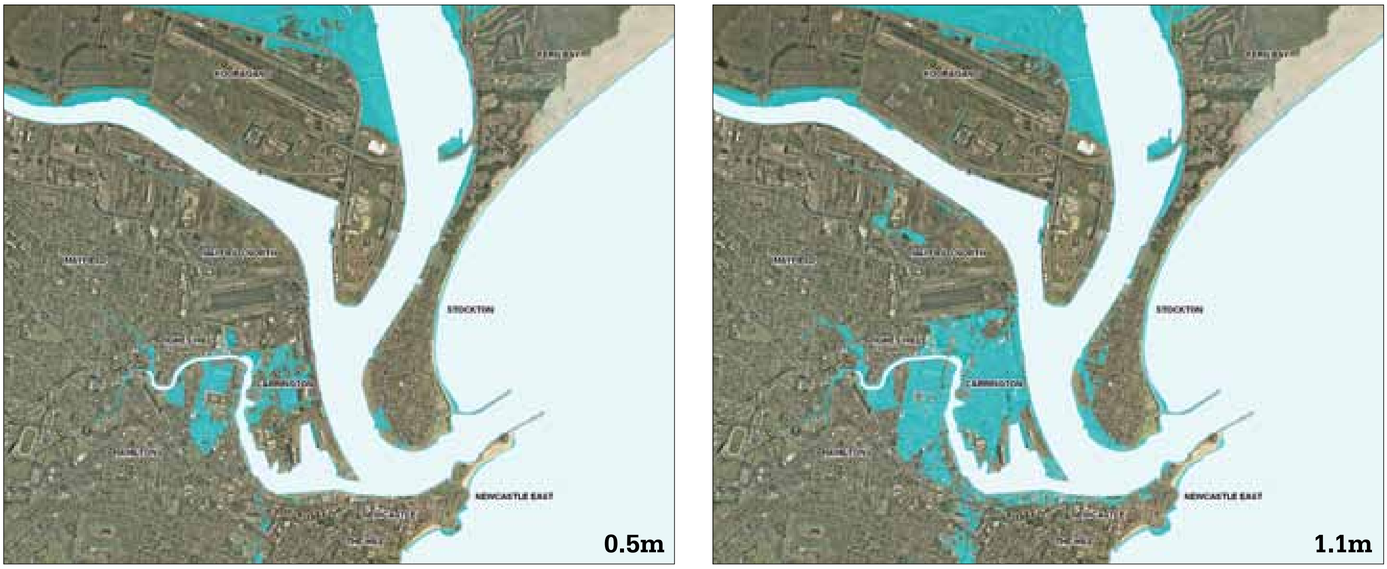
With a sea-level rise of 1.1m:

- Up to 1,200 commercial buildings and over 250km of highway may be at risk
- Parts of Sydney airport, the busiest in Australia, would be flooded with a storm surge, interrupting operations and damaging infrastructure
- Over 170km of railway would be at risk, with a replacement value of up to $1.3 billion. Wollongong and Newcastle have the longest lengths of railway of NSW cities at risk from a 1.1m sea-level rise – 43–51 km and 49–56 km respectively (DCCEE, 2011).

Erosion

Higher sea levels can contribute to the erosion of beaches, and the retreat of soft coastlines further inland. Coastal erosion can result in the loss of iconic beaches; it can also undermine buildings, such as surf clubs and houses, and infrastructure, such as roads and railways (**Box 6; Figure 14**). Approximately 3,600 residential buildings in NSW are located within 110 metres of soft shorelines. The local government areas of Sutherland and Port Stephens have the highest number of properties at risk in NSW (DCC, 2009).

Figure 15. Images of Newcastle with simulated coastal flooding from a sea level rise of 0.5m and 1.1m.



Source: Ozcoasts (www.ozcoasts.gov.au)

Box 6. Lake Cathie, NSW

Coastal erosion in Lake Cathie, near Port Macquarie, has occurred at an average of 0.2m each year since 1940 (Adamantidis, 2008; **Figure 16**). This small increase has already affected residents and infrastructure: beach access and storm water outlets have been destroyed, 330m of road is threatened, 14 private residences are at risk of losing their access and recreational qualities of the beach have been affected (Adamantidis, 2008).

