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replied by email
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Content:
On behalf of the members of Climate Action Now Wingecarribee, Inc. I advise that we OPPOSE the proposed Hume Coal Mine Project.
The detrimental impacts of continuing to burn coal over the short to long term are addressed in the attached files.
As citizens, taxpayers and rate payers in the local area we invoke our rights to breathe clean air free of contaminants, drink clean water free of contamination, operate other economic activities unencumbered by the operation of a coal mine in the Wingecarribee Shire.
We encourage the proponents, those charged with approval of the project, the NSW Government and Australian Government to take seriously the very real threats to the population's health and well being and negative impact on economic activity in the Wingecarribee Shire, State of NEW South Wales and the country by continuing to ignore the warnings of the climate scientists whose reports are attached.

IP Address: cpe-124-177-65-25.lns3.cha.bigpond.net.au - 124.177.65.25
Submission: Online Submission from company Climate Action Now Wngecarribee, Inc. (org_object)
https://majorprojects.accelo.com/?action=view_activity&id=212294

Submission for Job: #7172 Hume Coal Project
https://majorprojects.accelo.com/?action=view_job&id=7172

Site: #3137 Hume Coal Mine
https://majorprojects.accelo.com/?action=view_site&id=3137

CLIMATE COMMISSION

The Critical Decade: Illawarra/ NSW South Coast Impacts

Over many decades thousands of scientists have painted an unambiguous picture: the global climate is changing and humanity is almost surely the primary cause. The risks have never been clearer and the case for action has never been more urgent.

Our Earth's surface is warming rapidly and we can already see social, economic and environmental impacts in Australia.

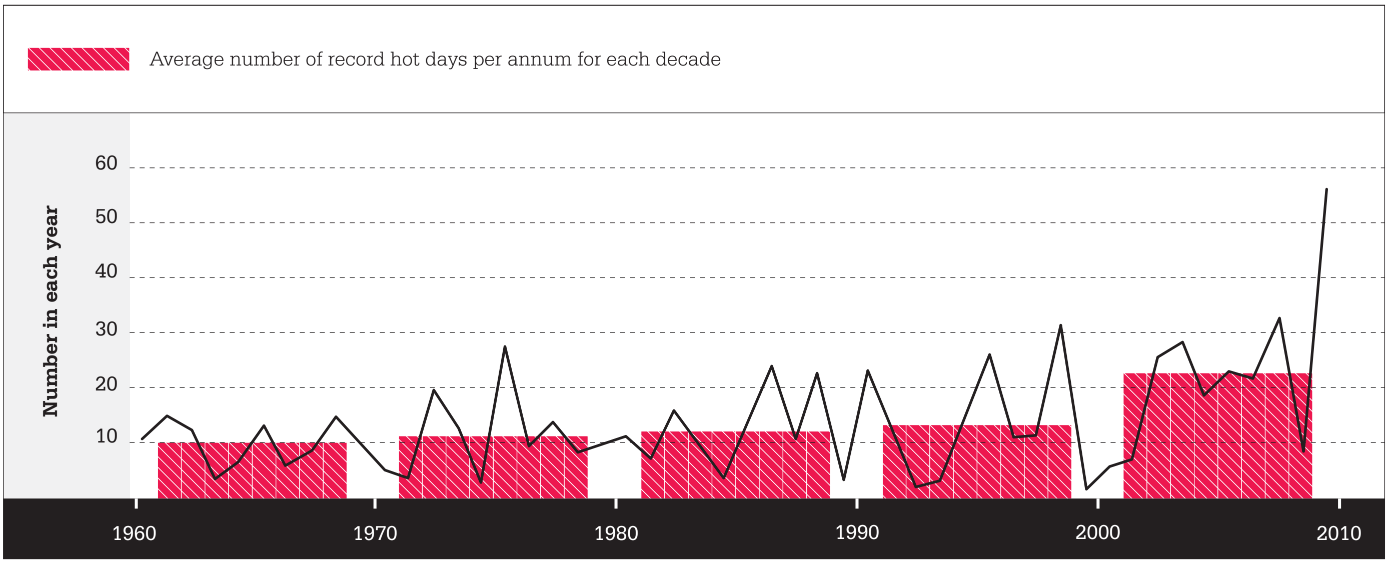
Failing to take sufficient action today entails potentially huge risks to our environment, economy, society and way of life into the future. This is the critical decade for action.

This document accompanies *The Critical Decade* report and highlights the key impacts for the Illawarra and NSW south coast region.

1. Higher temperatures will increase the likelihood of large and intense fires.

- Average temperatures in NSW have risen steadily by approximately 1°C since the 1950s. The number of high temperature extremes, such as heatwaves and record hot days, has also increased across Australia, especially over the past decade (Figure 1).
- Consistent with the observed temperature increase, the Forest Fire Danger Index rose by 10-40% at many locations in south-eastern Australia in 2001-2007 relative to 1980-2000, including a 30% rise in the Nowra area (Figure 2; Lucas et al. 2007). As temperature rises further, the number of very high to extreme fire danger days will increase. For example, the number of extreme fire danger days in the Nowra area is projected to rise by 2050 from its current value of about 1 per year to a value in the range of 2 to 4 (Lucas et al. 2007).

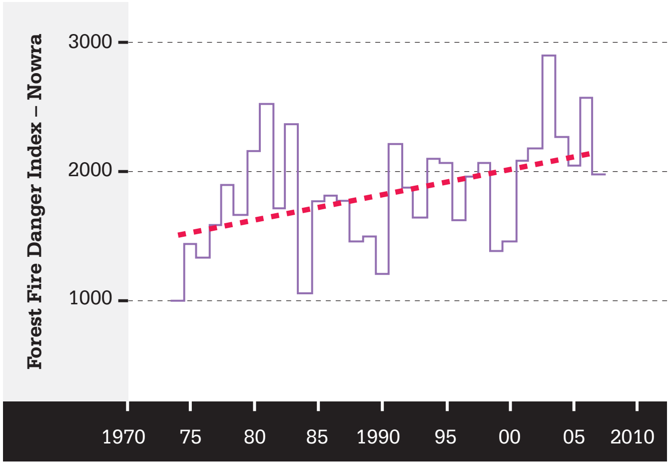
Figure 1. The number of record hot days at Australian climate reference stations is rising.



Source: Bureau of Meteorology.

- The conditions for large and intense fires – low humidity, high winds and extreme temperatures, which all contributed to the 1994 and 2001 Black Christmas fires – are likely to become more common in the region by mid-century, with intense fires projected to increase by up to 20% (Williams et al. 2011; Figure 3). Changes in atmospheric carbon dioxide and rainfall are also likely to affect fuel availability, although the magnitude and direction of these changes is uncertain (Williams et al. 2011).

Figure 2. The observed trend in the cumulative Forest Fire Danger Index for Nowra. While there is significant annual variability, there has been an underlying increase in forest fire danger days over the past three decades.



Source: Lucas et al. (2007)

- At particular risk of more frequent and intense fires are areas such as the Royal National Park and the forested escarpment behind Wollongong, including the Woronora Plateau.
- More intense fires in future will pose even higher risks to human health, property and infrastructure. To counteract these risks, we would need to more than double or triple prescribed burning, which is costly and comes with its own risks (Williams et al. 2011).

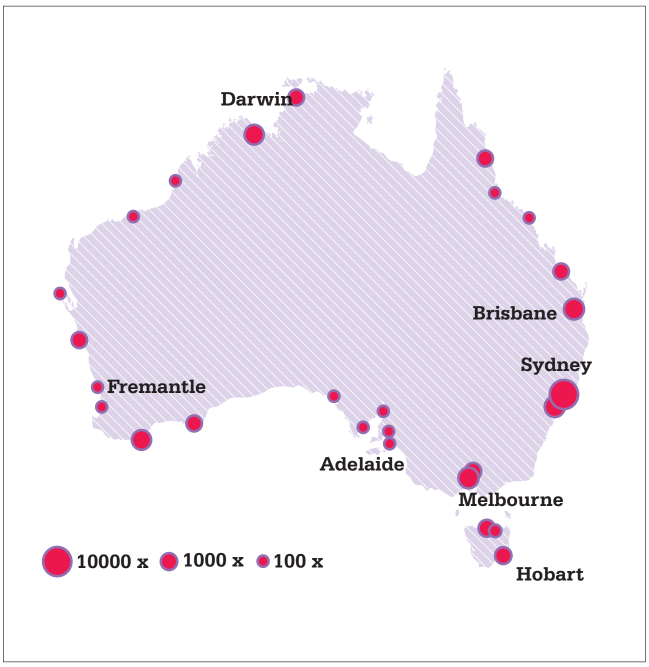
Figure 3. 2001 Black Christmas fires. NSW fire fighters near the Royal National Park in December 2001.

Source: copyright Newspix/Chris Hyde

2. Rising sea levels will exacerbate existing vulnerability of coastal towns and infrastructure in the Illawarra/ NSW south coast region.

- Global sea level has risen by about 20 cm since the late 1800s, and is projected to increase by a further 0.5 m to 1.0 m this century. A sea-level rise of 50 cm will lead to very large increases in the frequency of coastal flooding; flooding that is currently considered a 1-in-100 year event could occur every few months (Figure 4).
- These flooding events are likely to damage cities, towns and the supporting infrastructure in low-lying coastal areas and will lead to erosion of sandy beaches.
- Hundreds of commercial buildings in the local government areas of Wollongong and Shoalhaven are threatened by a 1.1 metre sea-level rise. Approximately 100-150 light industrial buildings in the local government area of Shellharbour may also be affected by a 1.1 metre sea-level rise. Second only to Newcastle, Wollongong has the greatest length of rail – about 50 km – exposed to coastal flooding in NSW (DCCEE 2011).

Figure 4. 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 very large increases in the frequency of coastal flooding; in the Illawarra region flooding that is currently considered a 1-in-100 year event could occur every few months.

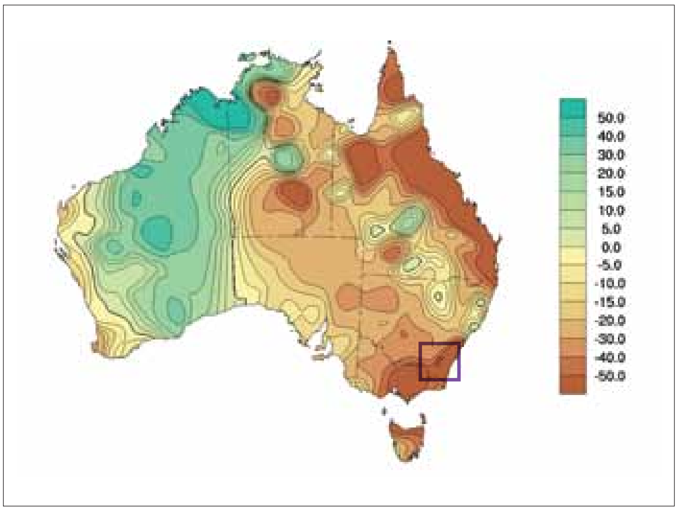


Source: ACE CRC 2008

3. Changing rainfall patterns and the risk of more intense rainfall events pose challenges for low-lying urban centres in the Illawarra/NSW south coast.

- The Illawarra/NSW south coast region has experienced a drying trend over the past 40 years (Figure 5), although the naturally-high variability of rainfall in the region makes it difficult to attribute this observed trend to climate change.
- In the longer term, rainfall patterns will change as a result of climate change, creating large risks for water availability. However, the magnitude and even the direction of change – wetter or drier – are often difficult to predict.
- Droughts and floods are important features of the natural variability of eastern Australia's climate. Droughts are becoming more severe because of the rise in temperature. In addition, the frequency and intensity of heavy rainfall events is likely to increase as the climate continues to warm.
- A pattern of more severe droughts and more intense rainfall events would increase the risk of severe flooding when rain does occur, particularly in the low-lying areas of the region. Urban centres along the coast are likely to become increasingly vulnerable to flooding because of both rising sea level and an increase in intense rainfall events.

Figure 5. Trend in annual total rainfall (mm/10 years) for the 1970–2010 period. The Illawarra/south coast NSW region is shown by the box.



Source: Bureau of Meteorology

4. Biodiversity will be at risk.

- The NSW south coast is known for its rich biodiversity and the many vulnerable species its ecosystems support. For example, the Illawarra region is home to 69 threatened animal species, including the southern brown bandicoot and the green and golden bell frog, and 31 threatened plant species, including the Illawarra *Zieria* (Figure 6; Illawarra Biodiversity Strategy 2011).
- Climate change poses a real threat to the region's biodiversity. Rare and threatened species, and those with small geographical ranges, will be particularly vulnerable to additional stresses from climate change, such as high temperature extremes, increased and more intense bushfires and changes to rainfall patterns. In addition, rising water tables and saltwater intrusion (flow of saltwater into fresh groundwater) are likely to affect lowland ecosystems in the coastal zone (NSW Climate Impact Profile 2010).
- Such climate change stresses will add to the pressures already placed on biodiversity by population growth and expansion of urban development in the region.

Figure 6. Rare and threatened species, such as the green and golden bell frog and the southern brown bandicoot, will be particularly vulnerable to climate change stresses.

Photo credit: A. Sparrow; Stephen Carter

This is the critical decade. Decisions we make from now to 2020 will determine the severity of climate change our children and grandchildren experience.

Without strong and rapid action there is a significant risk that climate change will undermine our society's prosperity, health, stability and way of life.

To minimise this risk, we must decarbonise our economy and move to clean energy sources by 2050. That means carbon emissions must peak within the next few years and then strongly decline.

The longer we wait to start reducing carbon emissions, the more difficult and costly those reductions become.

This decade is critical. Unless effective action is taken, the global climate may be so irreversibly altered we will struggle to maintain our present way of life. The choices we make this decade will shape the long-term future for our children and grandchildren.

Professor Will Steffen
Climate Commissioner

Professor Lesley Hughes
Climate Commissioner

Sources

Information is taken from the Climate Commission's report *The Critical Decade* unless otherwise noted below.

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CLIMATE COUNCIL

CLIMATE CHANGE AND THE NSW/ACT BUSHFIRE THREAT: UPDATE 2016

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Image credit: Cover photo "View of Sydney skyline during bushfires (October 17 2013)" by Flickr user Andrea Schaffer licensed under CC BY 2.0.

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Key Findings

1

Climate change is already increasing the risk of bushfires in New South Wales (NSW) and the Australian Capital Territory (ACT).

› Since the 1970s, extreme fire weather has increased across large parts of Australia, including NSW and the ACT.

› Hot, dry conditions have a major influence on bushfires. Climate change is making hot days hotter, and heatwaves longer and more frequent, with increasing drought conditions in Australia's southeast.

› The 2015/16 summer was Australia's sixth hottest on record and in NSW and the ACT the mean maximum temperatures were 1.4°C and 1.9°C above average, respectively. February 2016 was also the driest that NSW has experienced since 1978. Hot and dry conditions are driving up the likelihood of dangerous fire weather in NSW and the ACT.

2

In NSW and the ACT the fire season is starting earlier and lasting longer. Dangerous fire weather has been extending into Spring and Autumn.

› 'Above normal' fire potential is expected in most of NSW for the 2016-17 bushfire season, because of high grass growth experienced during spring and predicted above average temperatures during summer.

› In the ACT, predicted hotter and drier weather during summer will produce conditions conducive to bushfire development.

3

Recent severe fires in NSW and the ACT have been influenced by record hot, dry conditions.

› Record breaking heat and hotter weather over the long term in NSW and the ACT has worsened fire weather and contributed to an increase in the frequency and severity of bushfires.

› In October 2013, exceptionally dry conditions contributed to severe bushfires on the Central Coast and in the Blue Mountains of NSW, which caused over $180 million in damages.

› At the beginning of August in 2014, volunteers were fighting 90 fires simultaneously and properties were destroyed.

4

The total economic costs of NSW and ACT bushfires are estimated to be approximately $100 million per year. By around the middle of the century these costs will more than double.

- Bushfires cost an estimated $375 million per year in Australia. With a forecast growth in costs of 2.2% annually between 2016 and 2050, the total economic cost of bushfires is expected to reach $800 million annually by mid-century.
- These state and national projections do not incorporate increased bushfire incident rates due to climate change and could potentially be much higher.
- In 2003, abnormally high temperatures and below-average rainfall in and around the ACT preceded bushfires that devastated several suburbs, destroyed over 500 properties and claimed five lives. This also had serious economic implications for the ACT with insured losses of $660 million.

5

In the future, NSW and the ACT are very likely to experience an increased number of days with dangerous fire weather. Communities, emergency services and health services must keep preparing.

- Fire severity and intensity is expected to increase substantially in coming decades, especially in those regions currently most affected by bushfires, and where a substantial proportion of the Australian population lives.
- Increased resources for our emergency services and fire management agencies will be required as fire risk increases.

6

This is the critical decade to protect Australians.

- Australia must strive to cut emissions rapidly and deeply to join global efforts to stabilise the world's climate and to reduce the impact of extreme weather events, including bushfires.
- Australia's very weak target of a 26-28% reduction in emissions by 2030 compared to 2005 levels – and we are on track to miss even this target – leaves Australia lagging well behind other OECD countries.

Introduction

Residents of New South Wales (NSW) and the Australian Capital Territory (ACT) have often experienced the serious consequences of bushfires. In 2013, bushfires in January and October burnt 768,000 hectares of land and destroyed 279 homes in NSW. Tragically, 2 people lost their lives and damages were estimated to be more than $180 million.

The Australian population have always lived with fire and its consequences, but climate change is increasing fire danger weather and thus the risk of fires. It is time to think very seriously about the risks that future fires will pose.

This report provides an update to the previous Climate Council report on bushfire risk and NSW and the ACT (NSW: https://www.climatecouncil.org.au/be-prepared-climate-change-and-the-nsw-bushfire-threat and ACT: https://www.climatecouncil.org.au/be-prepared-climate-change-the-act-bushfire-threat). We begin this report by describing the background context of fire and its history in NSW and the ACT. We then outline the link between bushfires and climate change, before considering how bushfire danger weather is intensifying in NSW and the ACT, and what this means for the immediate future. We explore the impacts of fire on people, property, water supply and biodiversity, before considering the future implications of bushfires for NSW and ACT fire managers, planners and emergency services.

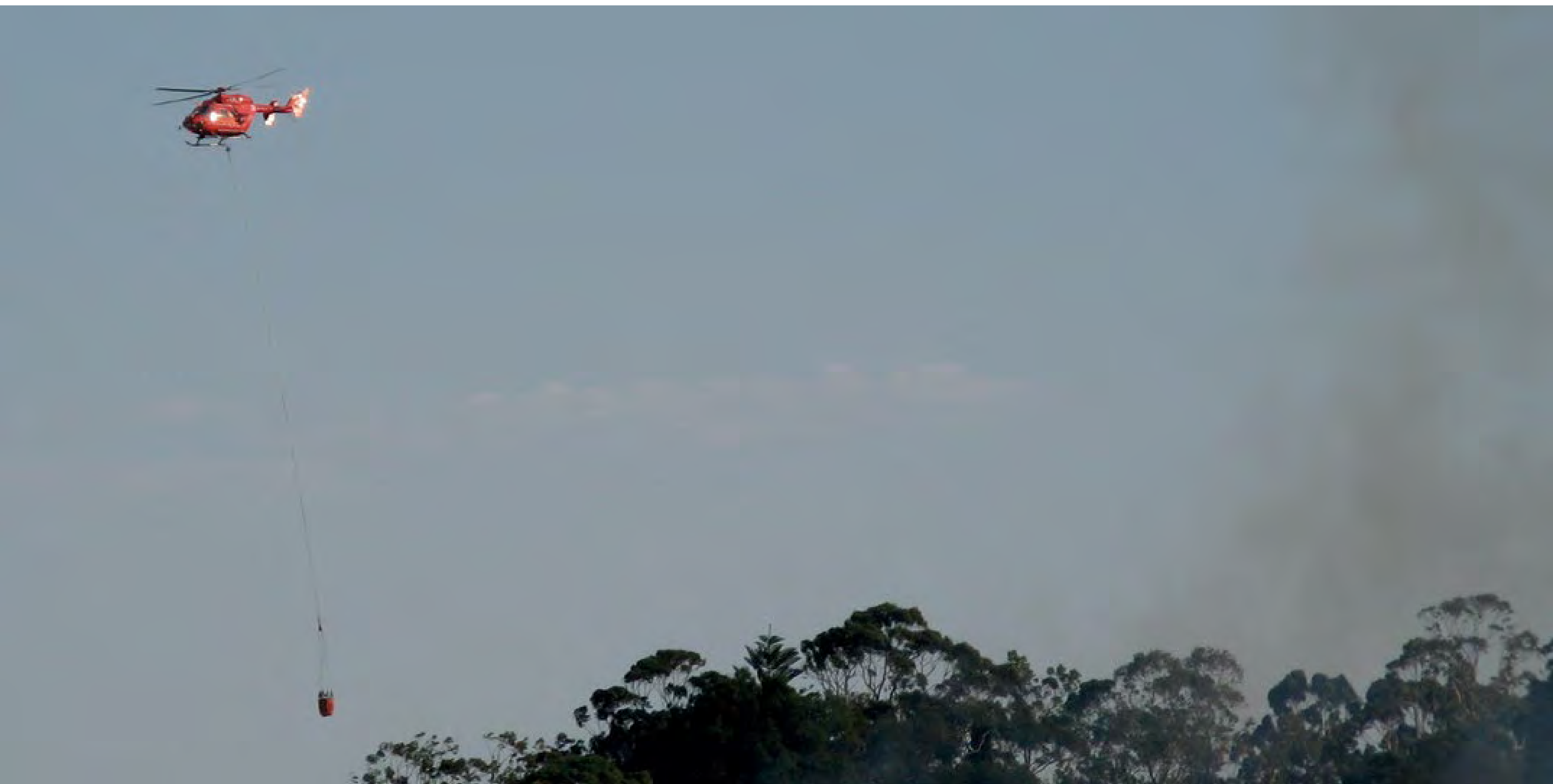
1. The Nature of Bushfires

Fire has been a feature of the Australian environment for at least 65 million years (Cary et al. 2012). Human management of fires also has a long history, starting with fire use by Indigenous Australians ('fire-stick farming') up to 60,000 years ago. Typically, 3 to 10% of Australia's land area burns every year (Ellis et al. 2004).

