CLIMATE
COMMISSION

THE CRITICAL DECADE

Victorian climate impacts and opportunities

Summary

Victoria's climate is already changing and is likely to change further in the future, posing significant risks to the state.

- Many types of climate-related extreme events are expected to increase in frequency and intensity in the future. The heatwaves, drought and bushfires of the past decade provide Victorians with a window into that future.
- The number of hot days has increased over the last few decades and is expected to continue increasing into the future. Critical infrastructure, such as roads, railways and power lines, is vulnerable to prolonged exposure to high temperatures.
- Conditions for large and intense bushfires are likely to become more common in the future. The number of 'very high' and 'extreme' fire danger days could increase significantly over the next few decades.
- Over the last 40 years much of eastern and southern Australia has become drier, with Victoria experiencing a 10-20% reduction in autumn and winter rain over the last 20 years.
- Global sea-level rise is tracking near the highest levels scientists expect. This means that a potential 1 m rise over this century is a serious risk threatening Victoria's iconic beaches, and thousands of residential and commercial buildings.

The next chapter of the climate story is about how Victoria, and Australia, can find solutions that minimise the risks of climate change while providing extra benefits for our health, community, economy and environment. Harnessing clean energy, taking advantage of new economic opportunities and building sustainable communities can all provide new opportunities for Victorians.

- Victoria has substantial renewable energy resources. Victoria receives enough energy from the sun to produce double the state's current energy needs, and parts of Victoria have some of the best conditions in the world to harness wind energy.
- Around the world, investment in renewable energy is growing strongly and costs are rapidly coming down. For instance, in some countries the cost of solar electricity is now competitive with retail electricity prices.
- Making our cities more sustainable can also make them healthier and more livable, 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. Melbourne has world class examples of green buildings.

With thanks to Climate Commission's Science Advisory Panel, Adjunct Professor Alan Pears and ClimateWorks Australia for their comments on the report.

This report draws from the Climate Commission's reports: *The Critical Decade and The Critical Decade: Climate Change and Health*, and is the Commission's 12th report.

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1. IMPACTS

1.1 Rising sea levels

- The observed sea level is tracking close to the upper range of the model projections.
- Global sea-level rise of 100 cm and above, possible by 2100, is a significant risk for many coastal regions in Victoria.
- Kingston, Hobsons Bay, Greater Geelong, Wellington and Port Phillip local government areas are the most at risk from rises in sea level.

A significant proportion of the Victorian population lives along the coastline. Rising sea levels pose considerable risk to coastal property, infrastructure and beaches, through:

1) Coastal flooding from storm surges and high tides coupled with higher sea levels

2) Coastal erosion/recession of the land on which buildings and infrastructure are built

Coastal flooding

The impacts of sea-level rise are most acutely felt 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 and sea-level rise, increase the risk of flooding to property, infrastructure and beaches (**Box 1**).

Global sea level has risen on average about 20 cm since the late 1800s and the rate of change has increased over the last two decades. Future rates of change are not simply an extrapolation of these changes. The rate of sea-level rise in the future will depend on the future level of warming in the oceans and the melting of glaciers and polar ice sheets.

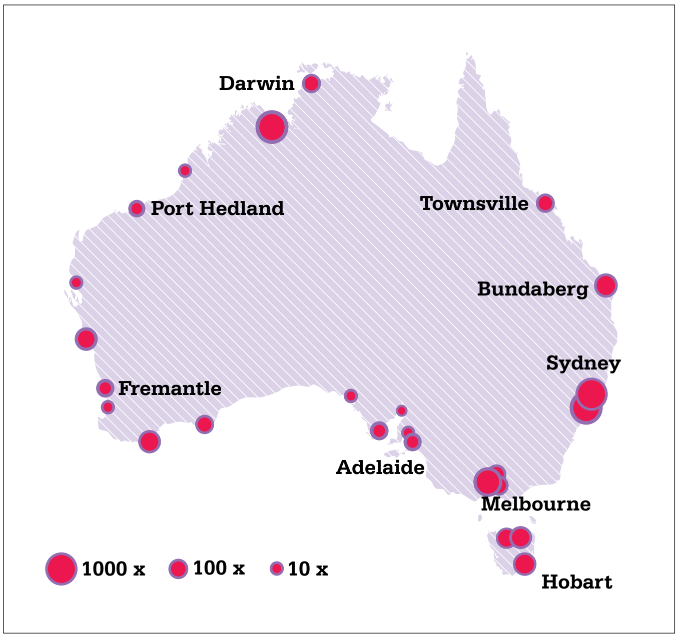
The sea-level rise projections for this century range from 20 cm to over 100 cm (IPCC, 2007 and DCC, 2009). Most experts agree that a rise of 50 cm – 100 cm is most likely this century. However, depending on the stability of the major ice sheets in Greenland and the Antarctic sea-level rise over 100 cm is a distinct possibility. The observed sea level is tracking close to the upper range of the model projections. This means that it is near the highest levels scientists have predicted in the past. This suggests that a global average sea-level rise of 100 cm this century is a serious risk. Consistent with the magnitude of this possible sea-level rise, the Australian Government has assessed the risk to Australia's coast from a 110 cm rise in sea level (DCC, 2009).

Even at the lower end of estimates, a 50 cm increase in sea level would contribute to a significant increase in the frequency of coastal flooding (**Figure 1**). The influence of sea-level rise can also be estimated by considering storm tide height, which is the combination of the storm surge height and the height of the tide that results from gravitational effects. For example, a one-in-100 year storm tide height in Geelong is likely to rise from 110 cm to 220 cm by the end of the century (McInnes et al., 2009).

Up to 2,000 commercial buildings in Victoria – the second highest number for any state in Australia – would be threatened by a 110 cm sea-level rise. This represented in 2011 a replacement value of $8 – $12 billion (DCCEE, 2011). An estimated 27,600 to 44,600 residential buildings in Victoria may also be at risk from flooding through the combined effect of sea-level rise and a storm surge from a one-in-100 year storm (DCC, 2009).

Local government areas at particular risk of a 110 cm sea-level rise and a one-in-100 storm tide include Kingston, Hobsons Bay, Greater Geelong, Wellington and Port Phillip (DCC, 2009). Storm-related flooding may affect up to 30% of residential buildings in the Kingston local government area by 2100 (DCC, 2009).

Figure 1. Estimated increase in the frequency of high sea level events caused by a sea-level rise of 50 cm. A rise of 50 cm will lead to a very large increase in the frequency of coastal flooding. Flooding that is currently considered a one-in-100 year event could occur every few years.



Source: ACE CRC 2012

Erosion and coastal recession

Higher sea levels can 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 approximately 4,700 residential buildings within 110 m of erodible coastline in Victoria (DCC, 2009). Particular areas of risk include the Mornington Peninsula with 1,140 residential buildings and Greater Geelong with 750 residential buildings located near erodible coastline (DCC, 2009).

Box 1. Impacts in Gippsland Lakes and Lakes Entrance

Within 50 years, parts of the Gippsland coast may be inundated to an extent requiring protection such as sea walls or relocation of assets, including residential and commercial buildings (Gippsland Coastal Board, 2008).

This region is already vulnerable to flooding, but rising sea levels could exacerbate this vulnerability. During high tides and heavy rainfall events, water is less able to escape from Gippsland Lakes. This has resulted in extensive flooding of low-lying towns and infrastructure such as in the Lakes Entrance township (DCC, 2009). The highest recorded flood level in Lakes Entrance was 180 cm above sea level (**Figure 2**). Rising sea levels, coupled with storm surges and barrier dune erosion, could intensify this existing flooding risk, affecting roads, bridges, buildings and utilities (such as powerlines).

Rising sea-levels also pose risks to the biodiversity and ecosystems of the Gippsland Lakes, a Ramsar wetland site of national and international importance.

Figure 2. Lakes Entrance with simulated coastal flooding of 180 cm above sea level.

Source: Wheeler et al., 2012

1.2 Heatwaves

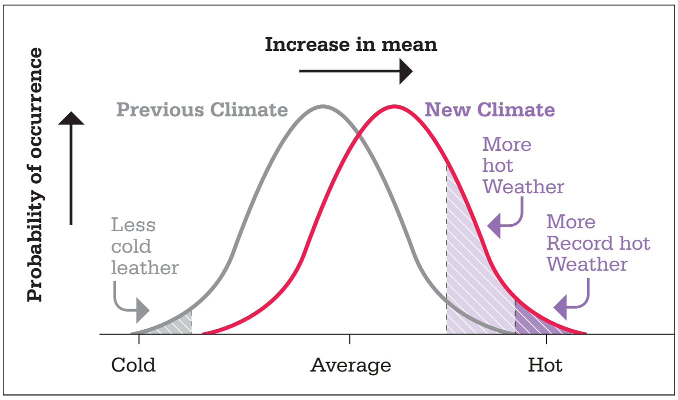
- Victoria is already experiencing an increased number of days above 35°C each year.
- Much critical infrastructure in Victoria is not designed to withstand extreme temperatures.