These impacts are likely to be exacerbated by rising sea levels, with a conservative estimate of erosion continuing at 0.2m each year. Studies have estimated that loss of beach recreational qualities is worth $13.5 million; by 2050, 16 houses could be in the erosion zone, and further houses and roads could have unstable foundations (Adamantidis, 2008).

In NSW, local councils are responsible for managing coastal hazards, such as erosion. The Port Macquarie-Hastings Council has undertaken studies to better understand the risks, and have identified four potential management options: sea walls, groynes, pumping sand (beach nourishment) and planned retreat. Each of these options has different financial, environmental and social costs and benefits (Port Macquarie-Hastings Council, 2012).

Figure 16. Commissioners Will Steffen, Lesley Hughes and Roger Beale visited Lake Cathie with the Port Macquarie-Hastings council in 2011.

6. Plants and animals

- Heat and extreme weather events threaten the breeding and regeneration cycles of plants and animals
- Extreme heat and extended dry periods put crops and livestock at risk, threatening a billion dollar industry
- Many invasive plants and pests such as cattle tick and cane toads are likely to flourish in a hotter climate
- Native animals such as the koala and the mountain pygmy possum are already suffering from climate change

Healthy biodiversity has many benefits, such as absorbing pollution and protecting soils that support water supply and agriculture, and supporting an extensive tourism industry.

Animals and plants provide an early indication of a changing climate; many species in NSW are already responding to higher temperatures. Many birds and insects are now found at more southerly locations or at higher elevations because they have migrated towards cooler habitats. Aspects of animal and plant life cycles, such as migrations and flowering, are also changing in response to a hotter climate (Hughes, 2003; Beaumont et al., 2006; OEH, 2010). For example, bold-striped cool-skinks in southeast Australia have changed the depth of their nests, and when they lay their eggs. More skinks are also being born female as nest temperature affects the sex of their offspring (Telemeco, 2009).

Bushfires are expected to become more frequent and more intense in response to a hotter climate, affecting the ability of species and ecosystems to bounce back from fire damage. For example, alpine ash, one of the iconic plant species of NSW, needs six weeks of seed-chilling to germinate, and approximately 20 years for young trees to

Figure 17. Snow melt at Mount Kosciuszko, where higher temperatures affect snow depth.

Source: Mel Schroeder

Figure 18. Cattle near Wagga during drought in 2006.

Source: Flickr/John Schilling

mature and produce seed. The 2003 bushfires burnt half of all the alpine ash forests in NSW and regeneration following the fires has been very poor. The combination of more frequent fires and hotter weather threaten the future of these forests (DECCW, 2010a).

Hotter temperatures and reduced precipitation threaten alpine regions and the biodiversity they support (**Box 7**). Spring snow depth at Spencers Creek in the Snowy Mountains has decreased by 40% since the 1960s (CSIRO and BOM, 2007). Snow is melting sooner, leading to decreases in sensitive plants that live in the alpine environment (**Figure 17**; OEH, 2011).

Agriculture is an important part of the NSW economy, contributing around $8.4 billion in 2009–10 (ABS, 2011a). In 2010–11, livestock contributed $3.1 billion to the NSW economy, and livestock products around $1.6 billion (ABS, 2011b). Increasing length of dry periods, more hot days and changes in rainfall pose significant risks to agricultural productivity. For example, grazing animals, particularly cattle, are likely to suffer heat stress more frequently. Animals with heat stress have a reduced appetite and are less likely to breed, leading to losses in productivity (**Figure 18**; DPI, 2012).

A changing climate may be favourable for many introduced pest species, with significant impacts for both ecosystems and agriculture (see **Box 8**). For example, higher temperatures may allow the cattle tick *(Boophilus microplus)* – the most significant parasite affecting cattle in Australia – to move further south into northern NSW (IPCC, 2007). The tick is estimated to cost $146 million in lost productivity each year, by reducing cattle productivity and spreading tick fever that can sicken and kill non-immune cattle (MLA, 2012; IPCC 2007). Several million dollars is currently spent each year in an effort to control the tick spreading further south; however, these efforts might become economically unsustainable with both developing tick immunity to poisons and an overall increase in cattle tick numbers (IPCC, 2007).