In Australia, the Forest Fire Danger index (FFDI) is used to measure the degree of risk of fire in our forests (Luke and Macarthur 1978). The Bureau of Meteorology (BoM) and fire management agencies use the FFDI to assess fire risk and issue warnings. The index was originally designed on a scale from 0 to 100, with fires between 75 and 100 considered 'extreme'. The unprecedented ferocity of the 2009 Black Saturday bushfires in Victoria saw a new 'catastrophic' category added to the FFDI for events exceeding the existing scale.

Since 1926, NSW has experienced 27 significant bushfire events that have affected hundreds of thousands of hectares of land, killed livestock and destroyed thousands of homes (NSW PRS 2014). Since 1901, bushfires have claimed 77 and 5 civilian lives in NSW and the ACT, respectively (Blanchi et al. 2014). NSW and the ACT account for 12% of Australian bushfire deaths (Blanchi et al. 2014).

Figure 1: Helicopter preparing to drop water on a developing bushfire at Lane Cove National Park in Sydney in February 2009.



Bushfires have claimed 82 civilian lives in NSW and the ACT since 1901.

Fire is a complex process that is very variable in space and time. A fire needs to be started (ignition), it needs something to burn (fuel) and it needs conditions that are conducive to its spread (weather and topography) (Figure 2). Fire activity is strongly influenced by weather, fuel, terrain, ignition agents and people. The most important aspects of weather that affect fire and fuels are temperature, precipitation, wind and humidity. Once a fire is ignited, very hot days with low humidity and high winds are conducive to its spread. The type, amount, and moisture level of fuel available are also critical determinants of fire behaviour, extent and intensity (Climate Council 2014a). The relationship between rainfall and fuel is complex. Wet seasons can lead to increased plant growth and therefore increase fuel buildup in the months or years before a fire is ignited (Bradstock et al. 2009). Warmer temperatures and low rainfall in the period immediately preceding an ignition, however, can lead to drier vegetation and soil, making the existing fuel more flammable. Warmer temperatures may also be associated with a higher incidence of lightning activity (Jayaratne and Kuleshov 2006), increasing the risk of ignition.

In the temperate forests of NSW and the ACT, fire activity is strongly determined by weather conditions and the moisture content of the fuel. As fire weather conditions become more severe, fuel moisture content declines, making the fuel more flammable. By contrast, in arid regions, vegetation and thus fuel in most years is sparsely distributed and fires, if ignited, rarely spread far. In Australia's southeast, fires are common in the heathlands and dry sclerophyll forests (Clarke et al. 2011; Bradstock et al. 2012).

People are a very important component of the fire equation. Many fires are either deliberately or accidentally lit, and in places where population density is high, the probability of a fire igniting increases close to roads and settlements (Willis 2005; Penman et al. 2013). Some of Australia's most catastrophic bushfires have been ignited by powerline faults. But people also play an important role in reducing fire risk, by vegetation management including prescribed burning to reduce fuel load and conducting fire suppression activities. Interventions such as total fire ban days also play a pivotal role in reducing ignitions under dangerous fire conditions.

MAIN FACTORS AFFECTING BUSHFIRES

1 | Ignition
Fires can be started by lightning or people, either deliberately or accidentally.

3 | People
Fires may be deliberately started (arson) or be started by accident (e.g. by powerline fault). Human activities can also reduce fire, either by direct suppression or by reducing fuel load by prescribed burning.

2 | Fuel
Fires need fuel of sufficient quantity and dryness. A wet year creates favourable conditions for vegetation growth. If this is followed by a dry season or year, fires are more likely to spread and become intense.

4 | Weather
Fires are more likely to spread on hot, dry, windy days. Hot weather also dries out fuel, favouring fire spread and intensity.

Figure 2: The main factors affecting bushfires including: (i) ignition, (ii) fuel, (iii) people and (iv) weather.

2. What is the Link Between Bushfires and Climate Change?

A fire needs to be started (ignition), it needs something to burn (fuel) and it needs conditions that are conducive to its spread (weather) (see Section 1). Climate change can affect all of these factors in both straightforward and more complex ways.

The role of climate change in ignition is likely to be relatively small compared to the fuel and weather, but may still be significant. For example, lightning accounts for ~27% of the ignitions in the Sydney region (Bradstock 2008) and the incidence of lightning is sensitive to weather conditions, including temperature (Jayaratne and Kuleshov 2006). Climate change can also affect fuel. For example, a lack of rainfall can dry out the soil and vegetation, making existing fuel more combustible. But whilst climate change can affect ignition and fuel, it is the impact of climate change on weather that has the most significant influence on fire activity.

The long-term trend towards a warmer climate due to increasing greenhouse gas emissions is making hot days hotter, and heatwaves longer and more frequent, increasing bushfire risk.

The 2013 October bushfires in the Blue mountains of NSW illustrate the role of weather conditions in affecting fire severity. The bushfires were preceded by the warmest September on record for the state, the warmest 12 months on record for Australia, and below average rainfall in forested areas, leading to very dry fuels (Bushfire CRC 2013). Very hot, dry and windy days create dangerous bushfire weather. The most direct link between bushfires and climate change therefore comes from the relationship between the long-term trend towards a warmer climate due to increasing greenhouse gas emissions, which are increasing the amount of heat in the atmosphere, in turn leading to increased incidence of very hot days. Put simply, climate change is increasing the frequency and severity of very hot days (IPCC 2013), and is driving up the likelihood of dangerous fire danger weather (see Box 1). The latest IPCC report confirms with high confidence that climate change is expected to increase the number of days with very high and extreme fire weather, particularly in southern Australia (IPCC 2014).

Figure 3: Firefighters using a monitor (high-capacity water gun) while fighting a fire at Mt. Riverview in the Blue Mountains in October 2013.

BOX 1: EXTREME HEAT

Climate change is now making hot days hotter, heatwaves longer and more frequent, and drought conditions have been increasing in Australia's southeast.

While hot weather has always been common in Australia's southeast, it has become more common and severe over the past few decades, including in NSW and the ACT. The southeast of Australia has experienced significant warming during the last 50 years (Timbal and Drosdowsky 2012). The 2015/16 summer was Australia's sixth hottest on record (BoM 2016a) and in NSW and the ACT the mean maximum temperature was 1.4°C and 1.9°C above average, respectively (BoM 2016b; BoM 2016c). There were several heatwaves during summer, while February 2016 was also the driest that NSW has experienced since 1978 (BoM 2016b).

Heatwaves are becoming more intense over time, with average heatwave intensity increasing in Sydney by 1.5°C, since 1950 (BoM 2013a; Climate Council 2014b). Eight out of ten of the hottest years on record in NSW and the ACT have occurred since 2002 (BoM 2016d; Figure 4). Record high temperatures occurred in 2013, which proved to be Australia's hottest year on record, with the mean maximum temperature during the year 1.45°C above average (BoM 2014a; Climate Council 2014c). The monthly mean average temperature record for NSW in September 2013 was shattered by a 4.68°C increase above average temperatures (BoM 2014b).

The IPCC projects with virtual certainty that warming in Australia will continue throughout the 21st century and predicts with high confidence that bushfire danger weather will increase in most of southern Australia, including NSW and the ACT (IPCC 2014). The direct effects of a 3 - 4°C temperature increase in the ACT could more than double fire frequency and increase fire intensity by 20% (Cary and Banks 2000; Cary 2002).

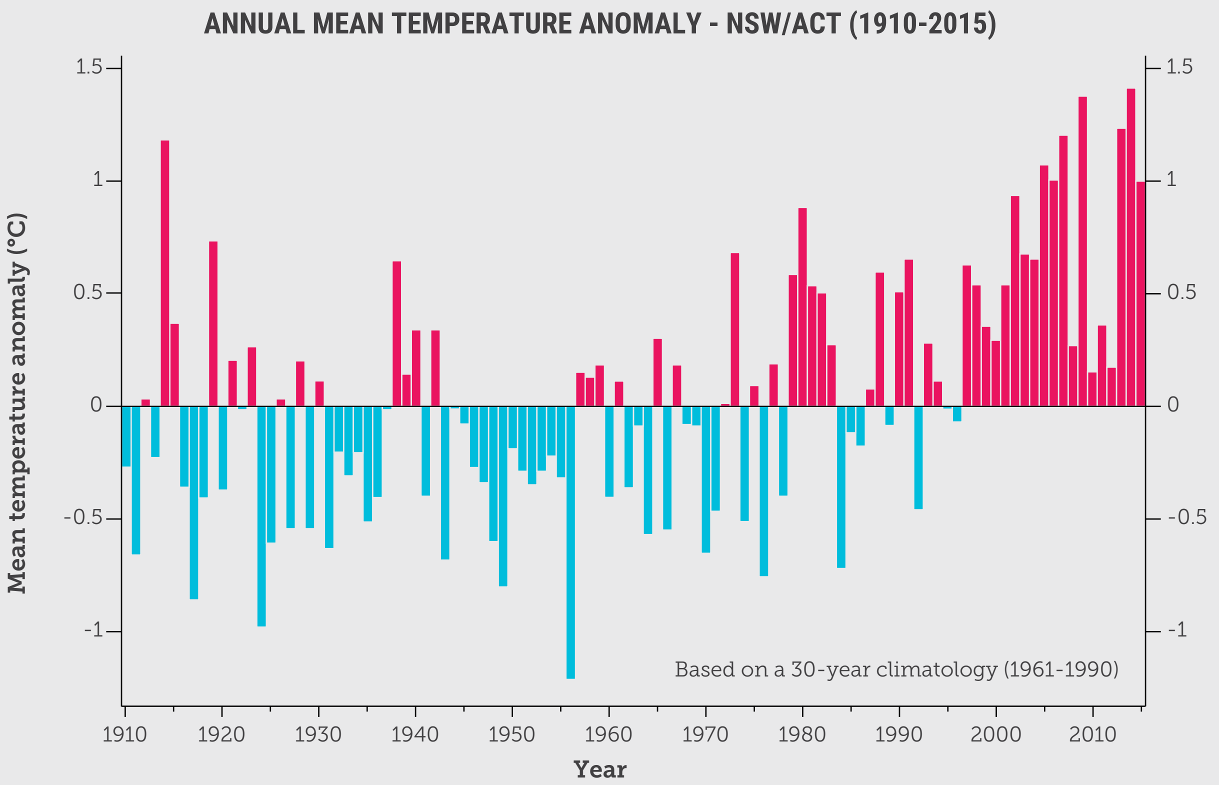


Figure 4: NSW/ACT increasing heat (BoM 2016d). Blue bars indicate years where annual temperatures were below average, and red bards indicate years with above average temperatures.

While there have been relatively few 'attribution' studies on bushfires, which quantify the probability that a bushfire was made more likely because of climate change, there is increasing evidence of the effects of climate change on worsening fire weather and the length of fire seasons. For example, a recent study by Abatzoglou and Williams (2016) of Western US wildfires has linked climate change to producing more than half of the dryness (fuel aridity) of forests since the 1970s, a doubling of the forest fire area since the mid-1980s, and an increase in the length of the fire season. In Northern California in 2014, the second largest fire season in the state in terms of burned areas occurred (Figure 5). Yoon et al. (2014) demonstrate that the risk of such bushfires in California has increased due to human-induced climate change. Most recently, in May 2016, an extreme wildfire forced the entire town of Fort McMurray, Canada of almost 90,000 people to be evacuated. The conditions leading to the wildfire were exacerbated by climate change and El Niño, which resulted in a drier than normal winter and reduced snowpack; moisture which normally limits the impacts of wildfires (Climate Central 2016; Independent 2016; New Yorker 2016). Attribution of climate change on fire events in Australia is harder because of highly erratic climate and short historical length (Williamson et al. 2016), but recent severe ecological impacts of 21st century fires in the Victorian Alps and Tasmania is unprecedented in recent history and is consistent with climate change (Bowman and Prior 2016).

Figure 5: Fire burns in the Klamath National Forest in Northern California in 2014. This was the second largest fire season on record in the entire state in terms of burned areas. The risk of such bushfires in California has increased due to climate change.

3. Observations of Changing Bushfire Danger Weather in NSW and the ACT

Since the 1970s, there has been an increase in extreme fire weather, as well as a longer fire season, across large parts of Australia, particularly in southern and eastern Australia (CSIRO and BoM 2016). Increasing hot days, heatwaves and rainfall deficiencies in NSW and the ACT are driving up the likelihood of extreme fire weather in the state.

Much of eastern Australia has become drier since the 1970s, with the southeast experiencing a drying trend due to declines in rainfall combined with increased temperatures (BoM 2016e; Climate Commission 2013). Since the mid-1990s, southeast Australia has experienced a 15% decline in late autumn and early winter rainfall and a 25% decline in average rainfall in April and May (CSIRO and BoM 2014).

The upcoming 2016/17 bushfire season in NSW and the ACT is set to be a potentially damaging one. September was the wettest and second wettest on record for NSW and the ACT, respectively (BoM 2016f; BoM 2016g). These wet conditions led to substantial grass growth (increase in fuel loads). October rainfall was 15% and 30% less than average for NSW and Canberra, respectively (BoM 2016h; BoM 2016i). Dry conditions are set to continue into summer, with BoM (2016j) predicting above average dry conditions and above average temperatures for the December–February period for the ACT and virtually all of NSW. These tinderbox conditions have led to the Bushfire and Natural Hazards CRC (2016) releasing a November update to their seasonal bushfire outlook, which shows the majority of NSW has 'above normal' fire potential, meaning that there is an increased risk of bushfires (Figure 6). In the ACT, the forecast warmer and drier than average conditions will provide conditions conducive to the development of bushfires.

Bushfires this season have already burned land and damaged some buildings in the NSW regions of Hunter, Port Stephens and Cessnock. In Sydney's west, bushfires threatened homes and led to evacuations in Londonderry and Llandilo. The trend of warmer and drier than average weather conditions mean both NSW and the ACT are extremely vulnerable to bushfires this summer.

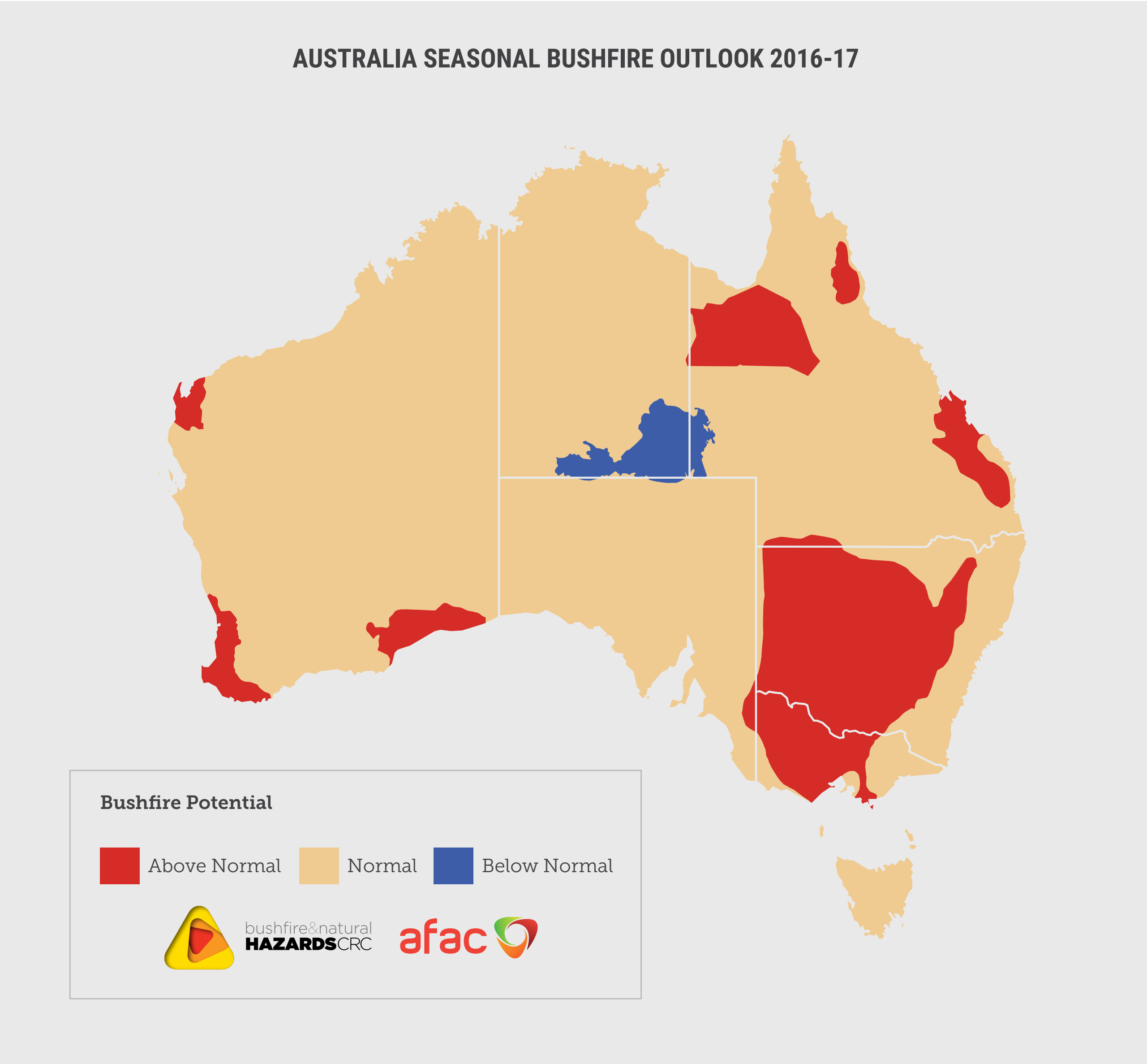


Figure 6: Southern Australia Seasonal Bushfire Outlook (Bushfire and Natural Hazards CRC 2016). Large parts of NSW are expected to have above normal bushfire potential for the 2016/17 summer.

Above average hotter and drier weather during the December–February period in 2016/17, along with high grass growth in spring, means the majority of NSW has above normal fire potential this bushfire season.

The concept of a 'normal' bush fire season is rapidly changing as bushfires continue to increase in number, burn for longer and affect larger areas of land (Bushfire and Natural Hazards CRC 2016). The influence of hotter, drier weather conditions on the likelihood of bushfire spread in NSW and the ACT is captured by changes in the FFDI, an indicator of extreme fire weather. Some regions of Australia, especially in the south and southeast have already experienced a significant increase in extreme fire weather days since the 1970s, as well as a longer fire season (CSIRO and BoM 2016). The FFDI increased significantly at 24 of 38 weather stations across Australia between 1973 and 2010, with none of the stations recording a significant decrease (CSIRO and BoM 2015). These changes have been most marked in spring, indicating a lengthening fire season across southern Australia, with fire weather extending into October and March. The lengthening fire season means that opportunities for fuel reduction burning are decreasing (Matthews et al. 2012).

The concept of a 'normal' bushfire season is rapidly changing as bushfires continue to increase in number, burn for longer and affect larger areas of land.

Figure 7: Extreme heat can cause severe impacts to infrastructure and essential services, including disruptions to electricity.

4. Future Projections of Fire Activity in Southeast Australia

Research aimed at understanding future fire activity in NSW and the ACT has a long history (Table 1). While the detailed results of these studies vary due to the use of different global circulation models (GCMs) and different climate scenarios, their collective conclusion is clear – weather conditions conducive to fire in the southeast and southwest of the continent are becoming increasingly frequent. The IPCC (2014) projects with virtual certainty that warming in Australia will continue throughout the 21st century. In addition, there is high confidence that bushfire danger weather will increase in most of southern Australia, including NSW and the ACT (CSIRO and BoM 2015).

Future changes in the El Niño-Southern oscillation (ENSO) phenomenon are also likely to have an influence on fire activity. There is a strong positive relationship between El Niño events and fire weather conditions in southeast and central Australia (Williams and Karoly 1999; Verdon et al. 2004; Lucas 2005) and between El Niño events and actual fire activity (Harris et al. 2013). Significant changes have occurred in the nature of ENSO since the 1970s, with the phenomenon being more active and intense during the 1979-2009 period than at any other time in the past 600 years (Aiken et al. 2013). It is likely that climate change is and will continue to influence ENSO behaviour, especially extreme El-Niño events (e.g. 1982/83, 1997/98, 2015/16), which are likely to double in occurrence due to anthropogenic warming (Cai et al. 2014). Recent projections suggest increases in El Niño-driven drying in the western Pacific Ocean by mid-to-late 21st century (Power et al. 2013; Cai et al. 2014); such a change would increase the incidence of heat and drought, and potentially increase fire activity in eastern Australia.

Weather conditions conducive to fire in the southeast of Australia are occurring more frequently.

Figure 8: Severe drought in the summer of 2006 in Canberra. Recent projections show that by the mid-to-late 21st century, increases in El Niño-driven drying in the western Pacific Ocean may increase the incidence of heat and drought, potentially increasing fire activity in eastern Australia, including NSW and the ACT.

Table 1: Summary of projections from modelling studies aimed at projecting changes in fire risk in southeast Australia.