Prolonged periods of very high temperatures threaten health, biodiversity, critical infrastructure and economic productivity. Average temperatures in Victoria have risen approximately 0.8°C since the 1950s, and although temperature increases of 0.8, 1 or 2°C may seem modest, they are associated with significant changes in the frequency and nature of extreme weather events. A small shift to higher *average* temperatures leads to large increases in the number of extreme heat events (**Figure 3**). Correspondingly, there are fewer extreme cold events.

Hot weather has become more common and severe in Australia. Over the last 50 years the average number of record hot days per year has increased across the country. In Melbourne, the long-term average number of days per year above 35°C was 10 (BoM, 2012a), but during the decade 2000–2009 the average number of such days rose to 13 (BoM, 2010). The January – February 2009 Melbourne heatwave event was consistent with the shift to more record hot weather.

Much of Victoria's critical infrastructure – such as roads, railways and power lines – is vulnerable to very hot temperatures. During very hot weather, bitumen road surfaces can melt, railway lines can buckle, and power can be cut when transponders, power lines and power stations fail or are shut down. For example, during the 2009 Melbourne heatwave when temperatures exceeded 43°C for three consecutive days, railway lines buckled from heat stress and across the three days over one-third of train services were cancelled (QUT, 2010; **Figure 4**). Additionally, the Basslink connection to Tasmania, which provides 6% of Victoria's electricity, was shut down at various times over 29 and 30 January due to the heat. Faults in major transformers caused outages of main transmission lines across the two days (QUT, 2010). More than half a million Melbourne residents lost power on the evening of 30 January 2009 (QUT, 2010).

Figure 3. The relationship between an average and extremes. For example, when the average temperature increases by a small amount, there is a disproportionately large increase in the number of extreme heat events.

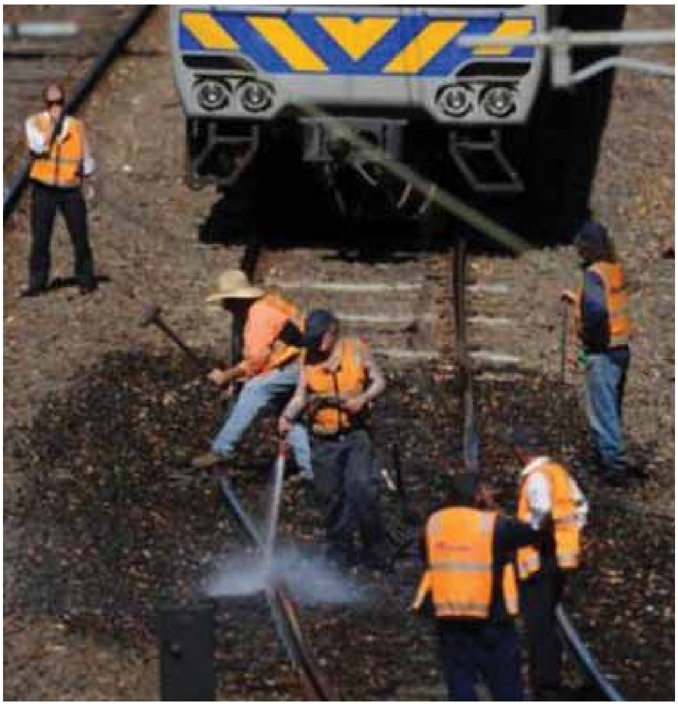


Source: IPCC 2007

Electricity outages during heatwaves are critical because they occur at the time when power is most needed for cooling systems. Inability to use air-conditioning on very hot days may exacerbate the risk of heat-related illness and death. More details of the potential impacts on human health are given in section 1.5.

As average temperatures continue to rise across Victoria, the number of hot days (over 35°C) is expected to increase. In Melbourne, the number of hot days is likely to increase from the long-term average of 10 (BoM, 2012a) to 15–26 days in 2070 (CSIRO and BoM, 2007). The 2009 heatwave has given Melbournians first hand experience of the risks of a warming climate.

Figure 4. Maintenance officers work on train tracks that buckled under the extreme temperatures of 28 January 2009.



Source: Herald Sun

1.3 Bushfires

- The weather conditions associated with high bushfire risk during the summer fire period have become more severe in some places across Australia.
- The number of ‘very high’ and ‘extreme’ fire danger days is very likely to increase as the average temperature rises further.

Bushfires can severely affect biodiversity, human health, property, economic activity and infrastructure (**Box 2**). Southern Australia is an extremely fire-prone region in summer, and bushfires are a natural part of the Victorian climate and ecosystems. The Forest Fire Danger Index, the measure used to gauge bushfire threat, has increased at 16 of 38 weather stations across Australia over the period 1973–2010, with none of the stations recording a significant decrease (Clarke et al., 2012). The increase has been more prominent in southeastern Australia.

The conditions for large and intense fires – low humidity, high winds and extreme temperatures – are likely to become more common in the future. The amount and condition of vegetation available to fuel fires is also likely to change, although the extent of these changes is uncertain (Williams et al., 2009). One of the largest uncertainties is related to the change in rainfall patterns, which influences both the amount of vegetation that is available to burn and its condition. See Box 3 for more information on Victoria’s changing rainfall patterns.

The number of ‘very high’ and ‘extreme’ fire danger days is very likely to increase as the average temperature increases further – by 4–25% by 2020 and 15–70% by 2050 (Lucas et al., 2007; **Figure 5**).

Box 2. Black Saturday bushfires

Victoria’s worst ever bushfire, which claimed 173 lives, destroyed 2,000 properties and affected 78 communities, occurred during one of the hottest and driest summers on record.

On Saturday 7 February 2009, the temperature in Melbourne peaked at 46.4°C. Melbourne had recorded no rainfall from 4 January to 7 February. When combined with high wind speeds and low humidity, perfect conditions for an unprecedented natural disaster were created. The estimated cost of the Black Saturday bushfires to Victoria was approximately $4.4 billion (PoV, 2010).

A new level of the fire danger scale has been added to recognise the significant increase in severe bushfire conditions over the past decade. ‘Code Red’ signals that the safest option for residents is to leave rather than stay to protect their homes (CFA, 2009). The weather conditions of 7 February 2009 would have meant a Code Red alert being issued for most of Victoria (CFA, 2009).

While several of the worst fires on Black Saturday were ignited by sparks from falling power lines, a CSIRO submission to the Victorian Bushfires Royal Commission suggested that the extreme heat and dryness that contributed to the extent and severity of bushfires was influenced by climate change (Hennessy, 2009).

Figure 5. The Code Red rating was released in 2009 to reflect days with the worst conditions for a bush or grass fire and to advise people to leave high risk bushfire areas well in advance of a possible outbreak of fire.

Source: DSE 2011

1.4 Rainfall, drought and floods

- Over the past two decades, Victoria has experienced drying during late autumn and winter and reduced frequency of very wet years.
- Climate models project that on average Victoria will be drier over the next several decades when compared with the 20th century.
- A decrease in rainfall results in a proportionately greater decrease in runoff, with significant effects on urban water supplies, environmental flows and agricultural water availability.

Despite the heavy rains in 2010 and 2011, southeast Australia is experiencing a long-term drying trend, particularly evident in the last two decades (**Figure 6**; **Box 3**). The Big Dry of 1997–2009 in Victoria (**Figure 7**), for example, was the driest period on record, surpassing previous droughts that extended from 1936–1945 (the World War II drought) and 1896–1905 (the Federation drought) (SEACI, 2010). In the last two decades, Victoria has experienced both a 10–20% reduction in rainfall during the late autumn/winter season and a reduced frequency of very wet years.

The scientific evidence suggests that dry conditions will continue across southern Australia. In particular, climate models estimate decreases in average rainfall during winter and spring over the next century. Observed decreases in rainfall have occurred in late autumn and winter, and the observed changes have been much larger than model projections for the next few decades (SEACI, 2010).