Box 7. Highly vulnerable mountain pygmy-possum

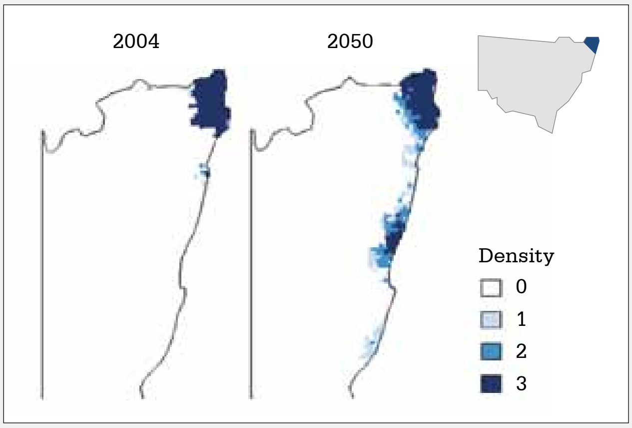
The endangered mountain pygmy-possum *(Burramys parvus)* is restricted to elevations above the winter snowline. It is a highly vulnerable species, already at risk from feral cats and foxes as well as habitat destruction (**Figure 19**; DECCW, 2010b). The pygmy-possum shelters from temperature extremes and predators under snow. Reductions in snow, coupled with high summer temperatures, may subject the species to considerable stress. The pygmy-possum population has already declined, resulting from a reduction in snow cover, droughts affecting food supply, loss of habitat from fire and increased predation from feral cats and foxes (DCCEE, 2009).

The pygmy-possum relies on seasonal food supplies, such as the bogong moths. Hotter temperatures may wake the pygmy-possum from hibernation before the migrating bogong moths appear. Over the past 30 years the spring thaw has arrived progressively earlier, but the arrival of the moth has not. In 2006, the spring thaw arrived at the earliest time ever recorded, while the moths arrived later than ever recorded. This mismatch in timing, increasing with climate change, affects not only the possum but many migratory birds, insects and flowering plants (DCCEE, 2009).

Figure 19. This pygmy possum, highly vulnerable to climate change, hid in a fire-fighter's pocket.

Source: Therese Cobcroft

Figure 20. Density of cane toads in 2004 and projected for 2050, without global action to reduce greenhouse gas emissions.



Source: Caley et al., 2011

Box 8. Climate more favourable for cane toads

Climate change is likely to be beneficial for the cane toad. The cane toad's distribution is predicted to increase fourfold, as higher temperatures create a more favourable climate, mainly in coastal areas (**Figure 20**; Caley et al., 2011).

Cane toads are a serious threat to Australia's biodiversity (**Figure 21**). They are highly toxic, killing native predators; they breed faster and grow more rapidly than native frogs and toads; they are very hardy and can tolerate a broad range of environmental and climatic conditions, potentially crowding out native species; and they eat about 200 prey per night, including native frogs (DSEWPC, 2010). The wallum froglet *(Crinia tinnula)*, which is found in lowland coastal habitats of northeast NSW, is vulnerable to predation by cane toads and is threatened by expansion of the cane toad's habitat (Queensland Government, 2012; Caley et al., 2011).

Figure 21. Cane toads are a serious threat to Australia's biodiversity, and may benefit from climate change.

Source: Flickr/!p4ul

Climate change is already affecting koalas, particularly in NSW and western Queensland where they are listed as threatened (NRMMC, 2009; **Figure 22**). Koalas and other plant-eating animals are affected by the nutritional quality of their plant food. High levels of carbon dioxide reduce the quality of their food by decreasing the protein content and digestibility of plants, making them less nutritious (DeGabriel et al. 2010).Koalas and other species are also likely to be affected by long periods of very high temperatures, which may lead to dehydration and heat stress.

Any increased frequency or intensity of droughts and bushfires may also reduce koala habitat, and lead to a contraction in koala distribution. Climate change is also likely to exacerbate existing stresses such as habitat loss and fragmentation, and increase the risks of disease, dog attacks and vehicle strike, as koalas are forced to move further afield in search of food (NRMMC, 2009).

Figure 22. Climate change presents many risks for Koalas.