Study	Projections
Beer and Williams (1995)	Increase in FFDI with doubling of atmospheric carbon dioxide, commonly >10% across most of continent, especially in the southeast, with a few small areas showing decreases.
Williams et al. (2001)	General trend towards decreasing frequency of low and moderate fire danger rating days, but an increasing frequency of very high and in some cases extreme fire danger days.
Hennessy (2007)	Potential increase of very high and extreme FFDI days in the range of 4–25% by 2020 and 15–70% by 2050.
Lucas et al. (2007)	Increases in annual FFDI of up to 30% by 2050 over historical levels in southeast Australia and up to a trebling in the number of days per year where the uppermost values of the index are exceeded. The largest changes are projected to occur in the arid and semi-arid interior of NSW and northern Victoria.
Hasson et al. (2009)	Projected potential frequency of extreme events to increase from around 1 event every 2 years during the late 20th century to around 1 event per year in the middle of the 21st century, and to around 1 to 2 events per year by the end of the 21st century.
Clarke et al. (2011)	In the southeast, FFDI is projected to increase strongly by end of the 21st century, with the fire season extending in length and starting earlier.
Matthews et al. (2012)	A warming and drying climate is projected to produce drier, more flammable fuel, and to increase rate of fire spread.
CSIRO and BoM (2015)	Projections of warming and drying in southern and eastern Australia will lead to increases in FFDI and a greater number of days with severe fire danger. In a business as usual scenario (worst case, driest scenario), severe fire days increase by up to 160-190% by 2090.

5. Impacts of Bushfires in NSW and the ACT

In NSW and the ACT, bushfires have had a very wide range of human and environmental impacts, including loss of life and severe health effects, damage to property, devastation of communities and effects on water and natural ecosystems.

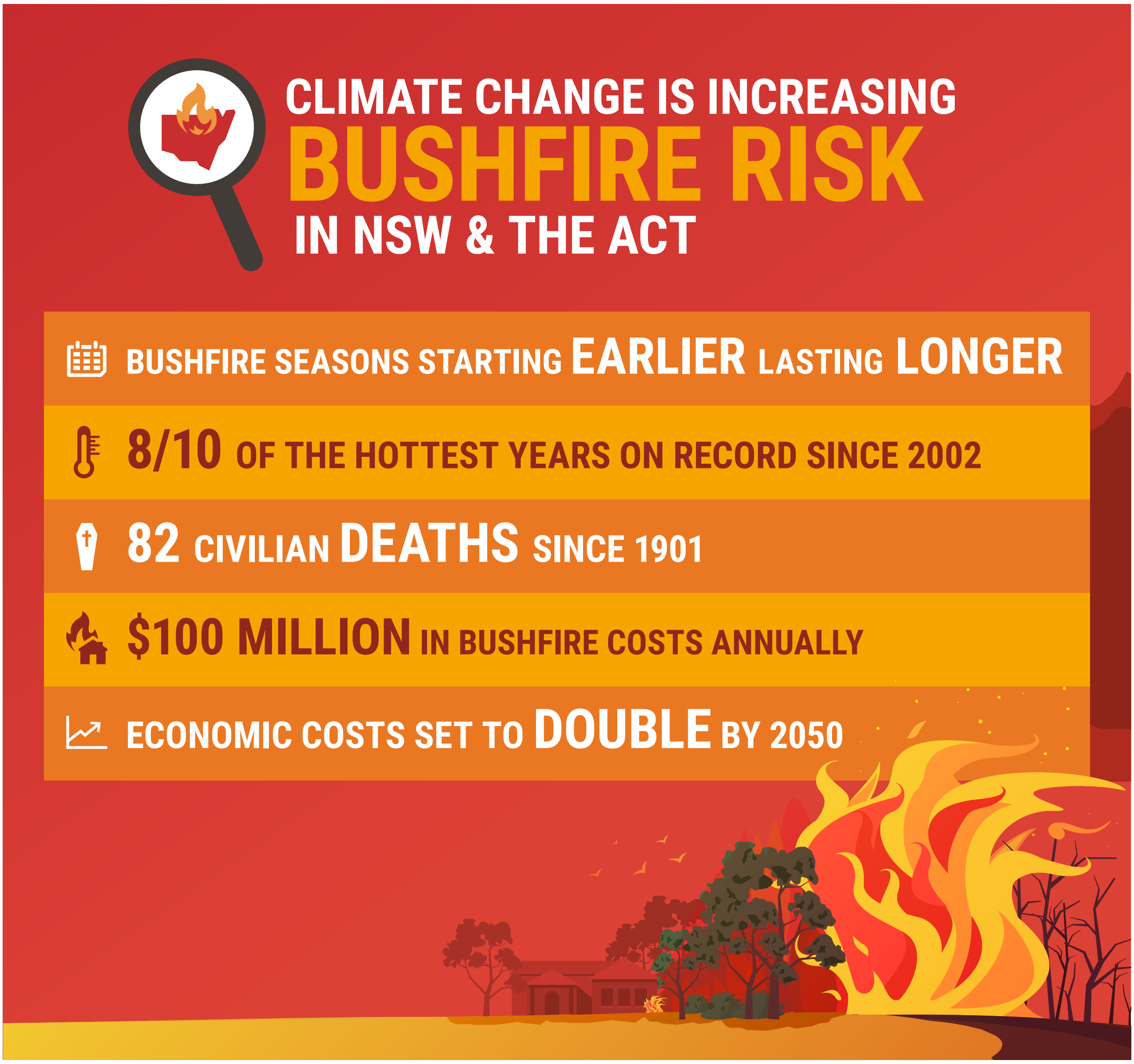


Figure 9: Climate change and bushfire impacts in NSW and the ACT.

5.1 Health Impacts

Large populations in NSW and the ACT are at risk from the health impacts of bushfires, which have contributed to physical and mental illness as well as death. Communities in NSW and the ACT are particularly vulnerable to bushfires because large populations live close to highly flammable native vegetation, such as eucalyptus trees, that are exposed to frequent severe fire weather (Chen and McAneney 2010; Handmer et al. 2012; Price and Bradstock 2013). For example, in the Blue Mountains, approximately 38,000 homes are within 200 m of bushland, and 30,000 within 100 m; with many of these homes backing directly onto bushland (McAneney 2013).

Tragically, in Australia there have been 825 known civilian and firefighter fatalities between 1901 and 2011 (Blanchi et al. 2014). Of the known civilian deaths, 82 (12%) have occurred in NSW or the ACT (Blanchi et al. 2014).

Bushfire smoke can seriously affect health. Smoke contains not only respiratory irritants, but also inflammatory and cancer-causing chemicals (Bernstein and Rice 2013). Smoke can be transported in the atmosphere for hundreds or even thousands of kilometres from the fire front, exposing large populations to its impacts (Spracklen et al. 2009; Dennekamp and Abramson 2011; Bernstein and Rice 2013). Days with severe pollution from bushfires around Sydney are associated with increases in all-cause mortality of around 5% (Johnston et al. 2011). Recently, an extreme smoke event in the Sydney Basin from fires designed to reduce fire hazard is thought to have caused the premature deaths of 14 people (Broome et al. 2016). The estimated annual health costs of bushfire smoke in Sydney are also high, at $8.2 million per annum (2011$) (Deloitte Access Economics 2014).

Large populations in NSW and the ACT are at risk from the health impacts of bushfires, which have contributed to physical and mental illness as well as deaths.

Figure 10: Bushfire smoke from the Blue Mountains blankets Sydney in 2013.

During the Blue Mountains bushfires in October 2013, air quality levels in the Sydney region were measured at 50 times worse than normal. NSW Health recorded that 228 people attended hospital with breathing difficulties; 778 other individuals were treated by ambulance staff and there was a 124% increase in patients with asthma conditions seeking hospital treatment (AEM 2013). A study of hospital admissions from 1994-2007 has found that hospital admissions for respiratory illness increased by 12% on days with bushfire smoke in Sydney (Martin et al. 2007). The health impacts of bushfire smoke are by no means confined to Sydney, with cities such as Newcastle and Wollongong also experiencing increases in hospital admissions due to respiratory conditions (Martin et al. 2007). The impacts of bushfire smoke in the community are also uneven, with the elderly, infants and those with chronic heart or lung diseases at higher risk (Morgan et al. 2010).

In addition to physical health impacts, the trauma and stress of experiencing a bushfire can also increase depression, anxiety, and other mental health issues, both in the immediate aftermath of the trauma and for months or years afterwards (McFarlane and Raphael 1984; Sim 2002; Whittaker et al. 2012). Following the 2013 Blue Mountains bushfires, mental health charity 'Beyond Blue' collaborated with the Australian Red Cross to develop resources to assist bushfire victims experiencing increases in depression and anxiety (Beyond Blue 2013a; 2013b) and over 100 households requested wellbeing assistance from Red Cross volunteers (Red Cross 2013). Post-traumatic stress, major depression, anxiety and suicide can also manifest among firefighters, sometimes only becoming evident many months after an extreme event (McFarlane 1988; Cook and Mitchell 2013).

5.2 Economic Costs

The economic cost of bushfires – including loss of life, livelihoods, property damage and emergency services responses – is very high. The total economic cost of bushfires in Australia, a measure that includes insured losses as well as broader social costs, is estimated to be approximately $375 million per year (2011$), a figure that is expected to reach $800 million by 2050 (Deloitte Access Economics 2014). The annual economic costs of bushfires in NSW and the ACT are estimated to average $45 million and $56 million per annum, respectively (2011$). By about mid-century these costs could increase by more than double, potentially reaching $232 million combined (Deloitte Access Economics 2014). These estimates take into account increases in the number of households, growth in the value of housing stock, population growth and increasing infrastructure density. However, they do not incorporate increased bushfire incident rates due to climate change and could therefore be significantly higher.

NSW has already experienced a significant increase in extreme fire weather since the 1970s, and bushfires occurring in NSW from 1970-2013 have contributed to at least 40 deaths, the destruction of nearly 800 properties and have affected over 14 million hectares of land (Table 2). Indirect costs, such as impacts on local tourism industries can also be significant. For example, a month after the 2013 Blue Mountains bushfires, tourism operators estimated losses of nearly $30 million due to declines in visitors and cancellations alone (ABC 2013).

The total economic costs of NSW and ACT bushfires are estimated to be approximately $100 million. By about mid-century these costs could increase by more than double, potentially reaching $232 million.

Table 2: Damage and loss estimates in ten significant bushfire events in NSW and the ACT since the mid-1970s. Data sourced from Stephenson et al. 2013; NSW PRS 2014; ICA 2012; and Climate Council 2014d.

Date	Location	Losses (including residential property, stock)	Deaths	Significant Insured Losses (normalised to 2011 values[1])
1974–75	Far west, Cobar, Balranald & Moolah-Corinya	4,500,000 ha. 50,000 stock	6 deaths	n/a
1977–78	Blue Mountains	54,000 ha. 49 buildings destroyed	3 deaths	n/a
1979–80	Duffys Forest, Lucas Heights, Terry Hills, Ingleside, Belrose, Elanora Heights, Lithgow, Mt Wilson, Mt Tomah & Grose Valley	> 1,000,000 ha. 28 houses destroyed. 20 houses damaged	13 deaths	n/a
1984–85	Western Division	3,500,000 ha. 40,000 stock	5 deaths	$179m
1993–94	North Coast, Hunter, South Coast, Blue Mountains & Sydney	> 800,000 ha. 206 houses destroyed	4 deaths	$215m
1997–98	Burragorang, Pilliga, Hawkesbury, Hunter, Shoalhaven, Central Coast & Menai	> 500,000 ha. 10 houses destroyed	4 deaths	$8m
2001–02	44 LGAs in greater Sydney, Hunter, north Coast, mid north Coast, northern Tablelands & Central Tablelands	744,000 ha. 109 houses destroyed. 40 houses damaged 6,000 stock	0 deaths	$131m
2002–03	81 LGAs in greater Sydney, Hunter, north Coast, northern Tablelands, northern rivers, north-west slopes, north-west plains, Central Tablelands, Southern Tablelands, Illawarra & South Coast	1,464,000 ha. 86 houses destroyed. 11 houses damaged 3,400 stock	3 deaths	$43m (October 2002 fires)
2003	Canberra and Alpine bushfires	500 properties and 300 agricultural buildings destroyed. 17,000 stock	0 deaths	$660m
October 2013	Blue Mountains, Port Stephens, Lake Munmorah, Hunter, Hawkesbury, Central Coast & Southern Highlands	118,000 ha. 222 houses destroyed, 168 houses damaged	2 deaths	>$183m

Figure 11: The 2003 bushfires in Canberra caused significant damage; 500 properties were destroyed and insured losses were $660 million.

The 2003 Canberra and Alpine bushfires caused significant economic damage; 500 properties were destroyed and insured losses were $660 million (2011$) (ICA 2012; Climate Council 2014d). A substantial proportion of these costs were borne by home owners as 27-81% of households affected by the fires were either uninsured or underinsured (by an average of 40% of replacement value) (ASIC 2005).

Bushfires can cause significant losses in farming areas. In the 2003 Canberra and Alpine bushfires, 13,000 sheep and nearly 4,000 cattle were killed, and more than 300 agricultural buildings were destroyed (Stephenson et al. 2013). Stock that survives the initial bushfires can face starvation in the post-fire period, as well as threats from predators due to the destruction of fences around properties (Stephenson 2010). In

The Canberra and Alpine bushfires in 2003 caused $1.5 billion worth of losses to the timber industry, the death of 13,000 sheep and 4,000 cattle, as well as destroying 4,000 km of fencing.

Figure 12: Burnt landscape in the wake of the Blue Mountains bushfires in October 2013. Tourism operators lost an estimated $30 million due to declines in visitors and cancellations alone.

2003, the bushfires destroyed nearly 4,000 km of fencing and $1.5 billion worth of timber was lost (Stephenson et al. 2013). Smoke damage can also taint fruit and vegetable crops, with wine grapes particularly susceptible (Stephenson 2010). For example, bushfires in 2003 significantly tainted grapes in NSW with smoky, burnt, ash aromas, making them unusable (Jiranek 2011).

It is important to note that these economic losses shown in Table 2 do not account for the full range of costs associated with bushfires – few attempts have been made to account for loss of life, social disruption and trauma, opportunity costs for volunteer fire fighters, fixed costs for bushfire fighting services, government contributions for rebuilding and compensation, impacts on health, and ecosystem services (King et al. 2013).

5.3 Environmental Impacts

Fire can affect the quality and quantity of water in catchments and have significant impacts on ecosystems. Large-scale high intensity fires that remove vegetation expose topsoils to erosion and increased runoff after subsequent rainfall (Shakesby et al. 2007). This can increase sediment and nutrient concentrations in nearby waterways, potentially making water supplies unfit for human consumption (Smith et al. 2011; IPCC 2014). For example, bushfires in January 2003 devastated almost all of the Cotter catchment in the ACT, causing unprecedented levels or turbidity, iron and manganese and significantly disrupting water supply (White et al. 2006). Fires can also affect water infrastructure. Fires in the Sydney region in 2002 affected the Woronora pumping station and water filtration plants, resulting in a community alert to boil drinking water (WRF 2013).

Fire is a regular occurrence in many Australian ecosystems, and many species have evolved strategies over millions of years to not only withstand fire, but to benefit from it (Crisp et al. 2011; Bowman et al. 2012). Particular fire regimes (especially specific combinations of fire frequency and intensity) can favour some species and disadvantage others. If fires are too frequent, plant species can become vulnerable to local extinction as the supply of seeds in the soil declines. Conversely, if the interval between fires is too long, plant species that rely on fire for reproduction may be eliminated from an ecological community.

Animals are also affected by bushfires, for example if they are restricted to localised habitats and cannot move quickly, and/or reproduce slowly, they may be at risk from intense large-scale fires that occur at short intervals (Yates et al. 2008). Deliberate fuel reduction burning can also destroy habitats if not managed properly. For example, in the Shoalhaven region of NSW, the threatened eastern bristlebird and the glossy black cockatoo face the potential destruction of their habitats which overlap with areas of bushland that are being targeted in hazard reduction burning (Whelan et al. 2009).

Figure 13: A glossy black cockatoo in NSW. This threatened bird species, as well as the threatened eastern bristlebird, face potential destruction of their habitats because their habitats overlap with areas of bushland targeted for hazard reduction burning.

6. Implications of Increasing Fire Activity

The population of NSW is expected to grow from 7.7 million people (as of March 2016) up to 12.6 million people by 2061 (ABS 2013a; 2013b), while the population of the ACT is expected to grow from 395,000 people (as of March 2016) up to 740,000 people by 2061 (ABS 2013c).

The steady urban encroachment into bushland, along with increasing fire danger weather, present significant and growing challenges for both NSW and the ACT. This challenge is exemplified in greater Sydney, a region considered to be one of the more bush fire-prone areas in Australia. It is home to a quarter of Australia's population, and 2005 projections have found that 190,000 homes are exposed to greater bushfire risk due to their close proximity (within 80 m) to dense bushland (Chen 2005). The challenge is also exemplified in Canberra, where over 9,000 Canberra homes are located 400-700 m from bushland, exposing residents to greater bushfire risk (Risk Frontiers 2004).

The economic, social and environmental costs of increasing bushfire activity in NSW and the ACT are potentially immense. In one of the few analyses to consider projected costs of bushfires in NSW, Deloitte Access Economics (2014) calculated the potential insured losses and broader social costs, to forecast total economic costs of bushfires in selected Australia states, finding that bushfires in NSW and the ACT could cost $232 million (2011$) by 2050. In addition to insured and social losses, health costs from particulate matter emitted during bushfires in NSW are projected to cost $8.2 million per annum. Attempting to mitigate these damages through practices such as prescribed burning can also be costly. For example, it is likely that NSW is burning around 0.5% of bushland in any given year, at a cost of 13.3 tonnes of carbon equivalent emissions per hectare (Deloitte Access Economics 2014). The Deloitte analysis notes that climate change will increase very high fire danger weather and associated bushfire incidents over time but their projections do not incorporate this, making them conservative economic forecasts.

190,000 homes in Sydney are exposed to greater bushfire risk due to their proximity to dense bushland.

Figure 14: Aerial view of Sydney. As the population of NSW continues to grow, steady urban encroachment into bushland is likely to continue, along with increasing fire danger weather, posing a higher risk to the city fringe to bushfires.

Figure 15: A hazard reduction burn being conducted by the NSW Rural Fire Service in Belrose, 2011. This can result in extensive smoke pollution as authorities attempt to meet burning schedules in the few safe days for burning.

There is increasing interest in how adaptation to an increasingly bushfire-prone world may reduce vulnerability. Current government initiatives centre on planning and regulations, building designs to reduce flammability, burying powerlines in high risk areas and retrofitting electricity systems, fuel management, fire detection and suppression, improved early warning systems, and community education (Preston et al. 2009; Buxton et al. 2011; O'Neill and Handmer 2012; King et al. 2013). Responses to bushfires can be controversial, particularly the practice of prescribed burning, where fires are lit in cool weather to reduce the volume of fuel. For example, during 2012-13, the largest ever hazard reduction burn was conducted in NSW, with 330 burns carried out across 206,000 ha of national parks (NSW Government 2014). Fire managers are constantly faced with the challenge of balancing the need to reduce risk to life and property whilst simultaneously conserving biodiversity and environmental amenity, and controlling air pollution near urban areas (Penman et al. 2011; Williams and Bowman 2012; Adams 2013; Altangerel and Kull 2013). The increasing length of the fire season will reduce the window of opportunity for hazard reduction at the same time that the need for hazard reduction becomes greater.

The increasing length of the fire season will reduce the window of opportunity for hazard reduction.

Figure 16: Elvis – the Erickson Air-Crane fire bomber – dumping about 9,000 L of water to assist firefighters battling a blaze in Australia's southeast. Specialised firefighting aircraft like this are loaned for the bushfire seasons in both the Northern and Southern hemispheres each year. Such aircraft are expensive to operate.

Australia's fire and emergency services agencies have recognised the implications of climate change for bushfire risk and firefighting resources for some time (AFAC 2010). For a number of years, the US and Australia have participated in a resource-sharing arrangement that enables states in either country to request additional firefighting personnel at short notice (NIFC 2002). As fire seasons in the two hemispheres increasingly overlap, such arrangements may become increasingly impractical (Handmer et al. 2012). For example, longer fire seasons have implications for the availability and costs of firefighting equipment that is leased from agencies in the Northern Hemisphere, such as the Elvis fire bomber (Figure 16).

During the past decade, state fire agencies have increasingly needed to share suppression resources domestically during peak demand periods. As climate change increases the severity of bushfire danger weather in NSW and the ACT and increases the fire season length, firefighting services will be less able to rely on help from interstate and across the world as fires occur simultaneously. This is a major challenge for NSW and the ACT. Substantially increased resources for fire suppression and control will be required. Most importantly, a significant increase in the number of career and volunteer firefighters will be needed.

7. Tackling Climate Change is Critical for Protecting Australians

The impacts of climate change are already being observed. Sea levels are rising, oceans are becoming more acidic, and heatwaves have become longer and hotter. For NSW and the ACT, these impacts include increased fire danger weather and longer bushfire seasons. Greenhouse gases from human activities, particularly the burning of fossil fuels, is the primary cause for the changes in climate over the past half-century (IPCC 2013; 2014).

The long-term trend of increasing global emissions must be slowed and halted in the next few years. Emissions must be trending sharply downwards by 2020 at the latest if we are to reduce the escalating risks of climate change and meet the goal of limiting global temperature rise to less than 2°C above pre-industrial levels. Investments in and installations of renewable energy such as wind turbines and solar must therefore increase rapidly.

Australia must do its fair share of meeting the global emissions reduction challenge. Australia's very weak target of a 26-28% reduction in emissions by 2030 compared to 2005 levels – and we are on track to miss even this target – leaves Australia lagging well behind other OECD (Organisation for Economic Co-operation and Development) countries. At present, Australia is ranked by Climate Transparency (2016) as the worst of all G20 nations on climate change action and is the only country to receive a rating of 'very poor' in a majority of categories. This lack of action is not consistent with effective action to tackle climate change.