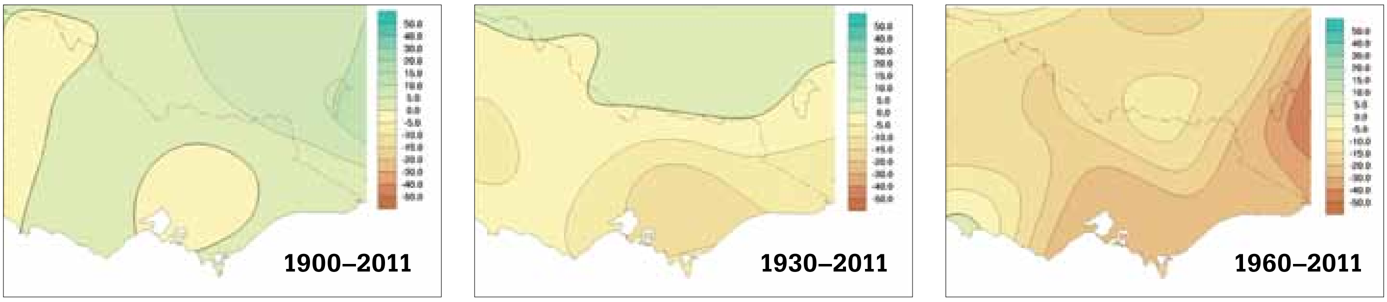
The causes of recent rainfall changes across southern Australia are complex. There is evidence that drying has been influenced not only by changes in greenhouse gases, but also by the loss of stratospheric ozone (the 'ozone hole') and by air pollution in the regions around Australia. Observed declines in rainfall over Victoria since the mid-1990s are similar to rainfall decreases in southwest Western Australia over the last 30 years, suggesting that similar processes could be affecting rainfall in both regions. It is likely that rainfall declines in the southwest have been influenced by global warming (Timbal et al., 2006).

Embedded in the overall drying trend are changes in the nature of rainfall when it does occur. For example, in southern Australia there has been a decrease in heavy rainfall in many areas, especially where average rainfall has decreased (IPCC, 2012).

The drying trend has important consequences for urban water supplies (**Box 4**) and agriculture across the state. Australian farmers have shown considerable adaptive capacity in dealing with present-day climate variability. For some farmers there may be limited advantages of a warming climate, such as longer growing seasons and the ability of some crops to use less soil water during their growth phase as a result of higher carbon dioxide concentrations in the atmosphere.

However the adaptive capacity of farmers and the beneficial aspects of climate change can easily be overwhelmed by the negative impacts of climate-related events. For example, in the Wimmera Southern Mallee region – one of Australia's main broadacre cropping and grazing zones – the Big Dry resulted in an 80% reduction in grain production and a 40% reduction in livestock production (BCG, 2008). The drought had physical, financial and personal costs for many farming families in the region (BCG, 2008).

Figure 6. Trends in annual total rainfall (mm/10 years) across southeast Australia.



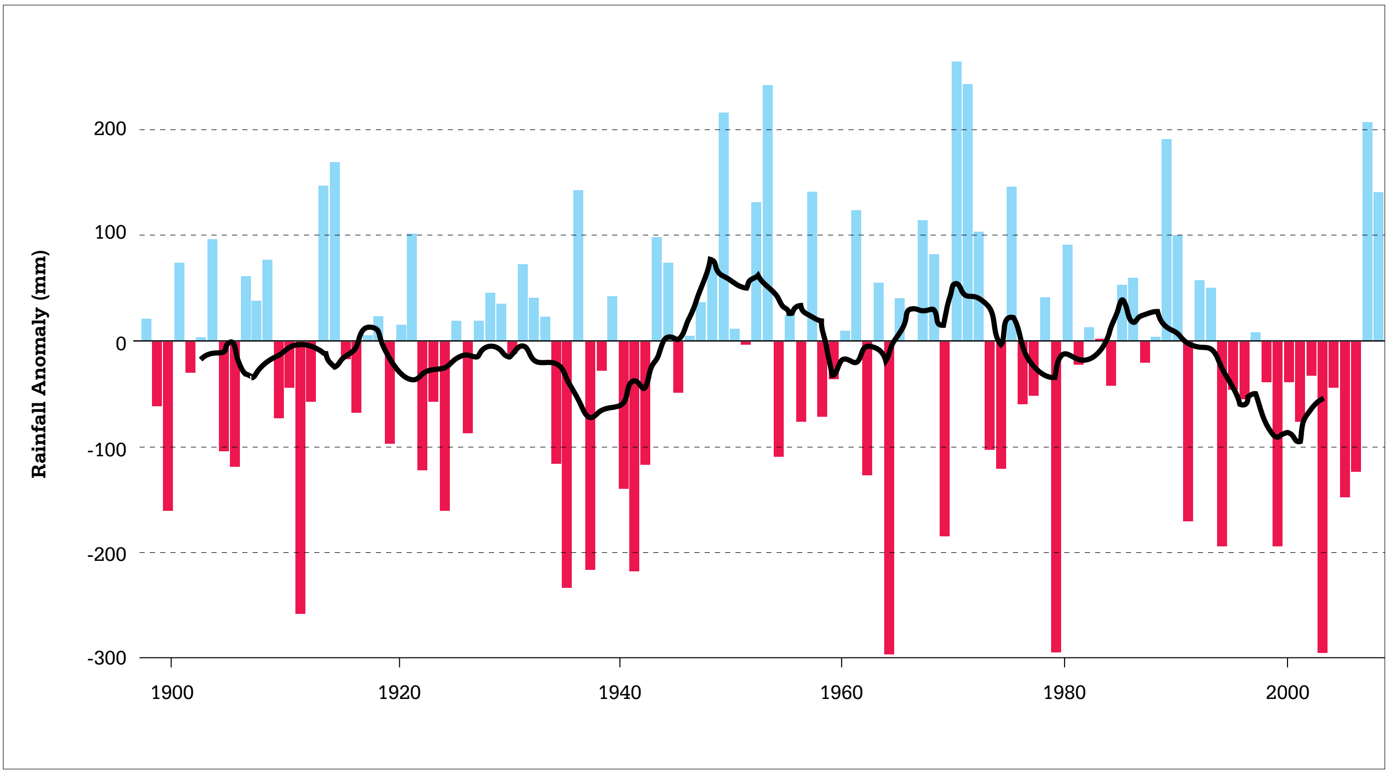
1900–2011

1930–2011

1960–2011

Source: BoM 2012b

Figure 7. Time series of the annual rainfall anomaly in Victoria 1900–2011.



Source: BoM 2012c

Box 3. Victoria's rainfall trends

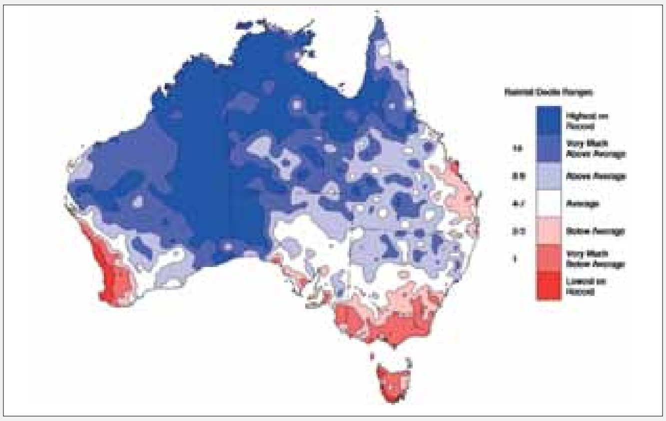
Frequent heavy rainfall events throughout 2010 and 2011 resulted in Australia's wettest two-year period on record, with the late 2010-early 2011 period bringing Victoria's wettest summer on record. However, the 2011 winter brought below-average rainfall resulting in dry conditions over southeast Australia. This continues a more than decade-long trend of drier than normal late autumn – early winters across this region.

The record rainfall of 2010–2011 effectively brought the Big Dry to an end. However, measurements of rainfall over the past 15 years compared to the historical average show that large areas of below-average and very-much-below-average rainfall remain over much of southeast Australia (**Figure 8**). Rainfall over half of Victoria in the past 15 years was very-much-below-average.

The exceptional rainfall of 2010–2011, resulting in the Victorian floods, was influenced by strong La Niña conditions and by record warm ocean temperatures around Australia. This heavy rainfall resulted in flooding over one-third of Victoria and caused widespread damage to residential and rural property, townships, agriculture and essential services (Comrie, 2011). Climate change cannot be ruled out as a factor influencing the conditions that generated this exceptional rainfall.

(Comrie 2011, BoM, 2012d and Climate Commission, 2012)

Figure 8. Australian rainfall deciles, which are the measurements of rainfall in comparison to the historical average, for the 15 years, January 1997 to December 2011.