Source: Flickr/SunriseOn7

7. Opportunities

- Renewable energy is a booming industry globally, with $5.1 billion invested nationally during 2010–11
- Companies are saving millions of dollars by moving to renewable energy sources and by implementing energy efficiency measures

Globally, the clean energy sector – mainly renewable energy, but also efficiency and low carbon technologies – attracted US$263 billion worth of global investment in 2011 (PEW, 2012). Excluding research and development spending, global investment in the sector is now over 600% higher than in 2004 (PEW, 2012). In Australia, more than $5.2 billion was invested in clean energy during 2010–11, an increase of 11% on the previous year. Around $4 billion was invested in household solar power alone (PEW, 2012; Morris and Johnston, 2011).

By 2020, it has been estimated that $43 billion will be invested in clean energy in Australia, including $20 billion in solar (Morris and Johnston, 2011). Even if solar panels are imported from overseas, around 30–40% of panel installation costs will go to local installers, creating jobs in installation, sales, marketing and metering (UNSW, 2010).

NSW has the largest state economy in Australia (DTI, 2012), with around 32% of Australia's light manufacturing, electronic equipment, heating, ventilation and air-conditioning manufacturing businesses. The state is therefore well placed to take advantage of increased demand for more energy-efficient products (DSRD, 2008). NSW is also home to about 35% of Australia's professional, scientific and technical services industry employees, so growth in this sector would be to its advantage (DSRD, 2008).

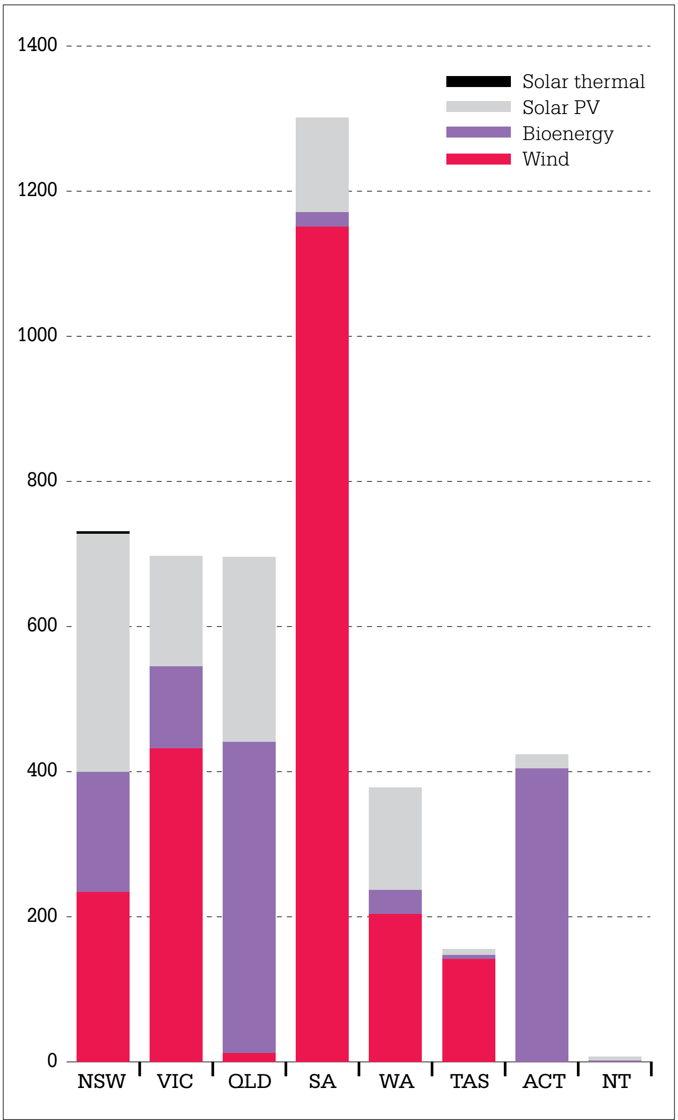
Renewable energy

Around 6% of NSW energy generation is from renewable sources and the NSW Government has a target of 20% renewable energy by 2020 (DTI2012a; DTI, 2012b). Wind speeds in several parts of NSW are very good for wind power (**Box 9**), and are similar to northern Europe, which has much of the world's installed wind power (DTI, 2012c).

South Australia, with the second highest wind energy penetration in the world after Denmark, has demonstrated the potential for renewable energy in Australia. South Australia is producing 53% of the nation's wind energy (**Figure 23**; CEC, 2012).