This is the critical decade to get on with the job of protecting Australians from the dangerous impacts of climate change. We are now well into the second half of the decade, and Australia is falling further behind in the level of action required to meet the climate change challenge. The window in which we can act to avoid the most damaging effects of climate change is almost closed. Australia urgently needs a plan to close our ageing and polluting coal-fired power plants and replace them with modern, clean renewables and to become a leader, not a laggard, in the worldwide effort to tackle climate change.

The only approach to keeping the risks from bushfires manageable is rapid and deep reductions in emissions.

Figure 17: Solar panels on a roof in Sydney. Nearly 15% of Australian households have solar panels on their rooftops (Bruce and MacGill 2016). More solar and renewable energy installations are required in Australia to move towards meeting the emissions reduction challenge.

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Preparing for a Bushfire in NSW and the ACT

IN AN EMERGENCY, CALL TRIPLE ZERO (106 FOR PEOPLE WITH A HEARING OR SPEECH IMPAIRMENT) 000

What can I do to prepare for a bushfire?

INFORM YOURSELF

The NSW and ACT Rural Fire Service has the resources available to help you prepare for a bushfire. Use these resources to inform yourself and your family.

ASSESS YOUR LEVEL OF RISK

The excellent resources of the Victorian Country Fire Service are available to assist you to assess your level of risk from bushfire. Take advantage of them. Visit: http://www.rfs.nsw.gov.au/plan-and-prepare/know-your-risk (NSW), esa.act.gov.au/community-information/bushfires/in-the-suburbs (ACT suburbs), esa.act.gov.au/community-information/bushfires/in-the-rural-areas (ACT rural).

MAKE A BUSHFIRE SURVIVAL PLAN

Even if your household is not at high risk from bushfire (such as suburbs over 1 km from bushland), you should still educate yourself about bushfires, and take steps to protect yourself and your property. Access the bushfire ready self assessment tool: www.rfs.nsw.gov.au/plan-and-prepare

PREPARE YOUR PROPERTY

Regardless of whether you decide to leave early or to stay and actively defend, you need to prepare your property for bushfire, An important consideration is retrofitting older houses to bring them in alignment with current building codes for fire risk and assessing the ammability of your garden. Use the Victorian Country Fire Service Fire Ready Kit to help recognise exactly what you need to prepare your property: www.rfs.nsw.gov.au/plan-and-prepare

PREPARE YOURSELF AND YOUR FAMILY

Preparation is not only about the physical steps you take to prepare – e.g., preparing your house and making a bushfire survival plan. Preparing yourself and your family also involves considering your physical, mental and emotional preparedness for a bushfire and its effects. Take the time to talk to your family and to thoroughly prepare yourself on all levels.

Key Links

NSW RFS
www.rfs.nsw.gov.au
1800 679 737

ACT RFS
esa.act.gov.au/actrfs
(02) 6207 8609

Bushfire Survival Plan App:
www.rfs.nsw.gov.au/plan-and-prepare/bush-fire-survival-plan
(Available for ioS and Android)

Fire Watch Map
myfirewatch.landgate.wa.gov.au

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RISKY BUSINESS: HEALTH, CLIMATE AND ECONOMIC RISKS OF THE CARMICHAEL COALMINE

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Preface

The Carmichael mine will be Australia's largest coalmine with a potential lifetime of up to 60 years. Australia has very large coal deposits, but for Australia to play its role in tackling climate change, over 90% of Australia's existing thermal coal reserves must be left in the ground unburned and no new thermal mines can be developed.

This report follows on from our previous reports in 2015 titled "Galilee Basin – Unburnable Coal" and "Unburnable Carbon: Why we need to leave fossil fuels in the ground". It outlines why – based on the "carbon budget" approach – opening up the Galilee Basin for coal mining is fundamentally at odds with global efforts to tackle climate change effectively and protect Australia from the dangerous impacts of climate change, such as more intense extreme weather events and destruction of our most iconic ecosystems including the Great Barrier Reef.

As the strong global trend away from coal to renewable energy and storage gathers even more momentum, Australia's thermal coal export industry future looks increasingly shaky. The Galilee Basin, if developed, could well become a stranded asset in a world rapidly moving away from coal. The need to move away from fossil fuels to renewable energy is extremely urgent. Furthermore, as climate impacts worsen, climate change litigation is becoming a significant risk for corporations. New coalmines, such as the Carmichael coalmine, potentially undermine the vibrancy of other major Australian industries that rely on water resources, land and healthy ecosystems, such as agriculture and reef tourism. The report also describes how coal and human health is deadly serious.

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Key Messages

1

Developing *any* new thermal coalmines, particularly of the scale of the Carmichael mine in the Galilee Basin, is fundamentally at odds with protecting Australians from the impacts of climate change.

- If the Galilee Basin were a country on its own, it would emit more than 1.3 times Australia's current annual emissions from all sources and rank in the top 15 emitting countries in the world.
- Climate change, driven by greenhouse gas pollution from burning coal and other fossil fuels, is increasing the severity and frequency of many extreme weather events in Australia, such as heatwaves, bushfires and intense rainfall.
- Developing the Carmichael mine fundamentally undermines any national or state action to tackle climate change.

2

Opening up the Galilee Basin undermines other industries, such as tourism and agriculture.

- Burning coal anywhere in the world, including India, increases the incidence and severity of many extreme weather events in Australia, with direct economic risks to the agriculture and tourism industries.
- Coal expansion will drive further warming of the oceans, which increases the risk of extreme bleaching to Australia's multi-billion dollar tourism asset, the Great Barrier Reef.
- Australia's agricultural industry is vulnerable to worsening extreme weather events, like extreme heat and more severe drought. Coal burning here, or abroad, further increases those risks.
- To protect Australia's tourism and agricultural industries from worsening extreme weather, coal burning must be rapidly and completely phased out; this includes coal burning in Australia, India and elsewhere in the world.

3

Coal is very harmful to human health.

- Particulate air pollution (fine particles that enter the lungs) caused 4.2 million deaths globally in 2015. Burning of coal is a major source of particulate air pollution.
- In India, to which the coal from Adani's Carmichael mine in Queensland will most likely be exported, an estimated 80,000-115,000 people die from coal pollution each year.
- It is estimated that the ash content from the planned Carmichael coalmine is about 26%, roughly double the Australian benchmark.
- There has been a recent re-emergence of the life threatening 'black lung' (coal workers' pneumoconiosis) in Queensland, with 21 reported cases.
- Coal's health impacts cost Australian taxpayers an estimated $2.6 billion every year.

4

The Carmichael mine is a risky financial investment and promises of economic benefit are overblown.

- Plummeting costs of renewable energy and the reduced coal demand from China combined with India's aggressive move towards energy self-sufficiency all place new coalmines, and associated rail/port infrastructure investments, on shaky ground, increasing the risk of stranded assets.
- 17 major banks worldwide have stated they will not fund the Carmichael mine based on both its lack of economic viability and environmental impact.
- As the world moves towards a more sustainable, lower carbon economy, company directors who do not properly consider climate change related risks may be held legally liable for breaching their duty of care and due diligence.

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Introduction

To protect Australia from the impacts of climate change, the vast bulk of fossil fuels must be left in the ground, unburned. This means that existing coalmines will need to be retired before they are fully exploited and new mines cannot be developed. This is particularly relevant for Australia as plans and approvals to open up the Galilee Basin for lower quality thermal coal mining operations, such as the Adani Carmichael coalmine, are advanced.

Existing coalmines will need to be retired before they are fully exploited and new mines cannot be built.

Climate change is driven by rising greenhouse gas emissions, particularly from the burning of coal, oil and gas. Since the 1970s, global average temperature has trended strongly upwards (e.g. Rahmstorf et al. 2017), with a global temperature now more than 1°C above pre-industrial levels. Furthermore, since 1970 global temperature has been increasing at a rate 170 times faster than the background rate over the past 7,000 years (Steffen et al. 2016).

Rising temperatures and the accelerating impacts of climate change are affecting all nations, including Australia. Heatwaves are now hotter, lasting longer and occurring more often in Australia (Perkins and Alexander 2013; Climate Council 2014). The ocean is also warming. Rising sea surface temperatures, driven by climate change, are increasing the prevalence of "marine heatwaves" (Perkins et al. 2016), which can trigger coral bleaching events, like those seen in 2016 and 2017 on the Great Barrier Reef. The reef is an environmental treasure, as well as a key tourism and fisheries asset. Ongoing damage to the reef driven by climate change puts marine life, livelihoods and the north Queensland economy at risk.

Climate change has also increased extreme fire weather in the south and east of Australia since the 1970s (Clark et al. 2013; CSIRO and BoM 2016; Figure 1), threatening people and property, while climate change is likely making drought conditions in southwest and southeast Australia worse (CSIRO and BoM 2015; Climate Council 2015c). At the same time, sea level has been rising rapidly, exposing coastal infrastructure and property to increasing coastal erosion and higher risk of inundation from storm surges (McInnes et al. 2015; Climate Council 2017).

Figure 1: Bushfire risk is increasing in Australia as a result of climate change (Clark et al. 2013).

Given that it has taken significant time to ramp up action on climate change globally, there is now only a relatively small "carbon budget" left. The carbon budget approach allows us to quantify the amount of fossil fuels that can be burned to have a good chance of remaining under a 2°C rise in global temperature, the upper warming limit agreed to in Paris in 2015. More than 140 governments around the world, including Australia, have already ratified the Paris Agreement. Anything more than 2°C warming is considered too dangerous for humanity, not only for unacceptably large increases in direct impacts such as extreme weather events, but also for crossing climate 'tipping points', where large, rapid and potentially irreversible changes occur in the climate system (Church et al. 2017). Examples of these tipping points are the loss of the Greenland and West Antarctic ice sheets, thawing of permafrost in Siberia and loss of the Amazon rainforest.

Consistent with the remaining global carbon budget, for Australia to play its role in tackling climate change, over 90% of Australia's coal reserves must be left in the ground unburned (McGlade and Ekins 2015) and no new mines can be developed. If all of the Galilee Basin mines are developed to their maximum potential, it is estimated that over 700 million tonnes (Mt) of carbon dioxide (CO_2) would be released to the atmosphere each year

Opening more Australian coalmines will directly worsen extreme weather.

(Greenpeace 2012). That's more than 1.3 times Australia's current annual emissions from *all* sources (2015 emissions were 527 Mt CO_2; Australian Government 2016). Put another way, if the Galilee Basin were a country on its own, it would rank in the top 15 emitting countries in the world (Olivier et al. 2016). Any new mine is fundamentally at odds with protecting Australia from the impacts of climate change, and runs contrary to good government policy to transition the Australian economy in a planned way, consistent with our Paris Climate Agreement commitments. It also poses serious and irreversible risks to tourism and agriculture, which are vital not only for the livelihoods of many Australians but also for the national economy.

In the last few years action on tackling climate change worldwide has been accelerating with the transition from fossil fuels to renewable energy. A global movement to decarbonise the world is underway and rapidly gaining momentum. Globally, carbon dioxide (CO_2) emissions were near flat for the third year in a row in 2016 (Le Quéré et al. 2016). Last year, 139GW of renewable capacity was built, an 8% increase on the previous year, largely driven by rapidly falling renewable energy costs (Frankfurt School-UNEP Centre/BNEF 2017). Much of the recent renewable energy growth has occurred in developing countries, with China, and more recently India, leading the way (IEA 2016). Meanwhile, in Australia new renewable power is now cheaper than new coal or gas power.

This report outlines why – based on the carbon budget approach – opening up the Galilee Basin for coal mining is fundamentally at odds with tackling climate change. Protecting Australia from worsening extreme weather and protecting the Great Barrier Reef from further damage requires a rapid transition away from coal. The report also tackles two of the key assertions proponents for the mine consistently make, that it is: (a) economically beneficial and (b) beneficial for those who are poverty stricken in India. The report also considers these assertions, finding that they are both false.

Coalmines are becoming an increasingly risky investment as carbon regulation is imposed, the world moves to renewables and coal increasingly loses its social licence. 17 major banks worldwide have stated they will not fund the Carmichael mine, with all of Australia's four major banks (ANZ, NAB, Westpac and Commonwealth Bank) now declaring they will not fund the project. With the global trend away from coal gathering momentum, any Galilee Basin coalmine could well become a stranded asset in a world rapidly moving away from coal towards clean energy systems.

Furthermore, coal mining and burning pose significant health risks which were brought into focus recently with 21 reported cases of black lung disease in Queensland. Human health risks from coal exploitation include lung cancer, bronchitis, heart disease and other conditions of ill health (Temple and Sykes 1992; García-Pérez et al. 2009; Hendryx and Zullig 2009). In India, approximately 100,000 people die from exposure to coal pollution each year (Guttikunda and Jawahar 2014). In addition, the impacts of climate change on people living in poorer and more vulnerable countries such as India are severe, with poorer people most at risk from climate-related hazards. An extreme heatwave in 2015 in India killed more than 2,000 people (ABC 2015c), many of whom were poorer people and the homeless, who had few resources to escape the extreme conditions (CNN 2015). People who are poor have the fewest resources to cope with the consequences of climate change and will suffer the most as extreme weather and sea-level rise intensify (IPCC 2014; The Guardian 2014a).

1. How Much Coal Can We Burn?

To tackle climate change, the Paris Agreement was signed by 197 countries around the world and has now been ratified by more than 140 countries, including Australia (UNFCCC 2017). The Agreement aims to limit global temperature rise to no more than 2°C above the pre-industrial level. It is very important for Australia that temperatures stay within this 2°C limit, to protect people in Australia from worsening climate impacts, which affect human health, livelihoods and the environment.

Australians are already feeling the impacts of climate change, with global average temperature about 1.1°C above the pre-industrial levels (UK Met Office 2017). This summer alone has seen more than 205 records broken across the nation, with heat and rainfall records broken widely in the east and west, respectively, in what has been termed the 2016/2017 "Angry Summer" (Climate Council 2017). For example, Brisbane, Sydney and Canberra had their hottest summers on record, while regional towns, such as Moree in New South Wales recorded 54 consecutive days of temperatures 35°C or above, a record for the state. To protect Australians from worsening climate impacts, Australia must rapidly reduce greenhouse gas emissions from the burning of fossil fuels to contribute its fair share to the global effort to limit temperature rise to less than 2°C.

To protect Australians from worsening climate impacts, Australia must contribute its fair share to eliminating global greenhouse gas pollution.

Figure 2: San Juan generating station and coalmine in New Mexico. The more CO_2 emitted into the atmosphere, the more the Earth warms.

There is a direct relationship between our emissions of CO_2, primarily from the burning of fossil fuels (Figure 2), and the rise in global average temperature (IPCC 2013). The more CO_2 we emit, the more the Earth warms. So, to limit warming to no more than 2°C, there is a limit to how much CO_2 we can emit. That is, there is a global carbon budget for the amount of fossil fuels we can burn. The global carbon budget provides a framework for understanding how much fossil fuels we can burn to have a good chance of staying below a 2°C rise in global temperature. While no amount of global warming is entirely 'safe', the budget approach can assist in planning the speed and scale of the transition away from fossil fuels.

Because the world is only now beginning to take substantial action on climate change, our remaining carbon budget is small. For a 75% chance of staying below the 2°C warming limit, the budget from 2012 is 672 billion tonnes (Gt) of CO_2 globally (Meinshausen et al. 2009; IPCC 2013). While this looks like a very big number, current annual global emissions are around 36 Gt CO_2 (Le Quéré et al. 2016) so the budget will be exhausted in less than two decades at current rates of emissions. The bottom line is that the need to move away from fossil fuels is extremely urgent.

A further analysis based on the economically optimal use of the three main fossil fuels – coal, oil and gas – highlights the need to eliminate coal usage as soon as possible (McGlade and Ekins 2015). Even for the most generous assumptions – just a 50% chance of staying below 2°C warming– only 38% of the world's fossil fuels can be burned (Figure 3). This drops to only 23% for the more prudent approach of a 75% of chance of staying below 2°C (Table 1).

Table 1: The carbon budget for three probabilities of meeting the 2°C warming limit, and the fraction of fossil fuel reserves and resources that can be burned within the budget.

Probability of meeting 2°C policy target	Budget from 2000 Gt CO_2	Budget from 2012 Gt CO_2	% of fossil fuel reserves that can be burned from 2012	% of fossil fuel resources that can be burned from 2012
50%	1440	1112	38	10
66%	1338	1010	35	9.2
75%	1000	672	23	6.1

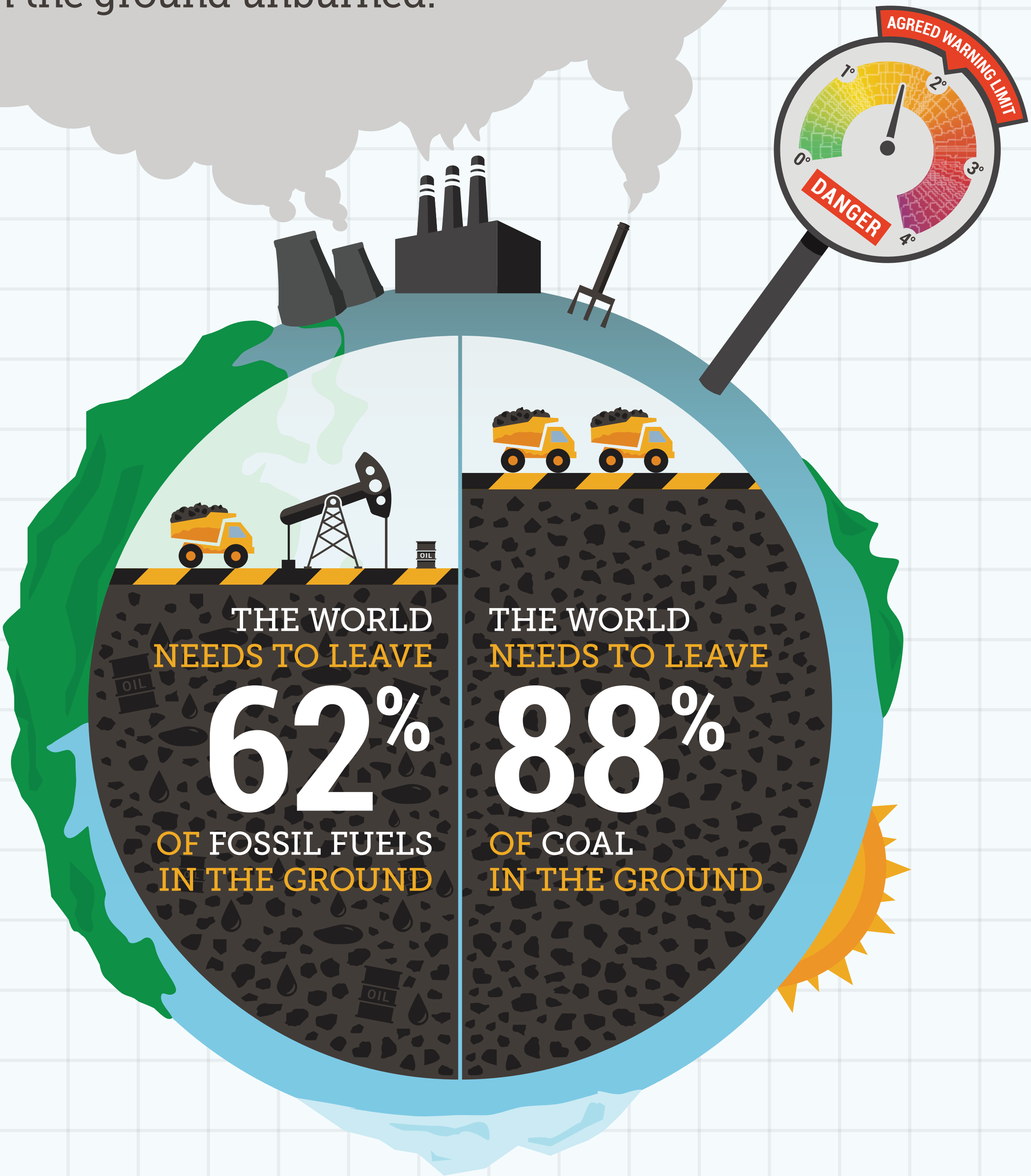
Sources: Meinshausen et al. 2009; IPCC 2013; McGlade and Ekins 2015.
Note: "resources" are all of the fossil fuels that we know exist, and "reserves" are the subset of resources that are economically and technologically viable to exploit now.

The news for coal is clear. Based on the economic optimisation of McGlade and Ekins (2015), the bulk of the allowable fossil usage comes from oil and gas, leaving very little of the carbon budget left for coal. In fact, for the most generous budget, only 12% of the world's coal reserves – deposits that are economically and technologically viable to exploit today – can be burned.

When the economic analysis is extended to geographical regions, it is clear that there is little room for coal burning and none at all for new coal mining in Australia's budget. Well over 90% of our coal reserves are unburnable (Table 2), even under generous assumptions and allowing for uncertainties in the analysis (see Climate Council 2015d for more details). This includes all types of coal, regardless of its quality. There is no such thing as "clean coal" (see Box 1).

WHAT IS OUR CARBON BUDGET?

To stay **below a catastrophic 2°C** rise in global temperature most of the world's fossil fuel reserves must be kept in the ground unburned.



AT THE CURRENT RATE

We will blow our carbon budget within the next **two decades** or even sooner.

Figure 3: The amount of coal and fossil fuels (coal, oil and gas) available for a 50% chance to keep global warming below 2°C. For a 75% change of staying within the 2°C limit, more than 90% of the world's coal reserves must stay in the ground, and 97% of Australia's coal reserves must stay in the ground, unburned (see Table 2).