Source: BoM 2012d

Box 4. Risks to Melbourne's water supply

The Big Dry of 1997–2009 had significant impacts on runoff into urban water catchments and on river flows. The relationship between rainfall and runoff is not linear; for a given change in rainfall – either increase or decrease – the consequent change in runoff is typically amplified two- or three-fold. However, the stream flow decline in Melbourne's catchments, Victoria and the southern Murray-Darling Basin has been disproportionately greater, with for example, a drop of 50% in the amount of water flowing into the River Murray system during the recent drought (SEACI, 2010).

While rainfall varies greatly from year to year, the overall trend over the past 50 years has been a decline (**Figure 7**). Annual inflow into Melbourne's four major reservoirs was lower by almost 40% in the period 1997–2011 compared with the previous 80 years (**Figure 9**). The inflow in 2006 was the lowest in recorded history (Melbourne Water, 2012a).

Projections of future rainfall – and therefore water availability – across southeast Australia indicate that water availability will likely continue to be reduced, particularly in winter, when compared to the 20th century (SEACI, 2010). As most of the streamflow in Victoria occurs in winter, this translates to a continuing significant reduction in winter and therefore annual streamflow.

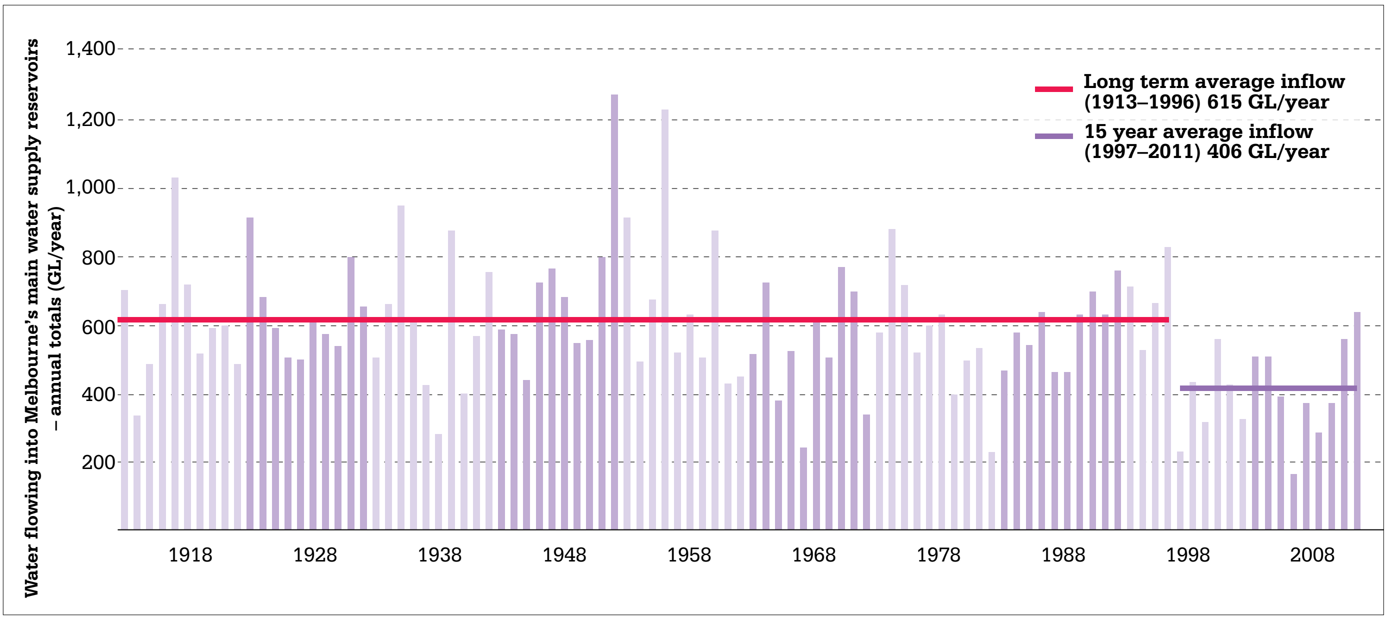
Figure 10. Flooding in Horsham, 2011

Source: Wiki Commons/Ralph Sanderson

While much of the interest in long-term rainfall changes in Victoria is centred on the drying trend and droughts, wet years with very heavy rainfall can still occur, as 2010 and 2011 demonstrated. Heavy rainfall events, and associated flooding, pose significant risks for health, infrastructure and agriculture. During flood events, immediate impacts can include road closures, power loss and evacuations. Floods can result in loss of roads and bridges, contamination of water supplies and damage to personal property (**Figure 10**). Agriculture is particularly at risk, as crops can be destroyed, water logged and/or become vulnerable to disease.

It is more likely than not that heavy rainfall events will become more frequent across southern Australia, although our level of confidence in this projection is low. A heavy rainfall event that currently occurs once every 20 years is projected to become slightly more frequent by mid-century, perhaps occurring once every 15 years, and more frequent again by the end of the 21st century – about once in every 10 to 15 years (IPCC, 2012).

Figure 9. Time series of total annual stream flow into Melbourne dams 1913–2011.



Source: Melbourne Water 2012a

1.5 The Victorian Alps

- There has already been a reduction in snow cover. For instance, spring snow depth at Spencers Creek on the NSW side of the Alps has decreased by about 40% since the 1960s.
- Biodiversity and tourism in the Alps will suffer as the region continues to warm and snow cover reduces further.

Victoria's alpine environment is extremely vulnerable to climate change. The Australian Alps, extending across southeast New South Wales and eastern Victoria, warmed at a rate of about 0.2°C per decade between 1962 and 2001 (Hennessy et al., 2003). Spring snow depth at Spencers Creek on the NSW side of the Alps has decreased by about 40% since the 1960s (Nicholls, 2005).

Declines in snow cover are expected to continue. Under a best case scenario (least warming and most precipitation) modelling suggests that areas with an average annual snow cover of at least 30 days per year could decline 14% by 2020 and 30% by 2050, relative to 1990 (Hennessy et al. 2008). Using a higher impact scenario (greatest warming and least precipitation), these losses could be as high as 54% by 2020 and 93% by 2050. The worst-case scenario is the complete loss of the alpine zone during this century.

Some changes to the alpine ecosystem have already been observed. For example, snow gums have already begun to establish in frost hollows where they have not previously occurred (Wearne and Morgan, 2001), and there have been increased sightings of feral and native mammals at higher altitudes than historically recorded (Pickering et al., 2004).

Ongoing losses of snow cover will seriously affect alpine species, many of which are already considered rare and threatened. Small native mammals such as the mountain pygmy possum and the broad-toothed rat (**Figure 11**) are experiencing habitat loss due to the reduction of protective snow cover and may become increasingly vulnerable to introduced predators such as foxes (Pickering et al., 2004). Habitats such as alpine bogs are threatened by the potential increase in frequency of fires. Food webs, such as those that rely of the yearly arrival of Bogong moths, may be disrupted because warming is affecting the timing of species' life cycles.

Reduced snow cover and increasing uncertainty about suitable conditions for recreational activities is also affecting alpine tourism. Ski-field operators have been at the forefront of climate change adaptation (Bicknell and McManus, 2006), most notably through their investment in artificial snowmaking to compensate for reduced snow availability. Snowmaking will, however, be limited in many places in Australia by water availability and costs. For example, an estimated 700 snow guns will be required to maintain skiing conditions in Australia's six main resorts until 2020, requiring A$100 million in capital investment and 2500–3300 million litres of water per month (Pickering and Buckley, 2010).

Figure 11. Broad-toothed rat.

Source: Wikimedia/Magnus Kjaergaard

1.6 Human health

- More extreme weather events create greater risks for human health.
- Children, the elderly, those with existing medical conditions, and those living in Indigenous and rural communities are most at risk.

The impacts of climate change, particularly increasing temperatures and increasing frequency and/or intensity of extreme weather events, pose serious risks to human health.