Many individuals and businesses are taking advantage of renewable energy (**Box 10**). NSW has the largest number of installed solar panels of any state (Morris and Johnston, 2011). Major projects under construction included 92 megawatt (MW) wind farm at Crookwell and 48 MW wind farm at Woodlawn, and 1.1 MW landfill gas plants at Woodlawn and Buttonderry (CEC, 2012).

Figure 23. Installed capacity of key renewable energy technologies (in megawatts).



Source: CEC (2011)

Note: This graph does not include hydro power.

Box 9. The Capital wind farm

The Capital wind farm, located near Bungendore, NSW, is the largest wind farm currently operating in the state (**Figure 24**; DECCW, 2010b), with 67 wind turbines and a total capacity of 140MW. The project provides rental income for landowners and local employment opportunities; employing 120 people during construction and 10 people on an ongoing basis.

The wind farm generates about 450,000 MWh per year, which is enough to power around 60,000 homes. The renewable energy generated by the wind farm represents a saving of around 400,000 tonnes of greenhouse gases each year, which is equivalent to the emissions of about 85,000 cars each year (Infigen Energy, n.d.).

Figure 24. Capital wind farm is the largest currently operating in NSW.

Source: Tim Lewer

Box 10. Sydney Theatre Company

Through solar power, water conservation, waste management and education, the Sydney Theatre Company is providing a best practice example of how businesses can adapt a sustainability model that will also save money.

The roof of the theatre houses the second largest photovoltaic solar array in the country, with almost 2,000 solar panels (**Figure 25**). The panels provide 70% of the theatre's energy requirements. In addition to the panels, theatre lights have been replaced with energy efficient bulbs, air conditioning and box office lights put on timers, gas-boosted solar hot water installed and additional windows fitted to bring in more natural light. Energy consumption has been reduced by 60%, saving the company money as energy prices increase, and has reduced carbon emissions by 550 tonnes per year (Sydney Theatre Company, 2012a).

The company overhauled its waste practices so that over the past two years, no waste has been sent to landfill. For example, all sets, props and costumes are reused if possible, reducing landfill waste as well as cutting costs and reducing the amount of timber purchased for set construction by 58% in 2011. All waste that cannot be recycled is sent to a bio-reactor for energy recovery (Sydney Theatre Company, 2012b).

The company has also factored public education into its plan, with touch screen kiosks throughout the theatre which explain the works undertaken and the impact on sustainability.

The 'Greening the Wharf' program, which received significant funding from corporate and government partners, earned a Banksia Award in 2011 for 'Leading in Sustainability'.

Figure 25. Sydney Theatre Company solar panels provide 70% of their energy needs.

Source: Sydney Theatre Company

Research and development

- NSW is home to some of Australia's leading researchers in renewable energy
- NSW residents have lead the country in solar uptake

Some of the world's leading clean technology research and development happens in NSW, placing the state in a position to take advantage of growth in clean technology markets worldwide (**Box 11**). The CEO of Suntech, the world's largest solar company, was previously a researcher with the University of NSW (UNSW) School of Photovoltaic and Renewable Energy Engineering (**Figure 26**). Four of the top six global manufacturers in solar photovoltaic technology have been students or researchers at UNSW, including JA Solar, Trina Solar and Yingli Green Energy Holding (UNSW, 2012).

Australian ocean waves have enough energy to power the nation many times over, and world leading wave-energy researchers and developers are located in NSW. Oceanlinx, one of Australia's wave energy developers, is based in Sydney and has partnered with the University of Wollongong in wave energy demonstration projects (University of Wollongong, 2012). The University of Wollongong hosts well-equipped laboratories and workshops researching wave energy technologies.

Figure 26. Shi Zhengrong, CEO of Suntech at the 'sustainability champions' session of the World Economic Forum, 2012.

Source: Flickr/World Economic Forum

Box 11. NSW research and development

Recent Eureka prize winners – for leading science developments – include:

- Dr Vanessa Peterson (Bragg Institute, Australian Nuclear Science and Technology Organisation, NSW), People's Choice Finalist 2011, for researching ways to store hydrogen for fuel cells and pave the way for a clean-fuelled future
- Professor Manfred Lenzen, Dr Christopher Dey & Dr Joy Murray (University of Sydney), Innovative Solutions To Climate Change Winner 2011, for developing tools to accurately identify which economic decisions are contributing most to environmental pressures, particularly climate change
- Scientia Professor Martin Green (UNSW), Winner of Leadership in Science 2010, for leading the field in solar cell research
- Professor Stuart Wenham (UNSW), Finalist of Leadership in Science 2009, for development of solar cell technology.