Over 90% of Australia's existing coal reserves must remain in the ground, unburned.

Table 2: Percentage of existing fossil fuel reserves that can be burned, based on a carbon budget approach for the OECD Pacific group (largely Australian reserves) for emissions from 2011 through 2050.

Fossil fuel	Percentage of reserves that can be burned
Oil	32
Gas	29
Coal	**3**

Source: Meinhausen et al. 2009; IPCC 2013; McGlade and Ekins 2015.

The bottom line is simple. If we are to tackle climate change:

- The vast majority of the world's, and especially Australia's, coal must stay in the ground unburned.
- Existing mines can only be partially exploited and will need to be retired before they are exploited fully.
- New mines, such as those in the Galilee Basin, cannot be built.
- New energy sources, such as solar and wind, must come online rapidly to replace coal to help transition the Australian economy towards clean industries of the future.

BOX 1: THE FALLACY OF "CLEAN COAL"

Coal is always polluting (Climate Council 2017a; Figure 4). When dug up and burned, coal pollutes the environment and damages our health in several ways. Burning coal for electricity emits toxic and carcinogenic substances into our air, water and land, directly and severely damaging the health of miners, other workers and communities. The Australian Academy of Technological Sciences and Engineering (2009) estimated coal's health impacts cost taxpayers $2.6 billion every year (see Section 4).

More efficient coal plants labeled "ultra supercritical" (called "clean coal" by the Federal Government) still emit a significant amount of greenhouse gases, which drive climate change with its many impacts on our health, livelihoods and ecosystems. A new high-efficiency coal plant run on black coal would still produce about 80% of the emissions of an equivalent old plant, while renewables (e.g. wind and solar) have zero emissions. So-called "clean coal" does not help Australia meet its (very inadequate) obligations to reduce its emissions 26-28% by 2030 below 2005 levels.

Building new coal plants would be a very expensive option for replacing Australia's ageing, inefficient coal fleet. New wind and solar plants both in Australia and overseas are beating new coal, gas and nuclear plants on price. AGL's Silverton Wind Farm will deliver power to the grid at a price of $65 per MWh (megawatt-hour) compared to new coal power, which could have costs of up to $160 per MWh (BNEF 2017).

For very clear and commercial reasons, major Australian energy companies have ruled out building new coal plants. The Australian Energy Council sees them as "uninvestable". Consistent with APRA's February 2017 Climate Risk position, banks and investment funds are not interested (APRA 2017). Any new coal plants would be much more expensive than renewables and carry a huge liability through the carbon emissions they produce (see Section 3).

Figure 4: Coal is never "clean"; it pollutes the environment and damages our health.

2. World Rapidly Moving Away From Coal to Renewables

After a slow start over the past two decades, the world is beginning to take action on climate change, and the primary emphasis is on the switch from coal to renewables for electricity generation. The speed and magnitude of the movement away from coal as an energy source in Europe and countries like China, the United States, India and Japan is striking, and it is gaining even more momentum in new markets like Mexico and Chile (Ernst & Young 2016; REN21 2016; Frankfurt School-UNEP Centre/BNEF 2017).

The US and Chinese economies have prospered while renewable energy has taken off.

The world's economy grew in 2016 by 3.1%, meanwhile growth in emissions stalled for a third straight year, meaning energy-related CO_2 emissions are no longer rising. This is due to rapid renewable energy growth, energy efficiency improvements, and gas replacing coal in some areas (IEA 2016b; 2017). In the United States, emissions fell 3% in 2016, while the economy grew by 1.6%. China's emissions also fell by 1%, while their economy grew by 6.7% (IEA 2017). Both these countries are achieving reductions in emissions while still experiencing strong economic growth.

The stall in global emissions is largely due to China's concerted and sustained policy drive to reduce coal usage and invest in renewables. China is both the world's biggest emitter of CO_2 and the world's largest producer and consumer of coal, and is now accelerating its transition away from a coal-based electricity generation system. In fact, China has most likely already passed peak coal use in 2013 (IEA 2017). In its 13th Five-Year Plan for the period 2016-2020, China scaled up plans for transitioning away from coal, introducing a cap on the country's total energy consumption and expanded renewable energy targets for 2020 (Carbon Tracker 2016; IEA 2016a). The country's coal use has declined for three consecutive years, with reductions in coal volume consumption of 2.9%, 3.7% and 4.7% reported in 2014, 2015 and 2016, respectively (National Bureau of Statistics 2015; 2016; 2017). Cities such as

Global CO_2 emissions stalled for the third consecutive year in 2016.

the capital Beijing, which has been plagued by severe air pollution from its coal-fired power stations, closed its last coal-fired plant in 2017 as the push for clean air and clean energy progresses rapidly (Sydney Morning Herald 2017; Figure 5).

Growth in renewable energy is booming across the globe as costs continue to fall rapidly.

- Since 2009, investment in new renewable capacity has passed investment in new capacity for all fossil fuels combined, including coal (REN21 2015).
- In 2016, 139GW of renewable capacity was built worldwide – an 8% increase on the previous year, largely driven by rapidly falling costs (Frankfurt School-UNEP Centre/BNEF 2017).
- 2016 was a record year for the solar photovoltaic (PV) industry, with 75GW of new capacity added, eclipsing the 2015 record of 50GW (Frankfurt School-UNEP Centre/BNEF 2017; Climate Council 2017d; Figure 6).
- The trend of rapidly growing solar PV and wind capacity in 2016 continued a decade of growth. For example, in the last ten years to 2016, wind capacity has grown around the world from 94GW to 467GW, while solar PV capacity grew from 9GW to 291GW (IRENA 2017).

Figure 5: Dense air pollution in China. The country is rapidly transitioning away from a coal-based electricity generation system.

In many parts of the world, renewables are now providing similar- or lower-cost power than fossil fuels. The costs are even lower when health, environmental and climate benefits of renewables, as well as the US$550 billion to $5.5 trillion in subsidies to fossil fuels are considered (IRENA 2015). When comparing new power plants on a cost per kilowatt-hour basis, many renewable energy technologies (biomass, hydropower, geothermal, onshore wind and industrial scale solar PV) are already cost-competitive with fossil fuelled power generation (IRENA 2015), particularly when compared to higher cost, imported thermal power alternatives. Since 2009, wind turbine costs have fallen 30-40%, and solar PV module costs have fallen 80% (IRENA 2016). The cost of power from solar and wind is expected to fall by a further 59% and 26% (respectively) by 2025 (IRENA 2016).

Between 2009 and 2015, the prices of wind turbines fell 30-40% and solar PV modules fell by 80%.

Figure 6: A large-scale solar farm (43MW) in southeastern Europe. More solar PV was added globally in 2016 than in any other year.

Most of the renewable energy growth has occurred in developing countries such as Brazil, South Africa, Mexico and Chile, with China leading the way (IEA 2016b; REN 21 2016). China is undertaking 30-40% of the world's total new investment in clean energy, which employs nearly 3.4 million people, with plans to install about 600GW of renewable power by 2020 (REN21 2015; Figure 7). It is set to invest close to $500 billion into renewable power generation (Deutsche Welle 2017).

India invested US$10 billion in renewable energy in 2015 and again in 2016, a direct result of the Indian government's increased focus on renewable energy, particularly solar power (REN 21 2016). In December 2016 the government of India announced a target for the cumulative installation of 275GW of renewable capacity by 2027, signalling a strong, clear policy shift towards renewables. This is leading to uncertainty concerning India's future use of coal as it aims to become a "renewables superpower" (The Guardian 2014b).

India is investing heavily in renewable energy.

Figure 7: Mulan Wind Farm near Harbin City. China accounts for over a third of global investment in clean energy (REN21 2015).

3. Coal is a Risky Business

Climate change, driven largely by greenhouse gas emissions from fossil fuels, presents a serious challenge to business and industry. As the world transitions to renewables, coal is becoming a risky business, with the possibility of stranded assets and liability for company boards that fail to account for the risks.

As nations worldwide strive towards limiting global temperature rise to less than 2°C, companies face increasing emissions regulation. Furthermore, when making investment decisions in a carbon constrained world, boards will need to consider if the climate risks and damage of those investments will mean assets have a liability and investment is risky. New fossil fuel projects will release more greenhouse emissions, worsening climate impacts, such as heatwaves, droughts and storms, with consequences for economies around the world.

Figure 8: In a carbon constrained world companies face increasing emissions regulation. Investing in new coalmines is a risky business.

3.1. Stranded Assets

Limiting global temperature increase to no more than 2°C above pre-industrial levels requires a drastic and rapid reduction in our economies' dependence on fossil fuels, with their associated greenhouse gas emissions (OECD 2015; University of Oxford 2016). Energy intensive economic activities will have to be retired quickly to make way for renewable energy, battery storage technologies, smart grids and improvements in energy efficiency. As climate policies drive this transition, some assets will become 'stranded' (OECD 2015; e.g. Figure 9). A 'stranded asset' is defined as an "asset that has suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities, and it can be caused by a range of environment-related risks" (Caldecott et al. 2013, p. 7). For example, air pollution and water scarcity in China may strand coal-fired power generation assets, as coal demand declines and affects global coal prices. Lower coal prices can increase the risk that coalmines, reserves and coal-related infrastructure could become stranded assets (Caldecott et al. 2013).

Coal is becoming a risky business, with the possibility of stranded assets and board liability.

Figure 9: Stranded asset. Anglesea coalmine in Victoria closed in 2016 after the coal plant owner Alcoa was unable to find a buyer for the power station (RenewEconomy 2015).

Recognising the risk of stranded assets as the world transitions to a low carbon economy, investors are moving away from putting money in fossil fuel assets, that is, they are 'divesting' (OECD 2015). It is estimated that investors engaged in divestment managed a total of US$50 billion in assets in 2014 and by early 2015 this figure grew to US$2.6 trillion (Arabella Advisors 2015). By December 2016, it is estimated that the value of assets of institutions and individuals committing to divestment from fossil fuel companies was US$5 trillion (Figure 10). One year on from the Paris climate agreement, 688 institutions and 58,399 individuals across 76 countries have committed to divest from fossil fuel companies, doubling the value of divested assets represented in just over a year (September 2015 – December 2016; Figure 10). Pension funds and insurance companies now represent the largest sectors committing to divestment, indicative of the growing financial risks of having fossil fuel investments in a world committed to staying below 2°C global temperature rise (Arabella Advisors 2016).

The significant economic and technological adjustments required to meet the 2°C target is already having a significant impact on fossil fuel companies, energy-intensive activities and asset values (IEA 2014; OECD 2015). This is because the majority of the world's – including Australia's – fossil fuel reserves must remain in the ground, unburned (McGlade and Ekins 2015).

Financial institutions around the world are moving away from fossil fuels. A number of large global banks including JP Morgan Chase, BNP Paribas, Crédit Argricole, HSBC, ING, Natixis, Société Générale have agreed to not directly finance new coalmines around the world (BankTrack 2016). The latter four banks listed have also ended direct financing of new coal power plants. In Australia, the 'Big Four' banks (ANZ, NAB, Commonwealth Bank and Westpac) have withdrawn the possibility of funding Adani's Carmichael coalmine (Holmes 2017).

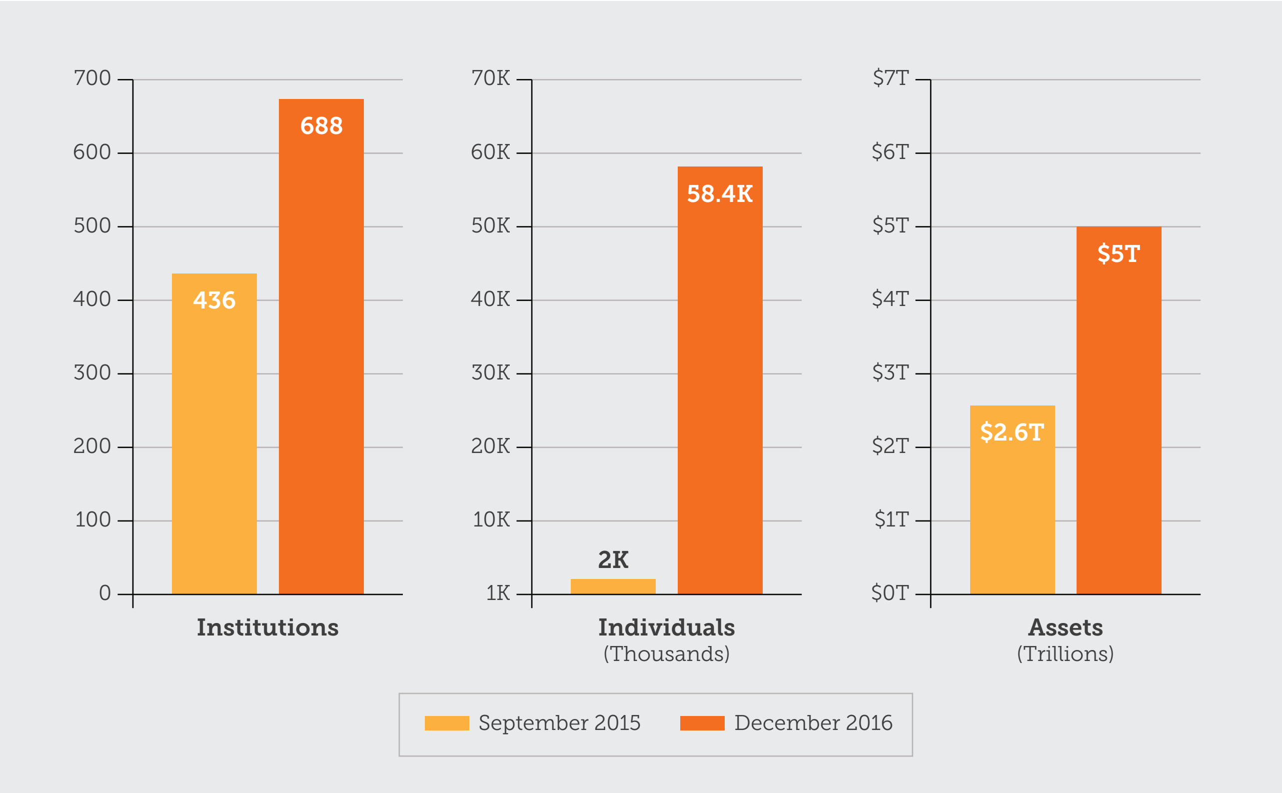


Figure 10: Fossil fuel divestment doubled between September 2015 and December 2016, with an asset value of over US$5 trillion. **Source:** Arabella Advisors 2016.

Governments are also opting for renewables rather than coal. For example, India's draft electricity plan released in December 2016, proposes no new coal-fired power stations in the next decade, while India ramps up renewable energy uptake, with 275GW of new solar and wind power planned by 2027 (Government of India 2016). This means the potential export markets for coal are rapidly dwindling as the world moves away from fossil fuels toward renewable energy. Coal mined at Carmichael in the Galilee Basin is primarily intended for export to India. However, India is experiencing extremely rapid growth in renewables, and is reducing coal imports overall, raising doubts about the projected, long-term market for coal (Climate Action Tracker 2016).

India's extremely rapid growth in renewables is raising doubts about the long-term market for coal.

3.2. Corporate Liability

Major institutions understand the need to tackle climate change. As the impacts of climate change from the burning of fossil fuels become more evident and as we work towards limiting global temperature rise, corporations could face severe liability challenges (The Australian 2017).

Global institutions such as the International Monetary Fund, World Bank, World Economic Forum, Organisation for Economic Co-operation and Development and Carbon Disclosure Project (representing 767 institutional investors with over US$92 trillion of assets under management) recognise the significant economic costs of climate change (Barker 2015). Climate change risks are now a major responsibility of the boardroom (Barker 2015; Horrigan 2016). For example, in 2015, France introduced a change in its Energy Transition Law requiring corporations to disclose climate-related vulnerability and counter-measures adopted. Furthermore, it mandated institutional investors to disclose the carbon exposure of their assets (Assemblée Nationale 2015). Boards in making investments need to consider if the climate risks and damage to those investments will mean assets have liability.

In Australia, the Centre for Policy Development (CPD) describes how companies and their directors now have a legal duty to consider foreseeable climate risks to their business (CPD 2016). Company directors who do not properly consider climate change related risks may be held legally liable for breaching their duty of due care and diligence (McLeod and Wiseman 2016). There is now more law applying to climate change responsibilities of Directors (The Australian 2017). For example, both the ASX Listing Rules and the ASX Corporate Governance Council standards recommend addressing climate change as part of a company's exposure to economic, environmental and social sustainability risks.

Financing the Carmichael could be risky business because:

- Assets risk becoming stranded as the world moves away from coal;
- Building new mines are not compatible with limiting temperature rise to less than 2°C; and
- Burning of coal will release more greenhouse gas emissions into the atmosphere, increasing temperature and worsening climate impacts such as coral bleaching on the Great Barrier Reef and increasing the severity of extreme weather events.

Climate change risks are now a major responsibility of corporations.

3.3. Carmichael Coalmine and Major Australian Industries

Not only is fossil fuel expansion a risky business for corporate boardrooms, proposed new projects, opening new coalmines and increasing coal burning will contribute to further climate change. Australia's agriculture and tourism industries are highly dependent on a stable climate and are at direct risk of further climate change. In addition, the Carmichael mine has been criticised for competing with agricultural interests for water.

AGRICULTURE

Australia's agricultural output as a proportion of the economy remains among the highest in the OECD (ABS 2012). The value of farm production in 2013-14 was worth $51 billion (ABARES 2014) and underpinned Australia's largest manufacturing sector – the food and beverage processing industry, worth $25 billion (ABS 2015). Yet Australia's agriculture industry is vulnerable to a wide range of impacts from the changing climate. Direct impacts of climate change on things like crop productivity (e.g. grains, grapes (Figure 11), fruit, sugar, vegetables) are relatively straightforward to quantify – such as the increased losses from more intense rainfall and storms, reduction in seasonal rainfall and a greater frequency and severity of extreme heat (Climate Council 2015a). Indirect climate impacts include changes to the distribution and incidence of pests and diseases, interruptions to supply chains and transportation networks, as well as altered seasonality and work schedules.

In addition to climate impacts, in recent years, prime agricultural land in some regions has become increasingly subject to competition from mining. In Queensland, local residents are concerned that the New Acland coalmine will affect the economic sustainability of the Darling Downs region by removing prime agricultural land for mining development (Miller et al. 2012; ABC 2015a). Further north, the proposed opening of the Galilee Basin, for example the Carmichael coalmine, has been opposed by landholders concerned about the loss of rangelands for cattle and sheep grazing (Duus 2013; The Sydney Morning Herald 2017).

Figure 11: Australia's wine industry contributes significantly to the Australia economy, but viticulture is highly sensitive to changes in the climate.

Because 90% of groundwater extraction is used in agriculture (Tan et al. 2015), one of the major areas of contention between farming and mining is the impact on aquifers (Lawrence et al. 2013; Tan et al. 2015). Community concerns have resulted in Federal and State governments agreeing to tighten regulations that protect aquifers and limit pollution (Lawrence et al. 2013).

In March 2017, Queensland's Department of Natural Resources and Mines granted an unlimited 60-year water licence to the Carmichael mine (Queensland Government 2017; Moon 2017). With North Queensland (e.g. Townsville area) currently experiencing water restrictions and with variable future rainfall projections (Queensland Government 2016), the provision of unlimited water for one of the largest mining operations in the Southern Hemisphere will no doubt compete with the water needs of the agriculture sector (Moon 2017). According to an environmental impact statement, the mine will draw 26 million litres of water a day from its pits by 2029 as annual production could reach as much as 60 million tonnes (The Sydney Morning Herald 2017). The decision has led to a range of questions about the coal mining industry's water use. For example, in Queensland, mining and industry possess around 1% (by number) of the water licences associated with the Great Artesian Basin but account for 10% of the water extracted.

Carmichael coalmine's unlimited water licence will likely affect agriculture water needs.

Figure 12: Bleached coral (white) and dead coral covered in algae (brown) at Port Douglas, on the Great Barrier Reef in March 2017.

TOURISM

Rapidly warming oceans, driven by the burning of coal, oil and gas, has led to the world's longest global bleaching event on record, beginning in 2014 and ongoing in 2017, with repeated bleaching of the Great Barrier Reef and other reefs worldwide with no reprieve (Figure 12; Climate Council 2017b). The rate of surface ocean warming in the 21st century is seven times faster than during the 20th century and the frequency of extreme sea surface temperature events has increased (Evans et al. 2017). Extreme coral bleaching and the death of reefs will become the new normal unless serious and rapid reductions in greenhouse gas emissions are achieved (Hughes 2016; ABC 2017; Climate Council 2017b).

Conservative estimates show that the observed warm conditions in the Coral Sea that caused the devastating bleaching on the north sector of the Great Barrier Reef in 2016 were at least 175 times more likely to occur because of climate change (King et al. 2016). Climate change is the greatest threat to the Great Barrier Reef.

Australia's reefs are incredibly valuable economic and environmental assets. For example, an estimated 69,000 jobs in the 2011-12 period were reliant on the Great Barrier Reef (Deloitte Access Economics 2013). The Great Barrier Reef contributes around $7 billion to the national economy annually, mainly via tourism (Jacobs 2016). A recent study by The Australia Institute (2016) showed that if coral bleaching persists, tourism areas adjacent to the Great Barrier Reef risk declines in visitors from 2.8 million visitors (2015 figures) to around 1.7 million per year. This is the equivalent of more than $1 billion in tourism expenditure, which supports around 10,000 tourism jobs in regional Queensland (The Australia Institute 2016).