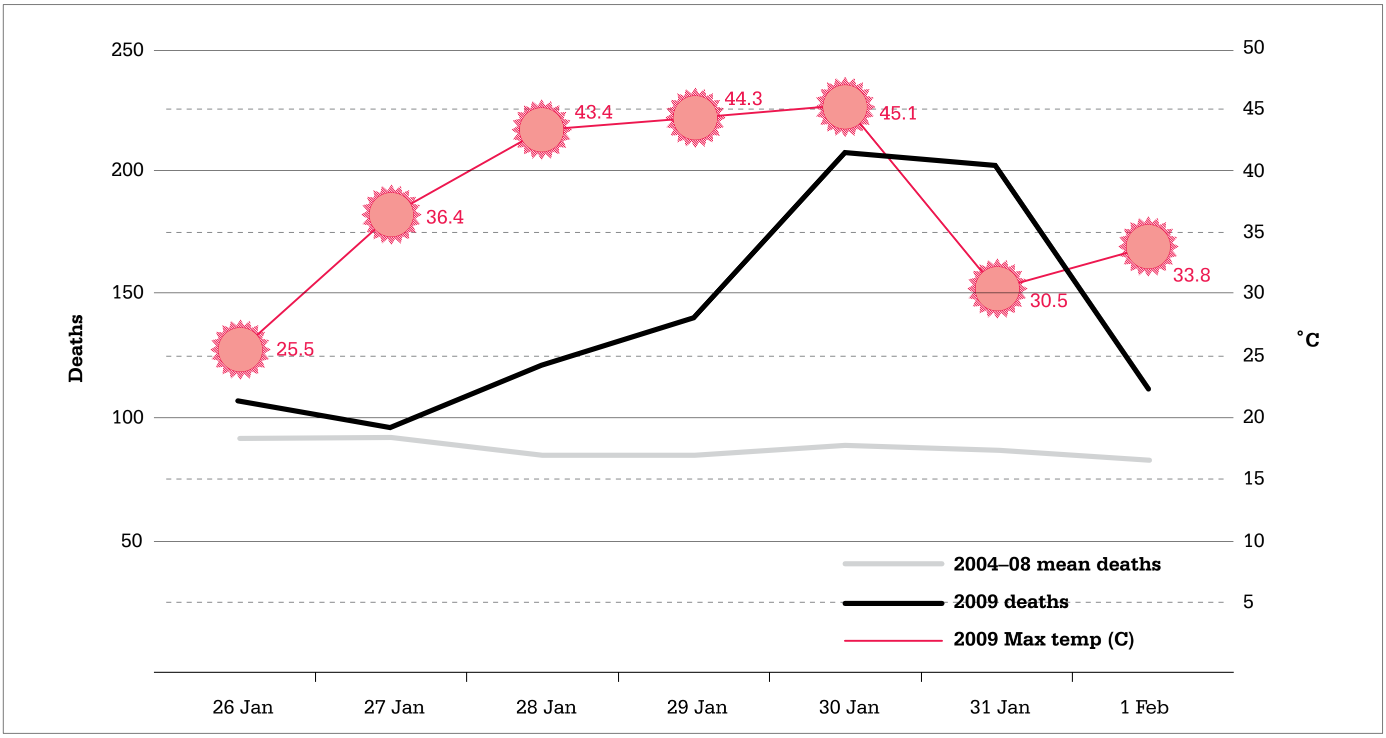
Hot days and heatwaves can have significant impacts on human health, including lethargy, heatstroke and organ failure. Extreme hot weather is likely to become more frequent, with the number of hot days increasing across most of Victoria (CSIRO, 2008). Victorians have already experienced the health consequences of very hot weather (**Box 6**); these impacts are likely to increase.

Despite the impacts of very hot days on human health in Victoria, increases in temperature may result in a modest reduction in cold-related deaths for several decades (Bambrick et al., 2008).

Other types of extreme events also pose significant risks to human health. For example, bushfires can cause injuries and deaths, and can also exacerbate existing respiratory conditions. During heavy rainfall events, contact with contaminated floodwater and soil can cause diarrhoea and other bacterial infections and pose risks to drinking water supplies.

People at most risk are those already vulnerable in our community, including children, the aged, those with existing medical conditions, and people living in remote Indigenous and rural communities (Bennett et al., 2011). For more information on the impacts of climate change on human health, see the Climate Commission's report *The Critical Decade: Climate Change and Health* (2011).

Figure 12. Mortality and temperature during the 2009 Melbourne heatwave. This graph shows the relationship between prolonged periods of higher temperatures and death rates over the same period.



Source: DHS 2009

To minimise the risks that climate change poses to human health, healthcare organisations are already taking action. Victorian hospitals had prepared for the anticipated increase in burns patients experienced during the 2009 Black Saturday bushfires (Cameron et al., 2009). For example, the specialised referral centre for burns at The Alfred Hospital transferred stable patients to increase ward capacity and additional staff and operating theatres were placed on standby (Cameron et al., 2009). This type of coordinated response allowed the hospital to respond to the emergency, and could be required more frequently into the future.

Box 6. Rising temperatures affect health

More record hot days and associated heatwaves increase the risk of heat-related illnesses and mortality, particularly in the elderly.

In January 2009, southeast Australia experienced a record-breaking heatwave and Melbourne recorded its highest temperature of 46.4°C (BoM, 2010). During this period, heat-related hospital admissions increased 8-fold, with almost half of the admissions being of people aged 75 years and older. There was a 46% increase in ambulance call-outs, including a 34-fold increase in direct heat-related cases (over 60% aged 75 years or older) (DHS, 2009). There were 374 deaths above what would normally be expected during the period – a 62% increase in mortality (DHS, 2009; **Figure 12**).

Heatwaves can also put pressure on hospital morgues; during the 2009 heatwave the Victorian Coroner mortuary took in 50 bodies a day, more than three times the usual average (16 per day). The State Coroner activated a contingency plan, calling on hospitals and funeral directors to assist with storage (The Age, 2009).

Without effective responses to extreme weather events, heat-related deaths in Melbourne are projected to increase by 10% by 2020 (based on the year 2000), and by 40% by 2050 (McMichael et al., 2002). One study using a mid-range warming scenario coupled with expected demographic changes estimated that deaths in Melbourne could reach 1,000 in a severe heatwave event by 2050; by comparison there were 374 excess deaths in the 2009 heatwave (PwC, 2011).

2. 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 the rate of economic growth will be very slightly 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 and Garnaut, 2008).

The costs are well understood and have often been at the centre of discussions about tackling climate change, but the opportunities are less widely known. This report illustrates some of the opportunities that are particularly relevant to Victoria.

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).

Periods of economic change tend to mean that some operations will close down and some industries will diminish, while other firms and industries grow.
For example, the Australian Government has allocated funds to support closure of some highly polluting power stations by 2020. 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 communications revolution.

2.1 Renewable energy

- There is technical potential for increased wind energy generation in Victoria.
- Victoria receives enough energy from the sun to produce double the state's current energy needs through solar power alone.
- Renewable energy currently accounts for about 5.5% of Victoria's electrical energy consumption (**Figure 14**).

Wind

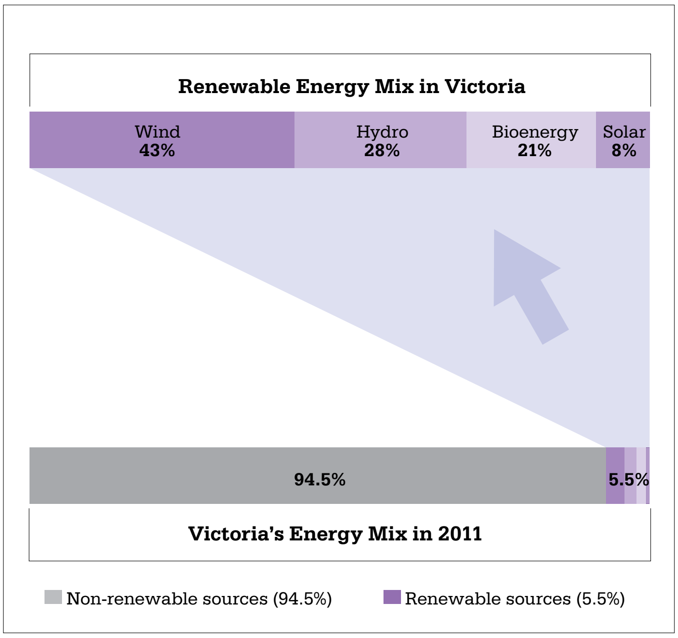
Wind energy is an important part of the renewable energy mix in Victoria. In 2011 wind generated 43% of the state's renewable electricity (Sustainability Victoria, 2012a). Victoria has the second-largest installed capacity for wind energy in Australia, after South Australia.

There are currently ten operating wind farms in Victoria (CEC, 2011a). The largest is the Waubra Wind Farm, northwest of Ballarat, with 128 turbines rated at 192 MW and distributed over 173 km^2 (CEC, 2012a).

Victoria's current installed wind energy capacity (the maximum amount of energy that could be produced by wind at any one time) is only a fraction of the total wind resources that could be harnessed (**Figure 15**). As a comparison, Denmark and Victoria have similar average onshore wind speeds (DPI and SKM, 2010; Troen and Petersen, 1989) yet in 2010 Denmark had about seven times the installed onshore wind capacity of Victoria (Danish Energy Agency, 2010).