Consumers around the world have become more conscious of energy prices, creating a wealth of opportunities for technical innovation and new business. The development and manufacture of new technologies requires capital and labour, and regions supporting new technologies are likely to attract higher amounts of investment and jobs (PEW, 2012). In NSW, take-up of solar in residential and medium scale businesses significantly increased in 2009 and 2010, creating new businesses, new jobs, reduced consumer bills, reduced network demand and greenhouse gas savings (Morris and Johnston, 2011). Early 2011 data shows a slight decline, as some programs, such as the NSW Solar Bonus Scheme, have now closed (Morris and Johnston, 2011).

Sustainable Cities

- NSW is home to three of Australia's largest cities; Sydney, Newcastle and Wollongong
- Traffic gridlock is a significant contributor to greenhouse gas emissions
- Better public transport would cut down on commute times and carbon pollution

Cities consume over two thirds of the world's energy and account for 70% of greenhouse gas emissions (C40 Cities, 2011). Cities are growing and are vulnerable to the impacts of climate change.

Sydney's population is currently 4.5 million and is forecast to increase to 5 million people by 2020 and to 6 million by 2036 (RDA, 2011). Sydney is home to 63% of the NSW population, and is growing at the fastest rate of any area in NSW (1.7% each year) (ABS, 2011c). In addition to Sydney, Newcastle and Wollongong are in Australia's top ten most populous cities.

The underlying factors that influence emissions in cities include: inefficient building heating, cooling, lighting and refrigeration; landfills releasing methane; inefficient outdoor lighting; high car use; heavy traffic congestion and inefficient water systems (C40 Cities, 2011).

With the higher population density, buildings and infrastructure of cities come many opportunities for taking advantage of clean energy technologies. Options for cities include: local energy generation (see **Box 12**), fast transit systems (see **Box 13**), higher population density along transit systems, walking and cycling areas in and between centres, phasing out freeways, phasing in congestion taxes and traffic-calming measures, improvement on car emissions and moving to electric vehicles (**Figure 27**; Newman et al., 2009).

Businesses are embracing energy saving measures in retrofits and new buildings. The new 161 Castlereagh Street building incorporates two 450 kilowatt tri-generation plants, which provide electricity, as well as heating and cooling for air conditioning and hot water systems. The building also has a high-performance thermally shielded glass exterior, which lets in light and acts as insulation. Environmentally friendly concrete was used during construction and effort was taken to reduce the amount of reinforcing steel needed (GBCA, 2011).

Recycling of waste products can have energy-savings and prevent materials going to waste (where they can break down, producing greenhouse gas emissions). For example, Dunlop Flooring now manufactures a 90% recycled carpet underlay and has introduced a program to buy old underlay

Figure 27. Technologies and solutions for transport already exist, and many countries around the world are taking advantage of the benefits. Electric car recharge points in the Netherlands and a cycleway in Copenhagen, Denmark, are shown below.

Source: Flickr/Maarten Takens and Flickr/Mikael Colville-Anderson from carpet retailers (Dunlop Flooring, 2012). Recycling of metals such as aluminium and steel – both manufactured in NSW – can have significant energy and cost savings. Recycling aluminium uses only 5% of the energy taken to manufacture new aluminium, and on average emits only 5% as much greenhouse gases (Australian Aluminium Council, 2010). Alcoa, a large aluminium recycler in Australia, recycles around 55,000 tonnes each year in Yennora, NSW. Recycling one aluminium can saves enough energy to run a television for three hours (Alcoa, 2012).

Improving energy efficiency has already reduced costs for business around NSW, with state energy audits identifying average annual electricity savings of 28%, and average cost savings of 31% (OEH, 2012).

For example:

- The Wrigley Company – maker of sweets such as Starburst – has installed solar and wind power, cut energy use by 10% and diverted 100% of waste from landfill
- Taronga Zoo has identified water pumping, lighting and other opportunities to save $84,700 a year, and 523 MWh
- SD Smash and Mechanical Repairs in Auburn now saves $1,511 a year after installing new lighting (OEH, 2012).