The development of the Carmichael coalmine and the Galilee Basin, is fundamentally at odds with tackling climate change and protecting the Great Barrier Reef. To protect the Great Barrier Reef and Queensland's tourism industry, rather than opening new coalmines, Australia's focus should be to phase out existing coalmines well before their reserves are exhausted.

Climate change is the greatest threat to the Great Barrier Reef.

4. Coal's Impact on Human Health

Particulate air pollution (extremely small particles that can be inhaled into human lungs) caused 4.2 million deaths globally in 2015 (SoGA 2017). The burning of coal is a major source of particulate air pollution (Cohen et al. 2017). For example, in China alone, 366,000 deaths from air pollution in 2013 have been attributed to coal, while in India about 100,000 deaths per year can be attributed pollutants from coal-fired power plants (Guttikunda and Jawahar 2014; HEI 2016).

Coal combustion causes death and a range of human health issues including lung cancer, heart and respiratory diseases.

Every aspect of coal's lifecycle – mining, transportation, combustion and the disposal of waste – produces pollutants that affect human health (Epstein et al. 2011). Health impacts from coal emissions on miners, workers and local communities can be severe (Kizil and Donoghue 2002; Castleden et al. 2011; Armstrong et al. 2013). For example, the risk of premature death for people living within 50 kilometres of coal-burning power plants can be as much as three to four times that of people living at a greater distance (Epstein et al. 2010).

Health risks from coal include lung cancer, bronchitis, heart disease and other health conditions (Temple and Sykes 1992; García-Pérez et al. 2009; Hendryx and Zullig 2009). In Australia, there has been a re-emergence of 'black lung' (coal workers' pneumoconiosis) (ABC 2017b). Black lung disease is caused by long-term exposure to coal dust. As at 27 April 2017, there have been 21 confirmed cases of coal workers' pneumoconiosis in Queensland (Queensland Government 2017).

4.1. Examples of how Coal Affects Health

UNITED STATES

In the United States, coal contributes to four of the five leading causes of mortality: heart disease, cancer, stroke and chronic respiratory diseases (Lockwood et al. 2009). 50,000 deaths each year have been attributed to air pollution from coal fired power generation (Lockwood et al. 2009).

CHINA

Coal combustion is the largest source of air pollution in China, accounting for about 40% of the deadly fine particulate matter (PM2.5) in the atmosphere (HEI 2016). PM2.5 is especially dangerous for health because it is inhaled deeply into the lungs (e.g. Figure 13). In 2013, there were 916,000 premature deaths from air pollution, with 366,000 of these

Coal combustion is the largest source of air pollution in China.

Figure 13: A young coalminer in China. Miners, workers and local communities can suffer serious health consequences from coalmining (e.g. Castleden et al 2011).

deaths attributed to coal (HEI 2016). Observed health effects from coal use in China include respiratory illness and lung cancer (Zhang and Smith 2007). In 2010, approximately 1.9 million people suffered from skeletal fluorosis due to toxic coal based pollutants (Chen et al. 2014). Skeletal fluorosis is a bone disease caused by excessive accumulation of fluoride in the bones (Krishnamachari 1986).

INDIA

In India, to which the coal from Adani's Carmichael mine in Queensland will most likely be exported, there are considerable human health issues associated with air pollution from coal. A recent study of 2010-11 emissions from coal-fired power plants attributes 80,000 to 115,000 deaths to coal-fired power station pollutants and 20 million new cases of asthma (Guttikunda and Jawahar 2014). It is estimated that up to 10,000 children in India under the age of five died because of coal pollution in 2012 alone (Friedman 2013), while in townships close to coalmines, incidence of respiratory illness was found to be higher than in sites not near coalmines (Hota and Behera 2015). Coal from the Galilee Basin is poorer quality than coal from other regions in Australia. It is estimated that the ash content from the planned Carmichael coalmine is about 26%, roughly double the Australian benchmark. This raises health concerns for importing country populations (e.g. India), particularly respiratory illness, heart disease, lung cancer and other health conditions associated with high-ash coal (ABC 2017c).

EUROPE

An estimated 24.5 people die for every terawatt hour of coal electricity produced (Markandya and Wilkinson 2007). Pollutants produced from coal power stations in the European Union caused about 22,900 premature deaths, about 11,800 new cases of chronic bronchitis, and 6.6 million lost working days in 2013 due mainly to respiratory and cardiovascular disease (Jones et al. 2016). Coal plants in the Western Balkans were associated with approximately 7,200 premature deaths (Holland 2016) while Turkish coal plants are attributed a burden of 2,900 premature deaths (Gümüsel and Stauffer 2014). Ecological studies point to elevated prevalence of lung and laryngeal cancer as well as bladder cancer close to coal power stations in Spain (Garcia-Perez 2009), skin cancers and hearing loss in children due to arsenic emitted by one coal plant in Slovakia (Ranft 2003; Pesch 2002; Bencko 2009), as well as elevated lung cancer mortality in women in one location in Italy (Parodi 2004). Atmospheric modelling also shows large trans-boundary transport and health impacts in Europe (Preiss et al. 2013; Jones et al. 2016). In April 2017 EU Member States introduced a new technical regulation called LCP BREF which aims to reduce coal emissions and the associated burden of disease by up to 85% compared to 2013 levels (Schaible et al. 2016).

High ash content of coal from planned Carmichael coalmine poses serious health risks for communities in India.

AUSTRALIA

Despite Australia's dependence on coal for electricity generation – it provides 63% of our electricity supply (Commonwealth of Australia 2016) – there has been limited research into the health impacts of coal mining and power generation in this country compared with Europe and the US (Armstrong and Tait 2014; Selvey 2014). Yet emissions from coalmine fires, like the recent Hazelwood mine fire in Victoria, and the release of heavy metal and organic compounds pose health risks for surrounding populations, such as respiratory and heart disease, cancers and other conditions of ill health. At least 11 and most likely 23 people died directly from the health effects of the Hazelwood mine fire (ABC 2015b) but longer term health consequences from that exposure are hard to estimate. A review of air pollution and cardiopulmonary disease in Australia by Howie et al. (2005) concluded that air pollutants were associated with an increase in cardiovascular and respiratory mortality and hospital admissions, consistent with the international evidence (Colagiuri et al. 2012).

Australia has seen a re-emergence of the deadly 'black lung' disease in Queensland coalminers.

There is a is a lack of consistent monitoring of air, water and soil quality at and around Australian coalmines (e.g. Figure 14). Furthermore, there is a deficiency in research into the effects of coal on Australian communities. Given the extensive work done overseas to quantify the risks and the impacts of coal burning and mining, Australia is well behind similar countries worldwide in understanding the human health impacts on our population (Climate Council 2014).

Following a re-emergence of 'black lung' in Queensland and 21 reported cases (Queensland Government 2016), recent Coal Workers' Pneumoconiosis (CWP) committee interim findings suggest "a massive systemic failure across the entirety of the regulatory and health systems intended to protect coal industry workers" (ABC 2017). A recent survey conducted by Environmental Justice Australia found that about half of 1,507 survey respondents said that the state and federal governments were not adequately responding to the harmful impacts of coal pollution on human health (Clean Air Action Network 2016).

Figure 14: Uncovered coal train wagons in the Hunter Valley, New South Wales.

4.2. The Hidden Costs of Coal

A global study of health indicators spanning 40 years and 41 countries found that there are large, hidden health costs associated with coal consumption (Gohlke et al. 2011). Estimated costs of health damages associated with coal combustion for electricity in Australia amount to $2.6 billion per annum (Beigler 2009). The associated costs of coal and health in Australia relate to, for example, time off work, health care costs for pollution-related chronic disease and early mortality. The annual costs associated with health damages from coal-fired power stations in Hunter Valley, NSW are estimated at $600 million per annum (Armstrong 2015). The global health costs (social cost of carbon) associated with coal from the Hunter region has been estimated at $16-66 billion per annum (Armstrong 2015). In Europe, the health cost of air pollution from coal-fired power stations is €43 billion (A$61 billion) a year. US economists have estimated the health impacts of coal-fired power stations in the US to be between one and six times its value added (Muller et al. 2011). In India, it is estimated that the health costs associated with pollution from coal-fired powered stations costs the Indian government US$3.2-4.6 billion (Guttikunda and Jawahar 2014).

Recognising the adverse effects of air pollution on human health from the combustion of fossil fuels for electricity, transport, agriculture and other human activities, the World Health Organization recommends a reduction in energy sector-related emissions and a greater uptake of renewable technologies (e.g. solar and wind) and improved energy efficiency. Air pollution is a major environmental health problem affecting everyone in both developed and developing countries (Lelieveld et al. 2015). By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma (WHO 2016; Cohen et al. 2017), thereby reducing the significant economic costs associated with the health burden of fossil fuels, including coal.

Coal's impact on Australian's health is an astounding $2.6 billion per year.

5. So Where Does This Leave Galilee Basin Coal?

Once completed, the Carmichael mine will be Australia's largest coalmine and would have a potential lifetime of 25 to 60 years (ABC 2016). Opening up the Galilee Basin for coal mining is completely at odds with protecting Australians, infrastructure, industry and ecosystems (Figure 15).

More emissions from new fossil fuel projects will expose Australia to more intense extreme weather events including bushfires, heatwaves and storms. The Great Barrier Reef and the millions of tourists it attracts each year is at even greater risk if mining goes ahead. Competition for water from within the mining industry places pressure on the agriculture sector. Furthermore, exploiting the Galilee Basin coal deposits could also drive major local and regional impacts, ranging from groundwater contamination, biodiversity loss, social impacts on local communities, and damages to human health (Duus 2012).

One argument pushed by proponents of opening up the Galilee Basin is that the world is better off using Galilee coal rather than lower energy content coal from India, and that opening the Galilee is therefore doing a service to the poor of India. Both are fact-free assertions that ignore the fact the cost of imported thermal coal is 2-3 times that of domestic Indian coal even after adjusting for energy content differentials (India wholesales thermal coal for an average US$20/tonne in 2016 vs the Newcastle export benchmark at US$80/tonne) (RenewEconomy 2014; Australian Financial Review 2016; IEEFA 2016). Further, it is not the access to electricity that is preventing India's poor from solving energy poverty, it is that the cost of the product is prohibitive and/or the electricity grid does not extend to many

Coal has no future if we are to protect our way of life.

Figure 15: Abbot Point Coal Terminal in Gladstone, surrounded by wetlands and coral reef. This may become one of the world's largest coal ports if the coal terminal expansion goes ahead.

regions in the poorest areas of India. Coal also causes early death and reduces work productivity, therefore contributing to the maintenance of poverty. Death and ill health from air pollution can be substantially lowered with emission reductions of major sources of pollution.

For effective action on climate change, under any set of assumptions or uncertainties, Galilee Basin coal is unburnable. Over 90% of coal in Australia's existing reserves must stay in ground (McGlade and Ekins 2015). Thus, the most pressing challenge we face is to phase out existing coalmines, well before their deposits are exhausted. There is no basis for developing any potential new coalmines, no matter where they are or what size they are. If all of the Galilee Basin mines are developed to their maximum potential, it is estimated that over 700 million tonnes of CO_2 would be released to the atmosphere each year (Greenpeace 2012), which is more than 1.3 times Australia's current annual emissions (Australian Government 2016). If the Galilee Basin were a country on its own, it would rank in the top 15 emitting countries in the world.

Australia has an important choice to make. We can advance our economy while protecting our population from climate impacts without losing ground to trading allies, partners and competitors who are transitioning rapidly to renewables.... or we can fall behind the rest of the world and continue to back polluting and expensive energy. Both China and the US have demonstrated that the economy can grow while ramping up investment in renewable energy. As the world transitions to renewables, coal is becoming a risky business, with the possibility of stranded assets and board liability. Recognising this risk of stranded assets as the world transitions to a low carbon economy, investors have already begun divesting from fossil fuel assets (OECD 2015).

Fortunately, Australia is a country of huge potential for renewable energy. Australia has the potential to generate 100% of our electricity from renewables (CSIRO and Energy Networks Australia 2017). Our renewable energy resources are among the best in the world, potentially capable of providing 500 times the amount of electricity we currently use (Commonwealth of Australia 2014; AEMO 2013). However, compared to similar countries, Australia has one of the lowest levels of renewable electricity generation (ESAA 2015), accounting for just 15% of Australia's electricity in 2015 (Clean Energy Council 2016). Nevertheless, there are a number of exciting large-scale renewable energy projects under construction or starting in 2017, totalling more than 3.5GW, worth $7.4 billion and providing 4100 jobs (Clean Energy Council 2017), including projects in North Queensland near the proposed Carmichael coalmine.

The exploitation of Galilee Basin coal would be bucking a global trend of transitioning away from fossil fuels to renewable energy. There are two undeniable trends – an accelerating uptake of renewable energy and coal plant closures. For Australia to fight these trends is economically, socially and environmentally unwise and counterproductive. Rather, we need to be preparing for – and indeed joining, facilitating and accelerating – this transition to a clean energy world. The future is in renewable energy, storage, smart grids and energy efficiency. Now is the time for action.

Australia's renewable energy resources could provide 500 times the amount of energy we currently use.

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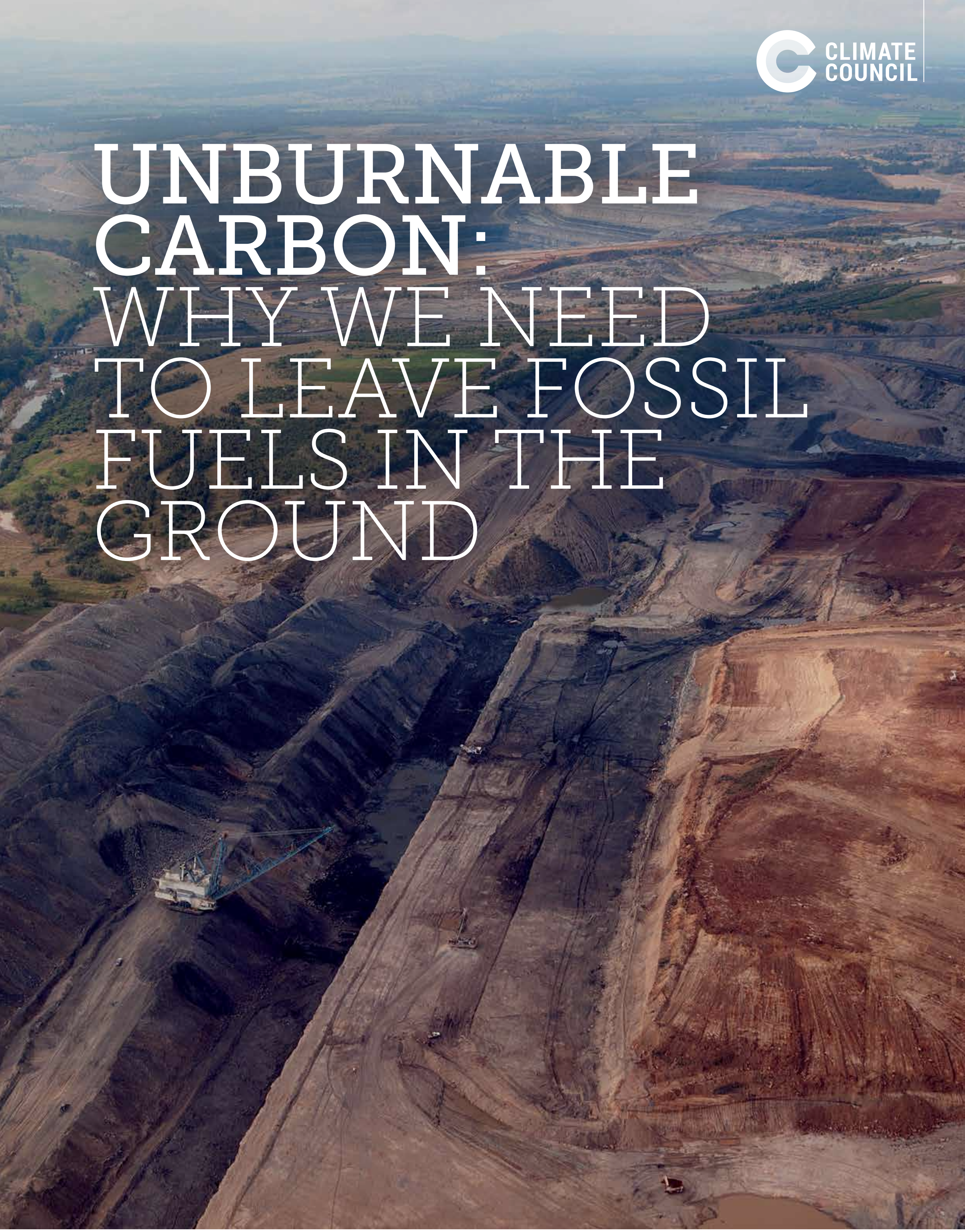
CLIMATE COUNCIL

UNBURNABLE CARBON: WHY WE NEED TO LEAVE FOSSIL FUELS IN THE GROUND



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Preface

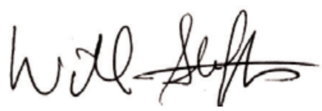
The Climate Council is an independent, non-profit organisation, funded by donations from the public. Our mission is to provide authoritative, expert information to the Australian public on climate change.

The international community has agreed to limit an increase in global average temperature to no more than 2°C. If we are to have any chance of meeting this target, we need to rapidly reduce our carbon emissions and transition towards a decarbonised society. This report describes an approach - the carbon budget – to track progress against this goal. The carbon budget is a simple, scientifically-based method to determine how much carbon humanity can "spend". The higher the probability of meeting the warming limit, the more stringent the budget. That is, the less carbon we can spend.

The carbon budget has important implications for Australia, a major fossil fuel producer and exporter. The report explores the challenges and opportunities for Australia in a carbon-constrained world before concluding how, with the carbon budget rapidly running out, the opportunities that an energy system based on renewables offers a bright future for Australia.

The Climate Council is extremely grateful to our team of reviewers whose comments and suggestions improved the report. The reviewers were: Tim Buckley (Institute for Energy Economics and Financial Analysis), James Leaton (Carbon Tracker Initiative) and Ian Dunlop (Independent commentator & Member, the Club of Rome. Former Chair of the Australian Coal Association, CEO of the Australian Institute of Company Directors and senior oil, gas & coal industry executive). We thank CSIRO for reviewing the accuracy and relevance of the science underpinning this report. Their review is not an endorsement of the conclusions drawn.

The author retains the sole responsibility for the content of this report.



Professor Will Steffen
Climate Councillor

Introduction

Scientists have been warning for decades that rising global temperatures, driven by carbon emissions, will have very harmful, and perhaps catastrophic, consequences for humanity. In response, governments the world over have agreed to keep global temperature rise to no more than 2°C above pre-industrial. While 2°C may not sound like much, it is a very substantial change to the Earth System and will have serious impacts on the lives and livelihoods of people world-wide. A good analogy is to the human body, where a 2°C rise in temperature is the difference between health and hospitalisation.

With just 0.85°C of warming we have already witnessed adverse consequences. In Australia hot days have doubled in the last 50 years, while heatwaves have become hotter, last longer and occur more often. Heatwaves are the most significant natural hazard in Australia in terms of loss of life and the elderly, the very young, and those with chronic disease are most at risk. Similarly, extreme fire weather has increased over the last 35 years in southeast Australia, putting people and property at risk. Property and infrastructure across Australia has been built for previous climatic conditions and much of it is ill-prepared to cope with increasingly frequent and/or intense extreme weather. For instance, over $226 billion in commercial, industrial, road and rail and residential assets around Australian coasts are potentially exposed to rising sea levels over the next 85 years.

A 2°C rise in temperature has long been considered a threshold that should not be crossed given the potential for catastrophic consequences. For instance, the threshold to trigger the melting of the Greenland ice-sheet, which would eventually raise sea level by about 7 metres, inundating major cities world-wide, lies between a 1 and 4°C rise, with the risk increasing through that temperature range. Moreover, as scientific knowledge has improved, it is clear that other risks previously anticipated to lie only above 2°C may well occur at lower temperatures.

"With the carbon budget rapidly running out, it is urgent that global emissions begin to track downward in the next few years."

Rising greenhouse gas emissions, primarily from the burning of coal, oil and gas, drive climate change. The most important gas is carbon dioxide, denoted in this report as CO_2. To tackle climate change the solution is simple: we need to reduce CO_2 emissions to virtually zero by the middle of the century, requiring a rapid rate of reduction from now. Furthermore, investment needs to switch rapidly and decisively away from fossil fuels to renewable energy systems.

This report considers the consequences of a 2°C rise in temperature and how much CO_2 we can emit and still have a good chance of staying below that limit.

To help governments create robust climate change policies based on science, the "carbon budget approach" has been developed. Analogous to a household budget, the budget tells us how much CO_2 can we "spend" and not exceed a 2°C rise in temperature.

How big the budget is depends on how determined we are to stay below a 2°C rise in temperature. Section 2 details a number of different scenarios based on the probability of avoiding a 2°C rise in global temperature. The bigger the budget, the greater the likelihood of crossing the 2°C threshold. The more stringent the budget, the higher the probability of avoiding crossing that threshold.

Section 3 explores what the carbon budget means for the use of fossil fuels, the primary contributor to climate change.

The inevitable conclusion from the commitment by the world's governments to protect humanity from climate change is that the vast bulk of fossil fuel reserves cannot be burned. To have just a 50:50 chance of preventing a 2°C rise in global temperature: 88% of global coal reserves, 52% of gas reserves and 35% of oil reserves are unburnable and must be left in the ground. Put simply, tackling climate change requires that most of the world's fossil fuels be left in the ground, unburned.

What does this mean for large-scale new fossil fuel developments? Developments like the Galilee Basin in Australia, the tar sands in Canada and new resources in the Arctic cannot be developed if we are to prevent a 2°C rise in temperature.