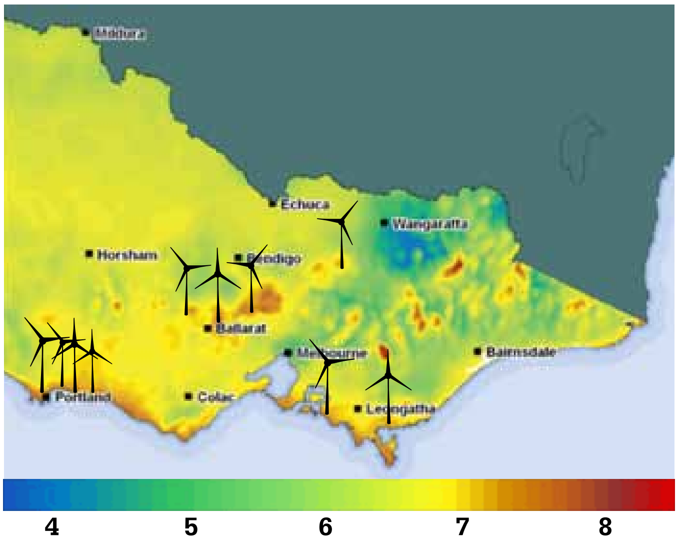
Wind turbines can provide a useful second income source for Victorian landowners. For example, the 35 turbines of the Challicum Hills wind farm, east of Ararat in western Victoria, extend across seven properties, which all receive rental income for the lifespan of the wind farm (Pacific Hydro, 2011). The wind farm and associated roads occupy only 1% of the land area (CEC, 2012b), so farming activities can continue as before. The Hepburn Community Wind Farm (**Box 7**) is on the property of a farming family who continue to grow potatoes and produce cattle alongside the two wind turbines (Hepburn Wind, 2011).

Figure 14. Renewable energy and non-renewable energy generation in Victoria.



Source: Sustainability Victoria 2012a

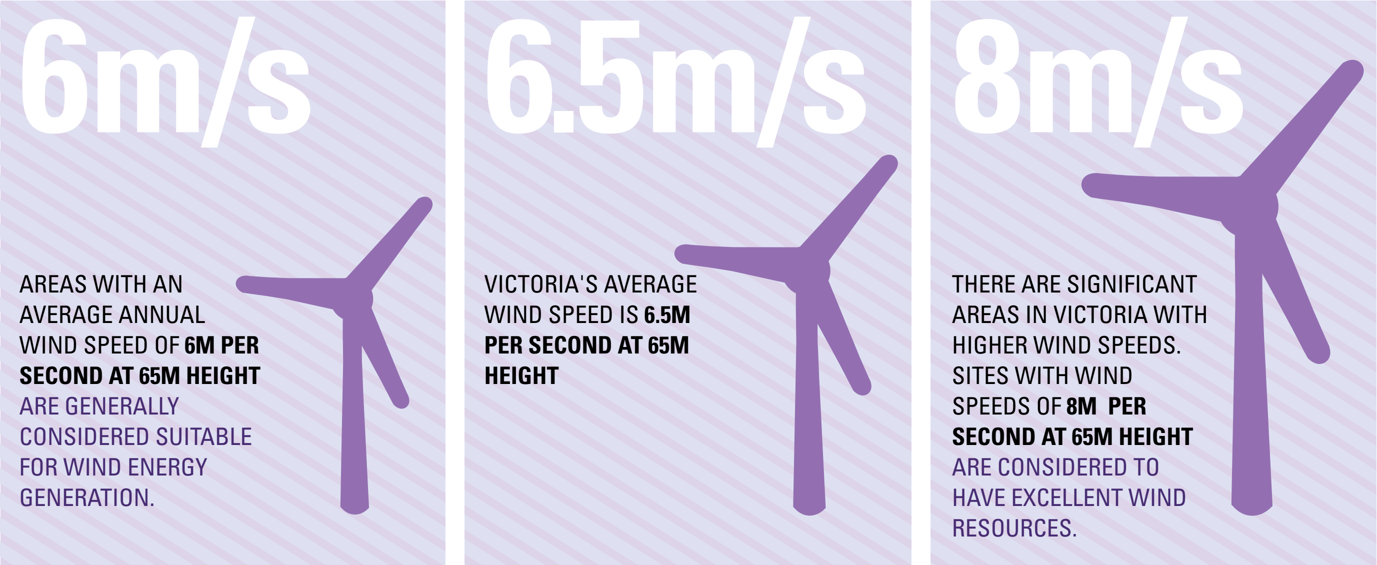
Figure 15(a). Victoria's wind energy resources.



Key: Average Yearly Wind Speed (metres per second at 65 metres above ground)

Source: Sustainability Victoria 2010 and CEC 2012a

Figure 15(b). Victoria's wind energy resources.



6m/s

AREAS WITH AN AVERAGE ANNUAL WIND SPEED OF **6M PER SECOND AT 65M HEIGHT** ARE GENERALLY CONSIDERED SUITABLE FOR WIND ENERGY GENERATION.

6.5m/s

VICTORIA'S AVERAGE WIND SPEED IS **6.5M PER SECOND AT 65M HEIGHT**

8m/s

THERE ARE SIGNIFICANT AREAS IN VICTORIA WITH HIGHER WIND SPEEDS. SITES WITH WIND SPEEDS OF **8M PER SECOND AT 65M HEIGHT** ARE CONSIDERED TO HAVE EXCELLENT WIND RESOURCES.

Source: AEMO 2010 and Sustainability Victoria

Box 7. Hepburn Community Wind Farm

Hepburn Community Wind Farm, at Leonards Hill, Central Victoria, is Australia's first, and the only currently operating, community wind farm (**Figure 16**) (Hepburn Wind, 2012a).

Hepburn Wind is a trading cooperative with over 1,900 members, the majority of whom live in the surrounding area (Hepburn Wind, 2012b). The power generated is sold to Victorian residents through Red Energy, a retailer of Snowy Hydro. In addition to providing a local source of renewable energy, a proportion of the revenue earned (with contributions from Red Energy) is invested back into community projects (Hepburn Wind, 2012b).

Hepburn Wind has an installed capacity of 4.1 megawatts (MW) (Sustainability Victoria 2012a) and can generate enough electricity to power approximately 2,300 Victorian households (Hepburn Wind, 2012a).

Hepburn Wind has received accolades including the 2012 World Wind Energy Award, the 2011 Banksia Built Environment Award, the 2011 Australian Sustainability Award (Infrastructure category) and the 2011 Premier's Sustainability Awards (Community category).

Figure 16. Hepburn Wind Farm 2011.

Source: Hepburn Wind/Karl von Moller

Biomass

Energy generated from waste products represents 21% of Victoria's renewable eletricity generation (Sustainability Victoria, 2012a). The technology for producing energy from waste is well established, and there is potential to make greater use of waste as an energy source.

Victoria has 24 bioenergy generators, producing energy from black liquor (a by-product of the papermaking process), landfill and sewage gases, and waste water treatment (Sustainability Victoria, 2012a). A single, large black liquor plant provides 45% of the state's bioenergy capacity, and landfill methane generators provide most of Victoria's remaining capacity (Sustainability Victoria, 2012a).

At Melbourne Water's Western and Eastern Treatment Plants, electricity is generated from biogas, a by-product of sewage treatment. Melbourne Water estimates that the Western Treatment Plant now generates 95% of the facility's energy needs, reducing the need to buy coal-powered energy and avoiding 87,000 tonnes of greenhouse gas emissions annually (Melbourne Water, 2012b).

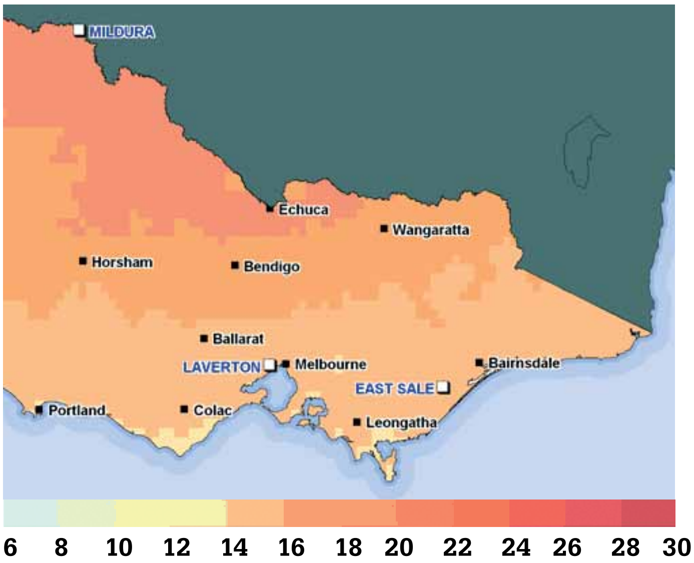
In addition to the above sources, energy can be produced from crop and plantation forest residues. For electricity generation, solid biomass can be combusted in base-load power stations, while liquid and gaseous biomass fuels can be combusted in gas turbines to meet peak-load demand.