Moving to energy savings, clean energy and better transport and planning has many benefits in addition to reducing greenhouse gas emissions, such as reducing negative impacts on human health, and creating jobs and better places to live and work (Mandag Morgen, 2011).

Box 12. City of Sydney 2030

The City of Sydney has committed to reduce its emissions 70% by 2030 (City of Sydney, 2011). As part of this commitment, Sydney has been the first of Australia's capital cities to start work on a decentralised energy generation network, or tri-generation network, which will eventually produce 70% of its energy needs (City of Sydney, 2012a).

Sydney's tri-generation network will use small local generators powered by natural or waste gases to produce and supply low-carbon electricity, heating and air-conditioning to networks of buildings in the Sydney CBD (**Figure 28**). The technique is more than twice as efficient as coal-fired power generation because it uses heat that would otherwise be wasted during electricity generation, to both heat and cool buildings (City of Sydney, 2012b).

Sydney currently gets 80% of its electricity from coal-fired power stations, with two thirds of the energy used to generate this electricity wasted as heat or in transmission losses (City of Sydney, 2012b). Tri-generation can reduce greenhouse gas pollution by 40–60 per cent compared to coal-fired power for connected buildings (City of Sydney, 2012b).

It could also save NSW electricity consumers up to $1.5 billion in grid upgrades and new power stations by 2020 (Dunstan and Langham, 2010).

The tri-generation plan is supported by both small and large business initiatives, such as the Better Buildings Partnership which works with large commercial building managers to cut carbon emissions and save energy, water and waste. Founding members include Colonial First State, The GPT Group, Investa Property Group, Lend Lease, Mirvac and Stockland.

Figure 28. A trigeneration plant operating in an Investa-managed Sydney building.

Source: City of Sydney

Box 13. Transport

Transport in Australia is likely to undergo a profound transformation during this century, as a result of higher oil prices, new transport technologies, rising incomes and population growth (Garnaut, 2008).

Transport is the second largest consumer of energy in NSW, and a significant contributor of greenhouse gases – around 14 per cent of total NSW emissions (DCCEE, 2012a). Cars make up approximately half of NSW transport emissions, and trains only 3% (DCCEE, 2012b). Technologies and solutions for more energy efficient transport already exist and many cities around the world are capitalising on the benefits of integrated transport systems, electric cars and active transport, such as walking and cycling.