What does this mean for governments? Energy policies that continue to support substantial fossil fuel use are inconsistent with tackling climate change.

What does this mean for Australia? If all of Australia's coal resources were burned, it would consume two-thirds of the global carbon budget based on a 75% chance of meeting the 2°C warming limit. For Australia to play its role in preventing a 2°C rise in temperature requires over 90% of Australia's coal reserves to be left in the ground, unburned. Similarly, the development of new coal mines, particularly the Galilee Basin, is incompatible with tackling climate change. Instead, if developed, they could well become stranded assets in a world that is rapidly cutting carbon emissions.

The international community has agreed to limit an increase in global average temperature to no more than 2°C. And if we are to have any chance of meeting this target, then we need to rapidly reduce our carbon emissions and transition towards a decarbonised society. This year in the lead up to the Paris climate talks, countries will announce their emission reduction targets for 2020 and beyond. The carbon budget will be an important tool in ensuring these targets are grounded in science.

While it is certainly a big challenge to reduce our fossil fuel dependency, there are also economic opportunities in moving to new sources of power. For example, many of Australia's coal-fired power plants are nearing the end of their lifetimes and are inefficient. Simultaneously, the costs of renewable energy technologies such as solar PV and wind continue to fall.

With the carbon budget rapidly running out, it is urgent that global emissions begin to track downward in the next few years. To have any chance of preventing a temperature rise of no more than 2°C, it is clear that new investment in fossil fuels, especially in coal, needs to be reduced to zero as soon as possible. There is no time to lose; now is the time to get on with the job.

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Key Findings

1. To tackle climate change, 195 countries around the world, including Australia, have agreed to keep global temperature rise to no more than 2°C.

› Already at a global temperature rise of less than 1°C, climate change is making many extreme weather events in Australia significantly worse. For instance, hot days have doubled in the last 50 years, while heatwaves have become hotter, last longer and occur more often.

› A 2°C rise in global temperature will have serious impacts on the lives and livelihoods of many people world-wide, and could trigger major changes in the Earth System. For instance, a 2°C rise could trigger the melting of the Greenland ice-sheet, which would eventually raise sea level by about 7 metres, inundating major cities world-wide.

2. Most of the world's fossil fuel reserves must be left in the ground, unburned, to keep global temperature rise to no more than 2°C.

› The carbon budget is a scientifically based method to determine how much carbon humanity can "spend". The higher the probability of limiting warming to no more than 2°C, the more stringent the budget.

› To have a 50% chance of meeting the 2°C warming limit at least 62% of the world's fossil fuel (oil, gas, coal) reserves must be left in the ground, unburned. To have a 75% chance of meeting the 2°C warming limit, at least 77% of the world's fossil fuels cannot be burned.

› Coal is the fossil fuel with the greatest proportion that cannot be used; 88% of global reserves are unburnable.

3. Australia is potentially a huge contributor to global CO_2 emissions through domestic use and exports. Use of our coal must be severely constrained to tackle climate change effectively.

- If all of Australia's coal resources were burned, it would consume two-thirds of the global carbon budget (based on a 75% chance to meet the 2°C warming limit).
- It is likely that over 90% of Australian coal reserves are unburnable under even the most generous carbon budget.
- Exploitation of Australia's Galilee Basin coal deposits is incompatible with effective action on climate change.

4. The remaining carbon budget is decreasing rapidly. This is the critical decade to get emissions tracking downwards and to move investment away from fossil fuels.

- Energy policies that support substantial fossil fuel use are inconsistent with tackling climate change. Huge new fossil fuel developments, like the Galilee Basin in Australia, the tar sands in Canada and new resources in the Arctic, cannot be developed.
- To have any chance of meeting the 2°C policy target, new investment in fossil fuels, particularly in coal, needs to be reduced to zero as soon as possible.
- To be consistent with the carbon budget approach, Australia needs to move to an emissions reduction target of 15% below 2000 levels by 2020, and to a 40-60% reduction below 2000 levels by 2030.
- Meeting the carbon budget also presents opportunities for the Australian economy by replacing its ageing, inefficient fleet of power stations with modern, clean renewables and by shifting our export industries to low-carbon primary products and minerals.

1. RISKS OF A 2°C RISE IN TEMPERATURE

1.1 Setting a limit to the level of climate change

The imperative to avoid a level of climate change that would have "dangerous" impacts on human society has been recognised by the 195 countries, including Australia, that are signatories to the United Nations Framework Convention on Climate Change (UNFCCC 2008). The UNFCCC has proposed that the collective global aim should be to limit the human-driven increase in average temperature to no more than 2°C above pre-industrial levels (UNFCCC 2010).

There is now, however, an enormous body of evidence that climate change is already having increasingly negative impacts on almost every aspect of human society, as well as the environment that supports us (IPCC 2014). In Australia, annual average temperature over the continent has risen by 0.9°C since 1910 - not quite halfway to the 2°C warming limit - yet even at this seemingly modest increase in average temperature, climate change is already making many extreme weather events significantly worse (CSIRO and BoM 2015).

Since 1971 heatwaves in Australia are occurring more often and are lasting longer, and the hottest day in a heatwave is becoming even hotter (Perkins et al. 2012; Perkins and Alexander 2013). In southeast Australia the bushfire season is becoming longer, and the area burned by bushfires has increased over the past 35 years (Bradstock et al. 2013; Figure 1). An increase in heavy rainfall events across the continent has been observed (CSIRO and BoM 2015). A long-term drying trend in the cooler months of the year is affecting southwest Western Australia and the southeast of the continent (CSIRO and BoM 2015). Coastal flooding from extreme sea-level events has increased three-fold at Sydney and Fremantle since the mid-20th century (Church et al. 2006). The risks that this worsening of extreme weather events creates for our health, communities, infrastructure, economy and livelihoods, and natural ecosystems is well documented (e.g., Field el al. 2014).

"The world's countries have agreed to keep global temperature rise to no more than 2°C."

Observations in Australia and around the world of significant impacts already at less than a 1°C rise in global average temperature (Field et al. 2014) means that the scientific underpinning for the 2°C warming limit as a "safe" level of climate change is now weaker than it was a decade ago. In fact, the scientific case for

Figure 1: Forest bushfire damage in Matlock, Victoria.

"Climate change is already making many extreme weather events significantly worse."

a limit below 1.5°C, as proposed by the small island states (UN-OHRLLS 2014), is more consistent with our current level of understanding.

Many small island states are extremely low-lying and are vulnerable to even modest changes in climate. For example, even small sea-level rises in the future will threaten many Pacific and Indian Ocean island communities, as well as Torres Strait island communities within Australia (Figure 2). Inundation from rising sea levels affects houses, roads, water supply, power stations, sewage and stormwater systems, cultural sites, cemeteries, gardens, community facilities and ecosystems, and is often accompanied by severe erosion. Even at a 1.5°C rise in global average temperature, climate change threatens the lives, livelihoods, and unique cultures of many small island communities (Green et al. 2010; Suppiah et al. 2010; Climate Council 2014). Therefore, at the UNFCCC Conference of the Parties (COP16) in Cancun in 2010, the Alliance of Small Island States (AOSIS) felt that any target other than to limit global average temperature rise to below 1.5°C would undermine the survival of these vulnerable communities (Tschakert 2015).

Figure 2: Coastal flooding in Saibai Island in the Torres Strait.

Nonetheless, the 2°C "warming limit" provides an agreed and clearly defined policy target that would prevent even more serious impacts affecting most people and countries around the globe. This has given nations and policymakers the capacity to craft a response to climate change. However, as scientific understanding has improved, it is increasingly clear that the risk of very significant changes to the climate system - some of them catastrophic for some communities, regions and countries - may occur at lower temperatures than previously thought.

To synthesise and communicate the observed and projected impacts of climate change at various levels of temperature rise, the Intergovernmental Panel on Climate Change (IPCC) has developed the "reasons for concern" approach (Smith et al. 2001). This approach, described graphically in what has been called the "burning embers diagram", is based on a small number of broad areas where climate change is either already driving observable impacts or is projected to pose major risks for human well-being (Figure 3).

The reasons for concern include (i) extreme weather events, where the influence of climate change is already apparent (IPCC 2012, 2013), (ii) the risks to unique and threatened ecosystems, (iii) the local and regional distribution of

"As science improves, it is clear that the risks previously anticipated above 2°C may well occur at lower temperatures."

impacts (e.g., showing relatively larger impacts on disadvantaged communities and countries), (iv) the aggregation of impacts to the scale of the global economy and Earth's biodiversity, and (v) the risk of crossing thresholds or tipping points in large-scale features of the climate system, called "large-scale discontinuities" in the figure. These tipping points, or "large-scale discontinuities", are described in more detail below. The figure is coloured from white through yellow to red, where increasing red tones denote increasing risk of damaging impacts.

Figure 3 consists of three panels, representing assessment of impacts or risk at three different times – 2001 (IPCC Third Assessment Report; Smith et al. 2001), 2007 (IPCC Fourth Assessment Report; Smith et al. 2009) and 2014 (IPCC Fifth Assessment Report 2014). The 2°C policy target is shown as a horizontal line, referenced to the pre-industrial estimate of global average temperature. Three features stand out in a comparison of the three panels.

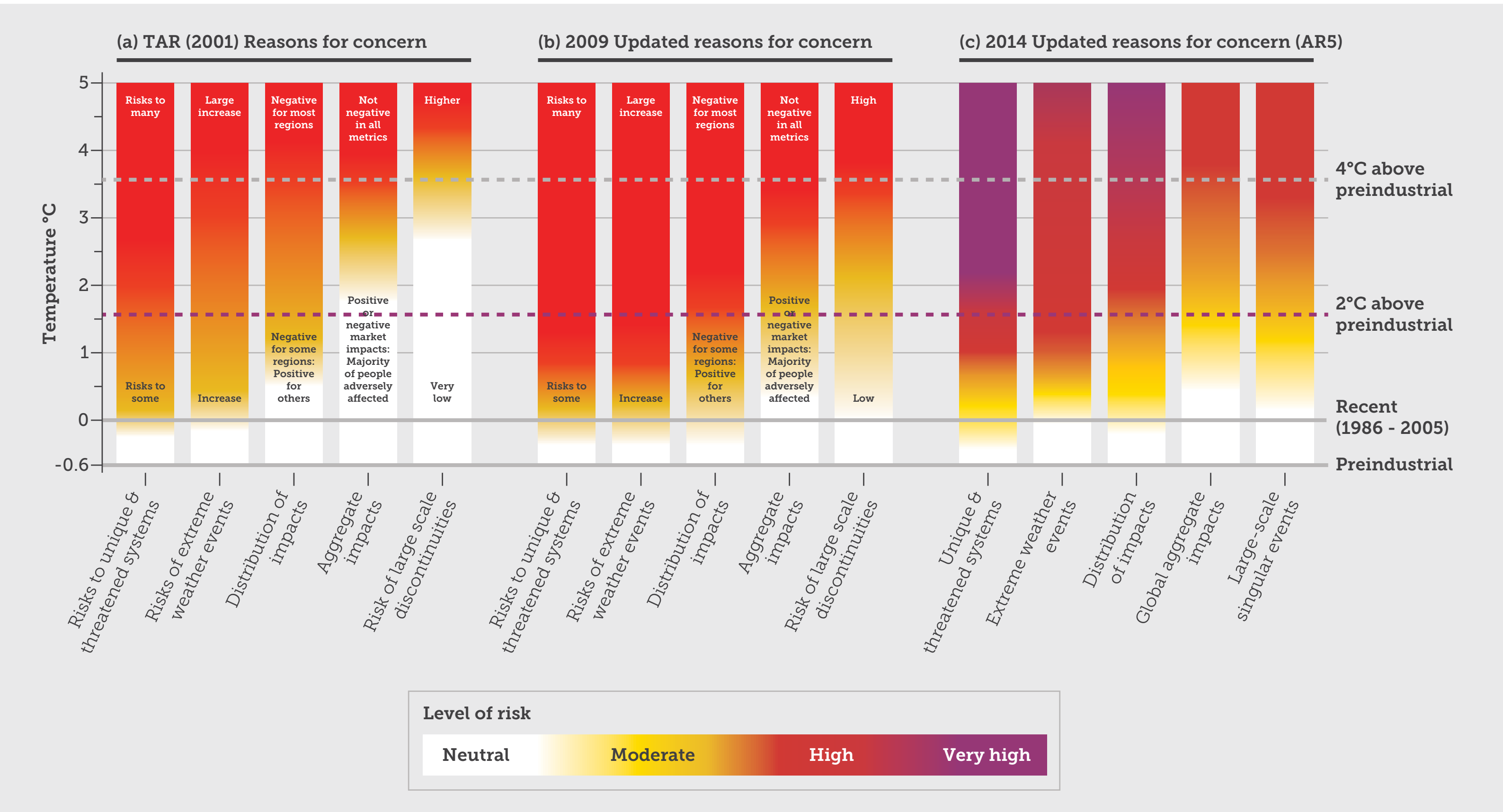


Figure 3: Risks from climate change by reason for concern (RFC) for 2001 compared with the updated data for 2009 and for 2014. Climate change consequences are plotted against increases in global mean temperature (GMT) (°C) after 1990. Each column corresponds to a specific RFC and represents additional outcomes associated with increasing global mean temperature. The colour scheme represents progressively increasing levels of risk. The historic period 1900 to 2000 warmed by about 0.6°C, which led to some impacts. (A) RFCs adapted from the IPCC Third Assessment Report as described in Smith et al. (2001); (B) Updated RFCs adapted from IPCC Fourth Assessment Report as discussed in Smith et al. (2009); (C) Updated RFCs adapted from the IPCC Fifth Assessment Report (IPCC 2014).

First, as the science improves, our assessment of risk changes. The enhanced knowledge base includes observations of actual impacts at the current temperature rise of about 0.85°C above pre-industrial, as well as improved modelling capability to project future impacts. For example, as the science has improved between 2001 and 2014, the scientific assessment of the risks of global warming between 1 and 2°C have been elevated (Figure 3). For example, in 2001 the expected risk of increasing extreme weather with a rise of between 1 and 2°C in global temperature was considered moderate. Today the risk is considered high. Risks to unique and threatened ecosystems, like coral reefs, at 1 to 2°C of warming were considered moderate in 2001. Today the risk is high. Globally aggregated impacts were estimated at the low end of the risk scale in 2001 whereas they are now assessed as the moderate risk level.

"In 2001 the expected risk of increasing extreme weather with a rise of between 1 and 2°C in global temperature was considered moderate. Today the risk is considered high."

Second, as discussed above, the scientific underpinning for the 2°C policy target as a "safe" level of climate change is now weaker than it was a decade ago, and the scientific case for the 1.5°C limit is more consistent with our current level of understanding.

Third, at a 2°C temperature rise, we are now closer to the risk of crossing thresholds or tipping points, or "large-scale discontinuities" as they are called in Figure 3. These refer to large features of the climate system that are prone to abrupt and/or irreversible change when a critical threshold level of temperature rise is reached. Examples include loss of the Greenland ice-sheet, the partial conversion of the Amazon rainforest to a savanna or grassland, and the large-scale emission of CO_2 and methane from thawing permafrost. Each of these examples would cause further disruptions to the climate system, with knock-on effects for human societies. For instance, melting of the Greenland ice-sheet would eventually raise sea level by approximately 7 metres (Church et al. 2013), committing humanity to continuously rising sea levels for centuries or millennia, devastating major coastal cities world-wide as their limits to adapt to coastal flooding were exceeded. While large uncertainties surround the position of many of these tipping points, a few are becoming better

Figure 4: Northwest Greenland sea ice.

understood. For example, the tipping point for the Greenland ice-sheet (Figure 4) is estimated to lie within a temperature rise of 1°C and 4°C above pre-industrial (Church et al. 2013). Potential emissions of CO_2 and methane from melting permafrost in the northern high latitudes (e.g., Siberia, Alaska), which can accelerate climate change, are assessed to be in the range of 50 to 250 billion tonnes of carbon over the 21st century under the highest emissions scenario (Ciais et al. 2013). By comparison, current human emissions of carbon averaged about 10 billion tonnes per year (or about 36 billion tonnes if measured as CO_2) over the most recent decade (Le Quéré et al. 2014).

This recent knowledge is now included in the 2014 burning embers diagram, where a moderate risk of crossing large-scale tipping points exists in the 1.5-2°C range and very high risk in the 3-4°C range. In contrast, in 2001 there was negligible risk of crossing tipping points up to a temperature rise of 3°C and a high risk did not appear until above 4°C.

In summary, the more we know about climate change, the riskier it looks, including at a temperature rise of 2°C above pre-industrial. This observation (i) underscores the urgency in stabilising the climate system as soon as possible to minimise the high-end risks; and (ii) emphasises the need to dramatically reduce CO_2 emissions from fossil fuel combustion.

“It is clear that a 2°C rise in global temperature will have serious impacts on the lives and livelihoods of many people world-wide.”

1.2 Measuring progress towards meeting the 2°C warming limit

To track emissions against the warming limit, the most commonly used method in the policy world is the "targets and timetables" approach, which is based on a target reduction in greenhouse gas emissions by a certain date or over a specified period. Examples of targets and timetables include China's target of peaking its total greenhouse gas emissions by 2030 (The White House 2014), the United States target of reducing emissions by 26-28% by 2025 against a 2005 baseline (UNFCCC 2015), and Australia's target of reducing emissions by 5% by 2020 against a 2000 baseline (Commonwealth of Australia 2013).

The scientific rationale for this approach is based on achieving the level of greenhouse gas concentrations in the atmosphere that correspond to the 2°C warming limit, and from that, determining the amount of emission reductions that are required to stabilise the atmospheric concentration at the desired level.

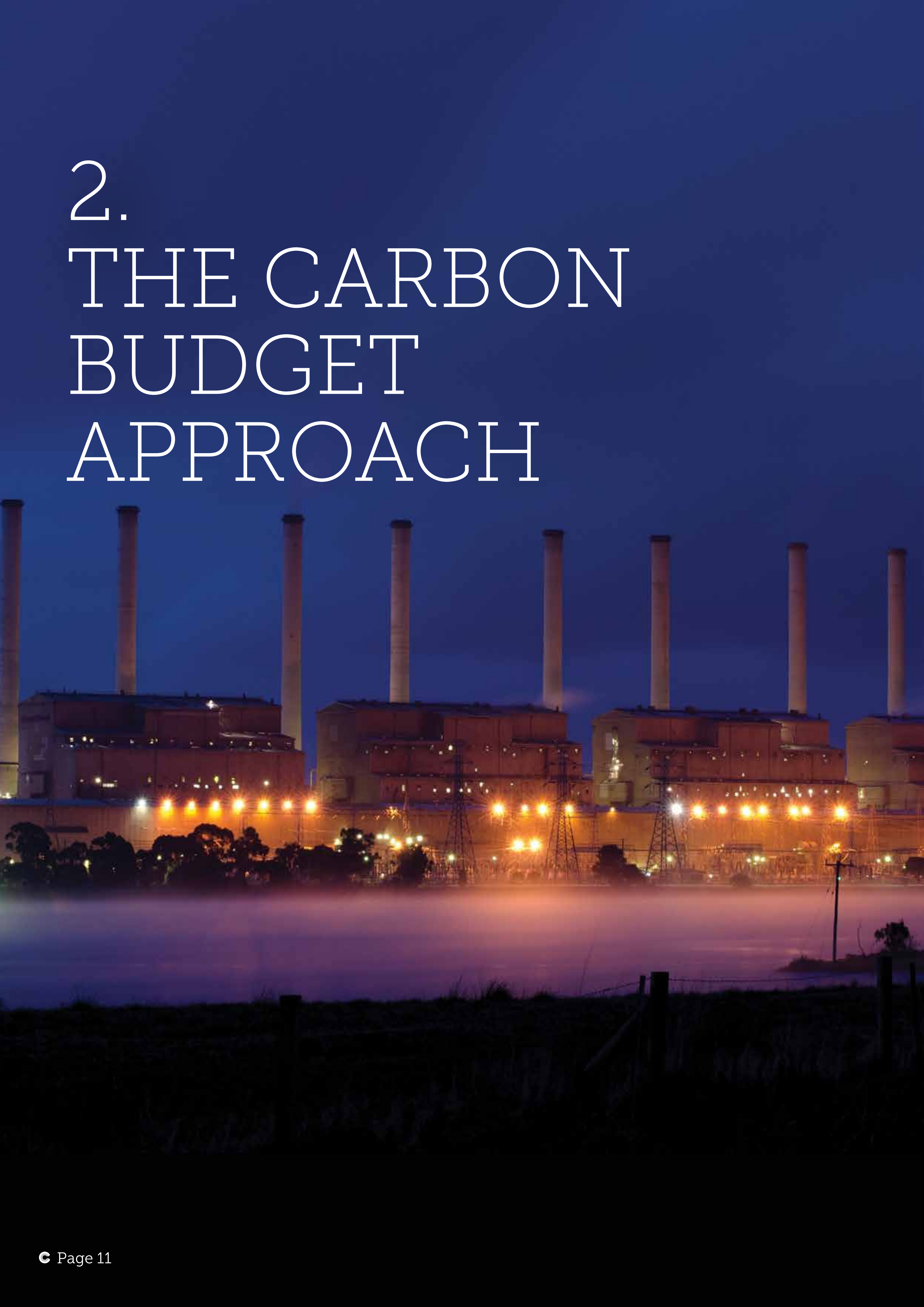
In practice, this approach is far more complex than it appears on the surface because national commitments can vary in many ways.

These include:

- the greenhouse gases included in the commitment.
- whether the promised emission reduction is expressed in absolute amounts (e.g., tonnes) of greenhouse gases or expressed as a percentage reduction.
- the baseline year against which the reduction is to be applied.
- whether a percentage reduction applies to actual emissions or to the 'emission intensity' of the economy, that is, the amount of emissions per unit economic activity.
- whether the reductions are applied against a business-as-usual (high emissions) scenario or against some other future scenario.