Solar

Solar energy is a minor player in the existing renewable energy mix in Victoria, representing only 8% of renewable energy generation (Sustainability Victoria, 2012a). Victoria's current 270 MW installed solar capacity mostly comprises small-scale rooftop systems (Sustainability Victoria, 2012a). In June 2012 there were only five solar photovoltaic (PV) systems over 100 kilowatts operating in Victoria, namely Bridgewater, Tulla Calder Interchange, Ballarat Solar Park, Bendigo Solar Park and Queen Victoria Market (CEC, 2012a).

Victoria has good technical potential for further solar energy generation (generally measured as 'solar exposure'), particularly in the northwest of the state (**Figure 17**) (DPI and SKM 2010). It is estimated that Victoria receives at least 2,500 petajoules (PJ) of useable solar energy annually (DPI and SKM, 2010) – or more than double the state's total yearly stationary energy consumption for 2009–10 (Sustainability Victoria, 2011). This estimate takes into account land availability, with about 8% of the state considered 'available' or as non-urban land with suitable solar exposure and not under other use (DPI and SKM, 2010). A further 11 PJ per year of useable solar energy is available in urban locations (DPI and SKM, 2010).

Figure 17. Victorian solar exposure.



Key: Average Yearly Global Solar Exposure (MJ/m^2)

Source: Sustainability Victoria 2006

Due to increasing investment and uptake, the cost of solar panels has reduced by around 70% over the past two years and is projected to fall further (Aanesen et al., 2012). In fact, 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). However, as solar output continues to be generally variable and only somewhat predictable (Bazilian et al., 2012), its value in a particular market will depend on variables such as system balance, transmission availability and costs. 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).

In places where direct (as opposed to diffuse) sunlight is prevalent, an efficient method to generate solar power is through Concentrated Solar Thermal (CST). CST plants have been shown to be highly effective in Spain, where in 2010 they had installed capacity of 900 MW and avoided 327,731 tonnes of greenhouse gas emissions (Deloitte, 2010). Mildura, Victoria, which has been identified as a potential location for a CST plant, receives an annual average direct solar exposure similar to that of existing CST plants in Spain (Wright and Hearps, 2010). Although the cost per unit of energy for CST is currently high, it is likely to decrease significantly as the technology is more widely adopted and cost-savings are found – similar to the reduction in costs of solar PV panels (Lovegrove et al., 2012).

There are many other applications of solar energy, such as solar hot water and heat pumps, which can be cost-effective and also produce minimal greenhouse gases. For example, heating water accounts for approximately 23% of household greenhouse gas emissions in Australia. Switching from an electric hot water system to a solar hot water system can save 3 tonnes of greenhouse gas emissions a year – and electric hot water systems make up 50% of total systems installed in Australia (CEC, 2011b).

Box 8. Solar-powered LED light developed in Melbourne

Melbourne-based business Illumination Solar, has developed a small solar-powered LED lamp, the Mandarin Ultra LED lamp, which is providing people in developing nations with affordable, healthy, disaster-resistant power.

The Mandarin Ultra (**Figure 18**) is made entirely of environmentally friendly and recyclable materials. It can provide light for up to eight hours when fully charged. In developing countries, use of the lamp in place of traditional kerosene lamps is helping improve air quality and reduce greenhouse gas emissions.

The lamp is in use across Africa and Asia. As the lamp charges from the sun and does not rely on power infrastructure, it has also been used in disaster and refugee situations. Governments have bought lamps for supply to refugees through the International Organisation for Migration. The lamp has also been used in natural disaster areas including the Pakistan 2011 floods and the 2011 tsunami in Japan.

Source: Illumination Solar, 2012 and Hanson, 2012

Figure 18. Melbourne-based business Illumination Solar has developed a solar-powered LED lamp that provides lighting for people in developing nations like Tanzania (pictured).

Source: Illumination Solar 2012

2.2 Business and industry

- Moving to cleaner energy will create new jobs, particularly in regional Victoria.
- There are many options for businesses to save money and also reduce greenhouse gas emissions.

The transition towards an economy with lower greenhouse gas emissions provides the opportunity for new investment and job generation in Victoria, for example in clean energy and the retrofitting of existing industries.

Clean energy investment and jobs

Investment in clean energy is growing globally. In 2011 US$263 billion was invested in clean energy worldwide (PET, 2012). This represents a 6.5% growth over 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). This represents a 28% growth in clean energy investment over the previous five years (PET, 2012).

In 2010 there were approximately 8,000 full-time equivalent jobs in construction, operation and maintenance of renewable energy facilities in Australia (Figure 19) (CEC, 2011a). Of this total, 20% of jobs were in Victoria (CEC, 2011a). The industry also indirectly employs people in sales, administration and management.

As a general rule, an investment in a 50 MW wind farm could generate 48 direct construction jobs (SKM, 2012). With construction staff spending locally, the wind farm can contribute up to about 3% to the regional economy (SKM, 2012). A further five to six jobs would be created for ongoing maintenance and operations (SKM, 2012). The wind farm would also provide farmers with payments of up to $250,000 annually (SKM, 2012). For example, the development of the Waubra wind farm, near Ballarat in Victoria, created 200 construction and 26 ongoing maintenance jobs and subcontracted 20 regional businesses (Acciona, 2012).

Business practices

There are many ways in which businesses can save money and also reduce greenhouse gas emissions. For example, production systems may be upgraded to improve energy efficiency, energy may be generated from waste products, or lighting may be improved – all of which can reduce operating costs and reduce greenhouse gas emissions.

Figure 19. Construction at Hepburn Wind Farm 2011.

Source: Hepburn Wind/Flickr

Research conducted by ClimateWorks Australia (2011) has found that improvements to the energy efficiency of industries in Greater Geelong – such as adopting more energy efficient processes and upgrading equipment – alone could save the local economy $8.7 million each year and reduce greenhouse gas emissions.

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

- The OneSteel Laverton Steel Mill has adopted new technology to reduce energy consumption and improve furnace productivity. The technology partially substitutes polymers, such as recycled tyres, for coke in electric arc furnace steel making. The new technology has allowed significant cost savings, through reducing the amount of carbon injectant used for each batch of steel by 16% and reducing electrical energy consumption by around 2.5%. The Laverton plant has consumed the equivalent of 900,000 passenger tyres, which may otherwise have gone to landfill, since 2008.

- Visy's co-generation plant in Coolaroo converts waste materials from Visy recycling operations into energy. This energy, in the form of steam and electricity, is used in paper and other manufacturing facilities at Visy's Coolaroo site.

- Amcor has implemented a range of energy efficiency improvements at its Brooklyn Corrugated Box Plant. These improvements include lighting upgrades, condensate pipe insulation and industrial space heating upgrades. These projects resulted in a 15% reduction in electricity use, a 30% reduction in gas use and a 20% reduction in greenhouse gas emissions.

Box 9. Carbon capture and storage

Carbon capture and storage (CCS) technology is being investigated for its potential to reduce emissions from coal-fired power stations, which currently supply most of Victoria's electricity.

The CCS technology is designed to capture carbon dioxide emissions where they are produced, such as from a coal-fired power station. The carbon dioxide is then compressed and injected deep underground, to depths of 1 km or more, into stable rock formations (GCCSI, 2012). Carbon dioxide must be stored for thousands of years without it escaping.

Investigations have found that the Gippsland Basin, close to Latrobe Valley power stations, has geological formations potentially suited to storing carbon dioxide (CST, 2009). Further feasibility studies are under way.

The commercial deployment of CCS for coal-based electricity generation remains technically challenging and expensive (Garnaut, 2011). However, the Cooperative Research Centre for Greenhouse Gas Technologies has been demonstrating carbon capture and storage at a site in southwest Victoria since 2008.

2.3 Sustainable cities

- Sustainable economy for the future requires holistic long-term planning for our cities considering population growth, density and infrastructure.
- Increasing use of public transport can ease congestion as well as reduce greenhouse gas emissions.
- Active transport (cycling and walking) could have a greater role, both as a transport mode in its own right and as a feed-in to public transport.
- Passive building design can save money on ongoing costs and reduce greenhouse gas emissions.