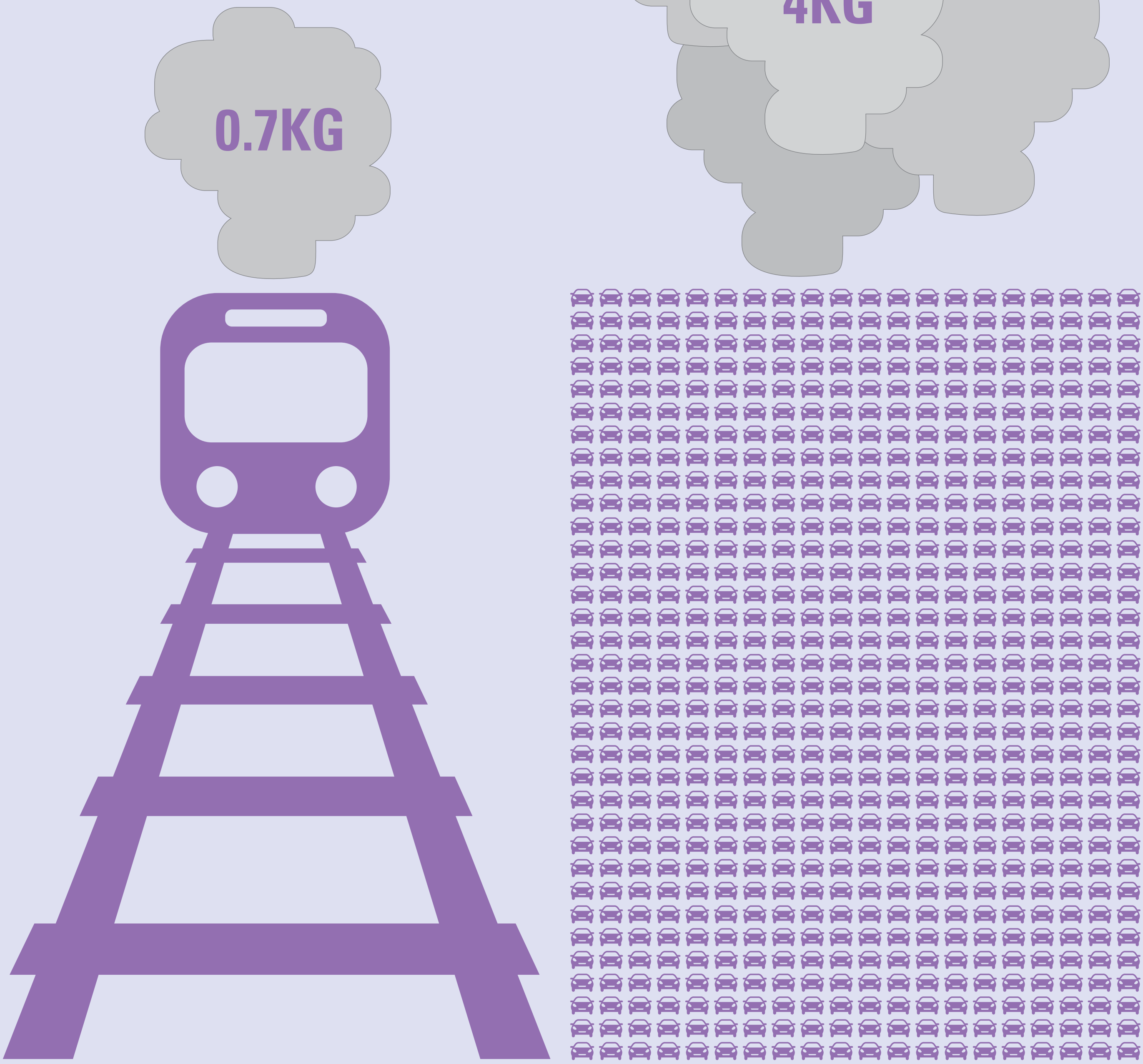
Trains are an extremely efficient and low emissions form of transport (**Figure 29**). A train line can move 50,000 commuters per hour, whereas a freeway lane can only move 2,500 in the same time. The potential to reduce greenhouse gas emissions is equally great. Just one commuter switching from road to rail from Castle Hill to the Sydney CBD reduces emissions by 3,150kg of CO_2 per year (TTF, 2009).

Efficient public transport systems, such as trains, reduce emissions and provide many other advantages. Benefits include improved air quality decreased traffic congestion and noise; reduced costs to the community; safe transport; less energy and public-land usage; improved accessibility to jobs, business and shopping districts and affordable transport for all (IAPT, 2012). The city of Copenhagen, Denmark, found that its public transport system saves $5.7 billion DKK (equivalent to around $ 1 billion AUD) in lost productivity from travel time (Mandag Morgen, 2011). In the United States, it is estimated a reduction of commuting time by 1 minute across the country is worth $19.5 billion in value added to the economy (Mandag Morgen, 2011). The social cost of traffic congestion in Sydney was estimated at $3.5 billion in 2005, and is forecast to rise to $7.8 billion by 2020 (DIT, 2007).

Figure 29. Trains are an extremely efficient and low emissions form of transport.

Source: Flickr/Gareth Edwards

A SINGLE PERSON'S JOURNEY FROM PARRAMATTA TO CENTRAL STATION BY CAR EMITS AROUND 4KG OF GREENHOUSE GASES, BY TRAIN ONLY 0.7KG



AN EIGHT-CARRIAGE TRAIN CAN MOVE 1,000 PEOPLE, THE EQUIVALENT OF 250–1,000 CARS. THIS WOULD REQUIRE AROUND 1.3 HECTARES OF PARKING SPACE.

Source: CityRail (2012)

Sources

Information is taken from the Climate Commission's report *The Critical Decade*, and *The Critical Decade: Climate change and health* unless otherwise noted below.

Further information on climate change impacts and opportunities in NSW is provided in the Climate Commission reports: *The Critical Decade: Illawarra/NSW South Coast Impacts* and *The Critical Decade: Consequences for the New England/Northwest NSW region*.

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