Melbourne's population is currently 4.14 million (ABS, 2012a) and is growing; its outer suburban fringes are some of the fastest-growing local government areas in Australia (ABS, 2012b). Developing Melbourne's existing and future infrastructure to match population growth presents many opportunities to become a low-carbon city and to maintain its status as the world's most liveable city (Ferguson, 2011).

Transport

Rethinking transport in Victoria provides opportunities to reduce greenhouse gas emissions and ensure a more efficient transportation system for the future.

Transport is the second largest contributor to Victoria's greenhouse gas emissions with road transport contributing 19.3 million tonnes in 2009 (DSE, 2012). In Melbourne, demand for transport is increasing as the population grows and the number of people travelling to, from and within the city increases (Melbourne City Research, 2012). Around 80% of trips to work are by cars (DOT, 2008) which produce more than six times the greenhouse gas emissions of buses and trains in peak periods of travel to the city (Garnaut 2008).

Using more trains, trams and buses in place of cars reduces greenhouse gas emissions while improving air quality and reducing traffic congestion (IAPT, 2012). A train line can move 50,000 commuters per hour, whereas a freeway can only move 2,500 (TTF, 2009). Trams are one of the most ecologically sound methods of transport, moving large numbers of people, easing congestion and reducing greenhouse gas and noise pollution. A tram route can move up to 12,000 people per hour (Lightrail, 2012).

Shifting to more active (walking and bicycle) transport and public transport also has substantial benefits for human health. Increased physical activity can help reduce incidence of cardiovascular and respiratory disease, type 2 diabetes and other obesity-related risks (WHO, 2012).

Buildings

Inefficient heating, cooling, lighting and refrigeration in commercial and residential buildings result in significant greenhouse gas emissions and wasted money. There are many ways to retrofit existing buildings so they use less power, while new buildings provide the opportunity to design an efficient and sustainable building from the ground up (**Figure 20**).

Melbourne has many examples of sustainable building design and the trend is being actively promoted. Some stand out examples include: the Royal Children's Hospital, CH2 Building (**Box 9**), the City of Melbourne's Green Roofs, Walls and Facades and 1200 Building Program (designed to improve the environmental performance of commercial buildings) and the Queen Victoria Market sustainability program. Other examples include the following.

500 Bourke Street, Melbourne, which was retrofitted to achieve a '5 star Green Star – Design' rating from the Green Building Council of Australia. The retrofit included efficient lighting and air conditioning, a more efficient and flexible building management system and more water-efficient fixtures. These features avoid approximately 8,000 tonnes of greenhouse gas emissions annually (Sustainability Victoria, 2009).

385 Bourke Street, Melbourne, which has increased its NABERS (National Australian Built Environment Rating System) rating from 0.0 to 3.5. Elements of its retrofit include the upgrading of ventilation and lighting systems, replacement of water boilers with six energy efficient heat pumps, flow restrictors in washrooms and improved metering. This retrofit avoids approximately 4,680 tonnes of greenhouse gas emissions annually (City of Melbourne, 2012a).

Figure 20. CH2 Building.

Source: Vernon Fowler/Flickr

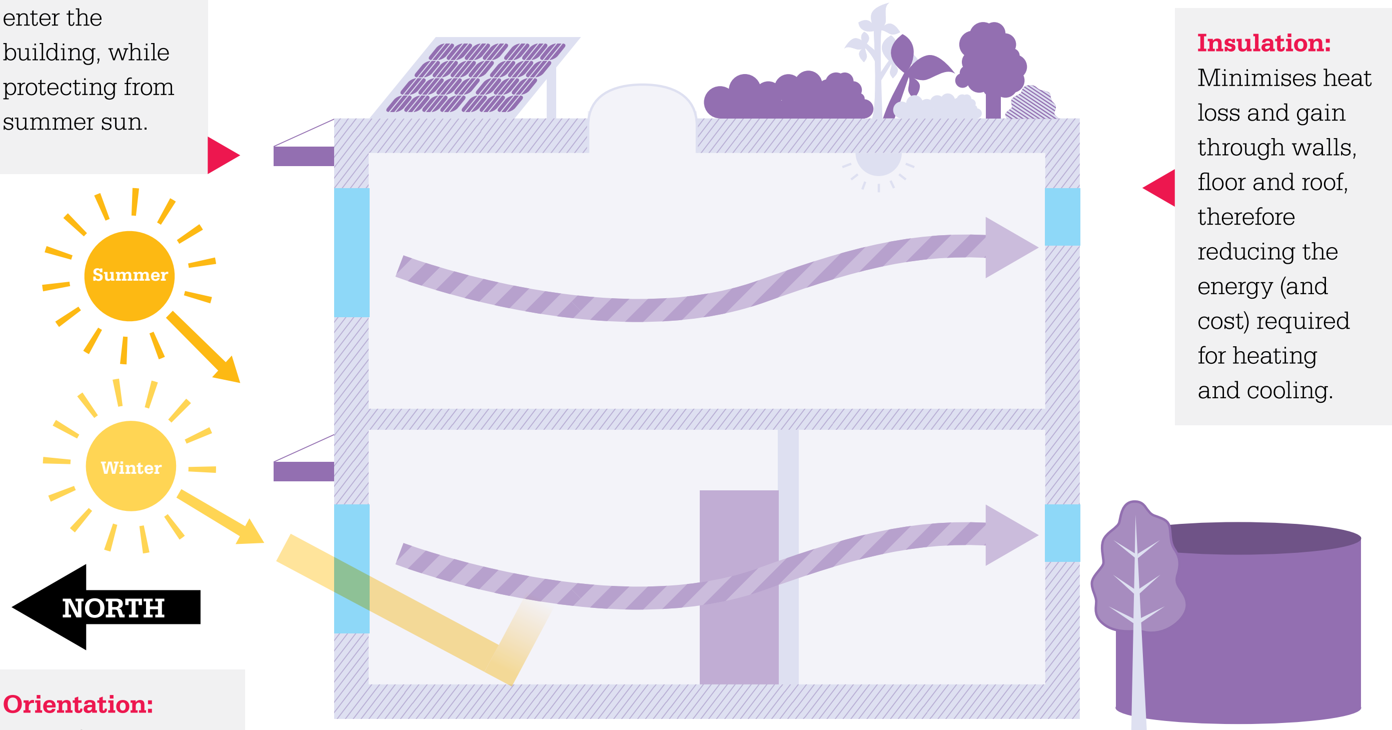
Box 10. City of Melbourne CH2 Building

The City of Melbourne Council House 2 (CH2) building (**Figure 20**), opened in 2006, was Australia's first '6 star Green Star – Design' building certified by the Green Building Council of Australia. It utilises passive design principles (**Figure 21**), is energy and water efficient, and through its internal design aims to improve wellbeing of staff.

The CH2 building also generates its own energy. It features a micro-turbine used in cogeneration, which produces 30% of the building's energy needs. The gas-fired micro-turbine generates electricity, and waste heat is used in the building's air-conditioning. CH2 is fitted with 23 solar panels that produce 3.5 kW of electricity. In addition, its lifts generate energy when braking, and 60% of the building's hot water is supplied through its rooftop solar hot water panels.

Source: City of Melbourne, 2012b

Figure 21. Some elements of efficient building design.



Shading: Shading should allow maximum winter sun to enter the building, while protecting from summer sun.

Energy generation: There are many ways that buildings can generate their own energy including solar, cogeneration and emerging technologies.

Lighting: High efficiency light fixtures and devices such as motion detection sensors and skylights can increase energy efficiency, by only using lighting when it is required.

Green roofs: Green roofs and walls can act like insulation – increasing energy efficiency – as well as improving air quality, reducing storm water runoff and moderating the urban heat island effect.

Insulation: Minimises heat loss and gain through walls, floor and roof, therefore reducing the energy (and cost) required for heating and cooling.

Orientation: North-facing buildings – including north-facing windows – take advantage of the sun for lighting, heating and even energy generation.

Thermal mass: Thermal mass moderates internal temperatures by regulating day/night extremes. This increases comfort and reduces energy costs.

Heating and cooling: Ensure the most efficient method of heating and cooling, for example cross ventilation can provide welcome breezes in summer and/or closing-off spaces to keep warmth in during winter. If artificial heating and cooling are required, consider the most efficient product for the space.

Rainwater storage and re-use: Reduce reliance on water supplies by installing a water tank. Tanks capture rainfall for use within the building and/or its gardens. Further savings can be made if waste water is treated for re-use inside the building or to irrigate gardens.

There are many ways passive building design can be adapted responding to geographic location and size and purpose of buildings. Good resources include: **www.builditbackgreen.org** and **www.yourhome.gov.au**

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