The complexity of the targets-and-timetables approach, especially the number of variations, makes it difficult to compare the level of effort of one country against another and to assess the aggregated effect of all countries' efforts in terms of their effectiveness in stabilising the climate system. For example, it is not easy to compare the "level of effort" of China, the United States and Australia based on their individual policy approaches.

2.
THE CARBON BUDGET APPROACH



The carbon budget approach was developed by scientists to build a clearer picture of the level of global effort required to stabilise the climate system. It is a conceptually simple approach based on the observation that the level of temperature rise is directly related to the cumulative amount of CO_2 that is emitted to the atmosphere (Figure 5; IPCC 2013; Meinshausen et al. 2009).

The carbon budget is defined as the maximum amount of CO_2 from human sources that can be released into the atmosphere to limit warming to no more than 2°C above pre-industrial levels. That is, the carbon budget is the amount of CO_2 that humanity can "spend". Once the carbon budget is spent, global emissions of CO_2 must be zero; the global economy must be completely decarbonised.

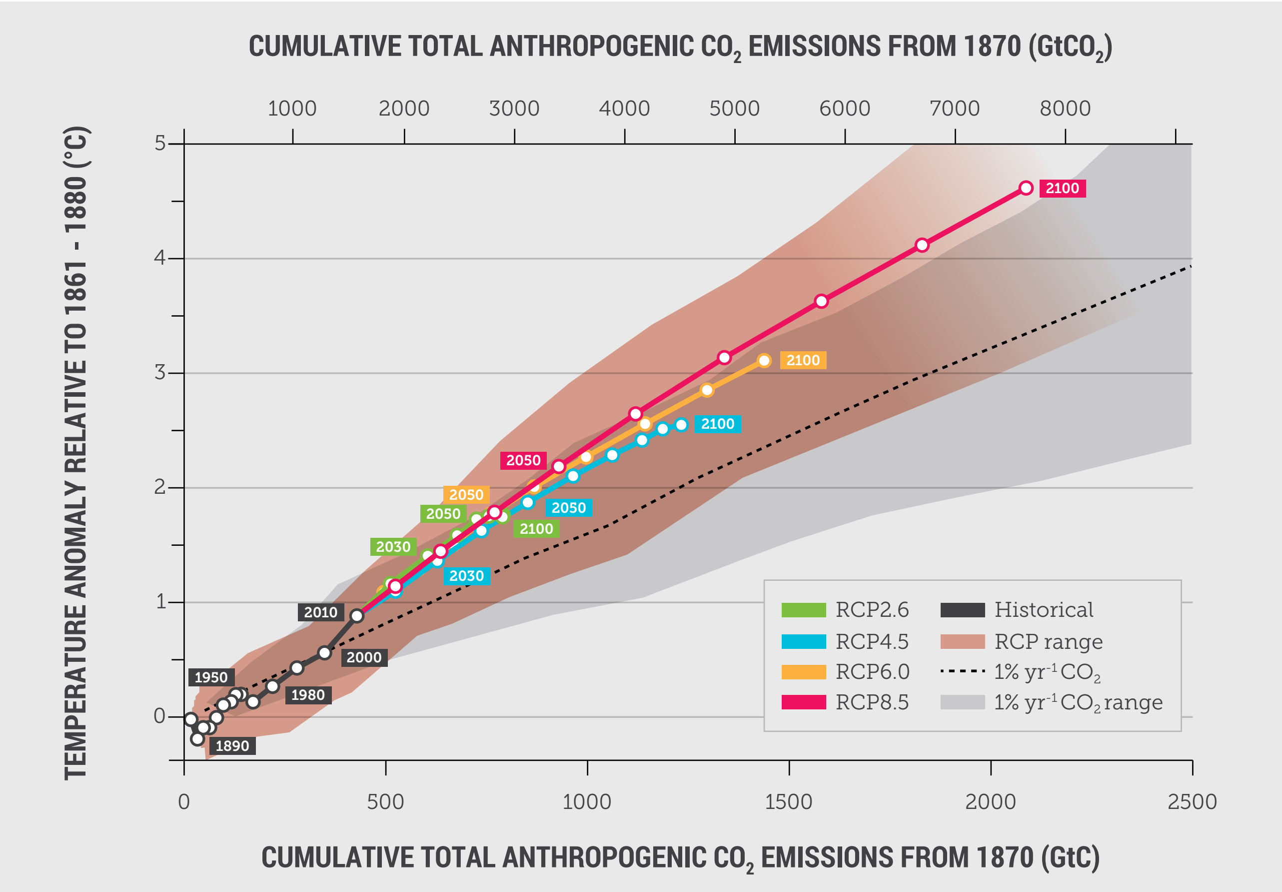


Figure 5: Global mean surface temperature increase as a function of cumulative total global CO_2 emissions from various lines of evidence. Multi-model results from a hierarchy of climate-carbon cycle models for each RCP (emission scenario) until 2100 are shown with coloured lines and decadal means (dots). Some decadal means are labeled for clarity (e.g., 2050 indicating the decade 2040-2049). Model results over the historical period (1860 to 2010) are indicated in black. The coloured plume illustrates the multi-model spread over the four RCP scenarios and fades with the decreasing number of available models in RCP 8.5. The multi-model mean and range simulated by CMIP5 models, forced by a CO_2 increase of 1% per year (1% yr^{-1} CO_2 simulations), is given by the thin black line and grey area. For a specific amount of cumulative CO_2 emissions, the 1% per year CO_2 simulations exhibit lower warming than those driven by RCPs, which include additional non-CO_2 forcings. Temperature values are given relative to the 1861-1880 base period, emissions relative to 1870. Decadal averages are connected by straight lines. **Source:** Adapted from IPCC (2013).

Figure 6: Coal loading at Korragang Island, NSW.

"The carbon budget is the amount of CO_2 that humanity can "spend"."

The Intergovernmental Panel on Climate Change (IPCC) summarised the carbon budget approach in its Fifth Assessment Report (IPCC 2013). Two critical features that affect the precise carbon budget are (i) the desired probability of meeting the 2°C warming limit, and (ii) the treatment of the non-CO_2 "forcing" factors that also contribute to the warming of the climate system.

The various carbon budgets are summarised in Table 1, showing two reference dates for the start of the budget (2000 and 2012) and three probabilities for meeting the budget. The budgets in Table 1 take into account the contribution of the non-CO_2 greenhouse gases to the warming of the climate. The budget constricts considerably when the probability of not exceeding the 2°C warming limit is increased from 50% (a toss of the coin) to 66% and 75%; from 2012 the carbon budgets based on these three probabilities are 1112, 1010 and 672 billion tonnes of CO_2, respectively. If a greater than 75% probability of not exceeding the 2°C warming limit is desired, the carbon budget drops sharply to values much lower than 672 Gt CO_2. For example, if a more risk-averse approach is taken (say, greater that 90% probability of not exceeding the 2°C policy target), then the carbon budget becomes very much smaller. As noted current human emissions of CO_2 are about 36 billion tonnes per year (Figure 5) (Le Quéré et al. 2014).

Two additional assumptions may also affect the budget. First, the approach assumes that the current strength of the

Table 1: The carbon budget for three probabilities of meeting the 2°C warming limit.

Probability of meeting 2°C policy target	Budget from 2000 Gt CO_2	Budget from 2012 Gt CO_2
50%	1440	1112
66%	1338	1010
75%	1000	672

Sources: IPCC (2013) and Meinshausen et al. (2009).

carbon "sinks" on land and in the ocean will remain the same as measured by the fraction of emissions. "Sinks" refer to the removal of CO_2 from the atmosphere by natural processes and its storage on land (vegetation and soils) and in the ocean. Sinks are important because the CO_2 is then not in the atmosphere trapping heat and contributing to global temperature rise.

The "strength" of a sink refers to how much CO_2 the land or ocean can remove and store. At present, these two sinks remove slightly more than half of the CO_2 that is emitted to the atmosphere from human activities (Le Quéré et al. 2014). There are concerns that these sinks could weaken. That is, as emissions continue to rise, the land and ocean sinks may remove proportionally less CO_2.

The future trajectory of these two sinks can be projected by Earth System models. As the CO_2 concentration rises in the atmosphere from human emissions, the strength of the land and ocean sinks will increase proportionally due to the effect of increasing CO_2 on its own. However, because the climate is also changing as atmospheric CO_2 concentration rises, it will affect the processes that underpin the land and ocean sinks. The likely net effect of climate change is to weaken these processes, thus partially offsetting the increases in land and ocean carbon sinks caused by the rising atmospheric CO_2 concentration alone (IPCC 2013). This possible weakening of carbon sinks would likely be small under the lowest of the IPCC emission pathways, which approximately corresponds to the budget required to have a 66% or better probability

"Land and ocean "sinks" remove about half the CO_2 emitted by human activities, slowing the rate of temperature rise."

of meeting the 2°C warming limit (Table 1), but will be larger if we do not meet this target, exacerbating the already serious risks of a temperature rise beyond 2°C.

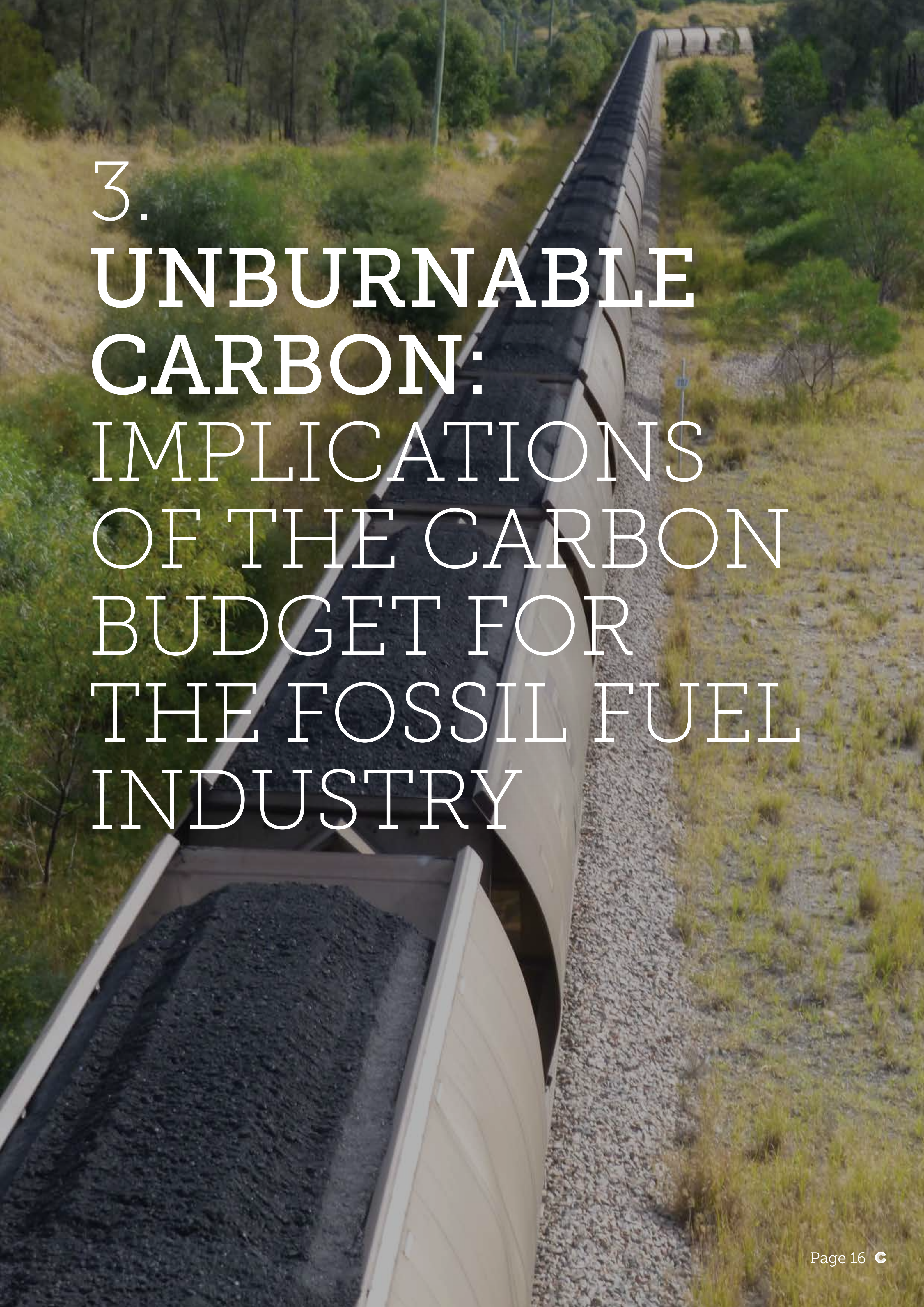
The second issue is feedback processes. A common feedback process in daily life is weight gain. As people gain weight, their appetite may increase and they become less inclined to exercise, and so they put on more weight, which in turn increases the appetite and reduces exercise even more, and so on. The climate system has a number of important feedback processes. For example, rising temperatures thaw permafrost, which releases CO_2 or methane to the atmosphere, which in turn, creates further warming, which then triggers even more emissions, and so on.

The budget approach cannot yet fully account for such feedback processes. As noted in Section 1, possible emissions from permafrost are assessed to be in the range of 50 to 250 billion tonnes as measured in carbon (not CO_2) over the 21st century under the highest emissions scenario (IPCC 2013). This corresponds to a range of five to 25 years of emissions from fossil fuel combustion at current rates. However, if the carbon budget is met, that is, the lowest of the IPCC emissions trajectories (an emission rate very much lower than the current one) is followed, loss of permafrost carbon is unlikely to become a significant problem.

In summary, if humanity exceeds the carbon budget for the 2°C warming limit, there is a strong risk of exacerbating the release of carbon from natural sources, causing further warming. On the other hand, if we cut our carbon emissions and stay within the 2°C warming limit, there is much less risk.

Finally, it is sometimes suggested that managing the land carbon cycle, through both avoided emissions from reducing deforestation and the sequestration of atmospheric CO_2 in soils and vegetation, could play a major role in climate stabilisation, offsetting a considerable amount of fossil fuel emissions. However, an analysis that includes the competing demands for land and its biomass – food production, wood products, biofuels for energy production, and biodiversity conservation – shows that land-based activities can play only a small role, accounting for only 3-8% of estimated energy consumption by 2050 (Canadell and Schulze 2014).

In summary, the carbon budget approach is a scientifically robust, conceptually simple way of estimating how much more CO_2 we can emit to the atmosphere before we raise global temperature above 2°C. It gives a single, globally aggregated amount of CO_2 that can be emitted before the world's economy must be decarbonised. The higher the probability we want of preventing a global temperature rise of 2°C, the more stringent the budget.



3. UNBURNABLE CARBON: IMPLICATIONS OF THE CARBON BUDGET FOR THE FOSSIL FUEL INDUSTRY

3.1 Calculating the amount of carbon that can be burned

One hundred and ninety-five countries around the world have agreed to limit global temperature rise to no more than 2°C as a key climate change policy (UNFCCC 2010; Figure 7), and simultaneously some of these countries have energy policies that include the extensive use of fossil fuels. Are these climate and energy policies consistent? Similarly, are the activities and plans of the large, multinational energy companies consistent with the agreed 2°C policy objective? Checking these consistencies is difficult with the targets-and-timetables approach to emissions reductions, but is much more straightforward and transparent with the carbon budget approach.

Figure 7: UNFCCC Climate talks in Cancun, Mexico 2010.

"Carbon capture and storage technologies do little to extend the carbon budget."

An obvious way to test this consistency is to compare the world's fossil fuel reserves with the remaining carbon budget. In the analyses that follow, we use the least stringent of the three budgets from 2012 (Table 1), the budget of 1112 billion tonnes of CO_2 that gives a 50% probability of avoiding a greater than 2°C rise in global temperature. For better-than-even chances of meeting the policy target, more stringent carbon budgets will be required. Thus, the analyses described below are the most "optimistic" ones from the perspective of fossil fuel usage. Higher probabilities of meeting the 2°C warming limit, and hence lower risks of suffering damaging or catastrophic climate change impacts, will require much lower usage of fossil fuels than the numbers cited below.

An initial study in 2013 compared the known global fossil fuel reserves (coal, oil, gas) with the carbon budget (Carbon Tracker and Grantham Institute 2013). That study estimated that if all of the world's indicated reserves of fossil fuels were burned, 2,860 billion tonnes of CO_2 would be emitted to the atmosphere. This is more than 2.5 times greater than the allowed budget.

Some have suggested that carbon capture and storage (CCS) technologies, which capture CO_2 from the smokestacks of power plants and allow it to be buried underground, could alleviate the constraint on burning fossil fuels. However, CCS does little to extend the carbon budget. Even optimistic estimates of the deployment of CCS suggest that the carbon budget could be extended by, at most, about 125 Gt of CO_2 (Carbon Tracker and Grantham Institute 2013). This would still leave the amount of burnable carbon well under half of the known reserves.

A recent study has examined in much more detail the implications of the carbon budget for the use of fossil fuels (McGlade and Ekins 2015). Their carbon budget is also based on a 50% probability of meeting the 2°C policy target, and spans the time period from 2011 to 2050. Based on the IPCC budget approach, their proposed budget is about 1,100 billion tonnes of CO_2, very similar to the budget shown in Table 1.

Their analysis compares this budget to both fossil fuel "reserves" and fossil fuel "resources". Resources are defined as "... the remaining ultimately recoverable resources, that is, the quantity of oil, gas or coal remaining that is recoverable over all time with both current and future technology, irrespective of economic conditions". Reserves are defined as "...a subset of resources that are defined to be recoverable under current economic conditions and have a specific probability of being produced." (McGlade and Ekins 2015). In other words, "resources" are all of the fossil fuels that we know exist, and "reserves" are the subset of resources that are economically and technologically viable to exploit now.

Table 2: The carbon budget for three probabilities of meeting the 2°C warming limit, and the fraction of fossil fuel reserves and resources that can be burned within the budget. See text for definition of "reserves" and "resources".

Probability of meeting 2°C policy target	Budget from 2000 Gt CO_2	Budget from 2012 Gt CO_2	% of fossil fuel reserves that can be burned from 2012	% of fossil fuel resources that can be burned from 2012
50%	1440	1112	38	10
66%	1338	1010	35	9.2
75%	1000	672	23	6.1

Sources: IPCC (2013), Meinshausen et al. (2009) and McGlade and Ekins (2015).

"Tackling climate change requires that most of the world's fossil fuels be left in the ground, unburned."

Current reserves consist of 1,294 billion barrels of oil, 192 trillion cubic metres of gas, 728 billion tonnes of hard coal, and 276 billion tonnes of lignite (McGlade and Ekins 2015). If all of these reserves were burned, nearly 2,900 billion tonnes of CO_2 would be emitted (virtually identical to the Carbon Tracker and Grantham Institute 2013 estimate), while combustion of all of the world's fossil fuel resources would release nearly 11,000 billion tonnes of CO_2 to the atmosphere (McGlade and Ekins 2015). These estimates are combined in Table 2 with the range of carbon budgets that are based on the three different probabilities of meeting the 2°C policy target. For each probability the table shows the percentages of fossil fuel reserves and resources that can be exploited and still stabilise the climate system at no more than a 2°C temperature rise above pre-industrial levels.

The results confirm the earlier study (Carbon Tracker and Grantham Institute 2013), which estimated amounts of burnable carbon based on a number of assumptions. The most generous budget, which allowed (i) an additional 300 billion tonnes of CO_2 because of deeper cuts in the emissions of non-CO_2 greenhouse gases such as methane and nitrous oxide, and (ii) an additional 125 Gt CO_2 from the most optimistic roll-out of CCS technologies, estimated that only about 35% of the world's known fossil fuel reserves could be exploited.

The McGlade and Ekins (2015) analysis, under the most generous assumptions for fossil fuel usage (which give only a 50:50 chance of meeting the 2°C target), estimates that 38%, at most, of the world's reserves can be burned (Table 2). The amount of fossil fuel reserves that can be burned is reduced if we want a better-than-even change of limiting the rise in global temperature to no more than 2°C.

For a 75% chance of meeting this target, this allowance reduces substantially to only 23% of reserves. That is, 77% of the world's fossil fuel reserves cannot be burned. To have an even greater chance of limiting the rise in global temperature to no more than 2°C, the allowance would shrink rapidly towards zero. The conclusion is clear: under any set of assumptions, effectively tackling climate change requires that most of the world's fossil fuels be left in the ground, unburned.

The inevitable conclusion from the commitment of the world's governments to protect humanity from climate change means the vast bulk of fossil fuel reserves and almost all fossil fuel resources cannot be burned. Many countries are now moving rapidly away from fossil fuels toward alternative sources of power, like wind and solar (Climate Council 2015). However, some countries, like Australia, are committed to both tackling climate change and maintaining a fossil fuel industry long-term rather than phasing it out and vigorously supporting the transition to a decarbonised energy system (Commonwealth of Australia 2015). Energy policies that continue to support substantial fossil fuel use are inconsistent with tackling climate change.

"Energy policies that support substantial fossil fuel use are inconsistent with tackling climate change."

3.2 How does each type of fossil fuel fare?

The McGlade and Ekins (2015) analysis goes further than earlier studies by estimating the relative amounts of the three major types of fossil fuel – coal, oil and gas – that can be burned and stay within the carbon budget. The combustion CO_2 emissions embedded in the major types of fossil fuels are shown in Figure 8 for both reserves and non-reserve resources. Furthermore, the study also estimates the geographical distribution of the fossil fuels that can be burned from an economic efficiency perspective.

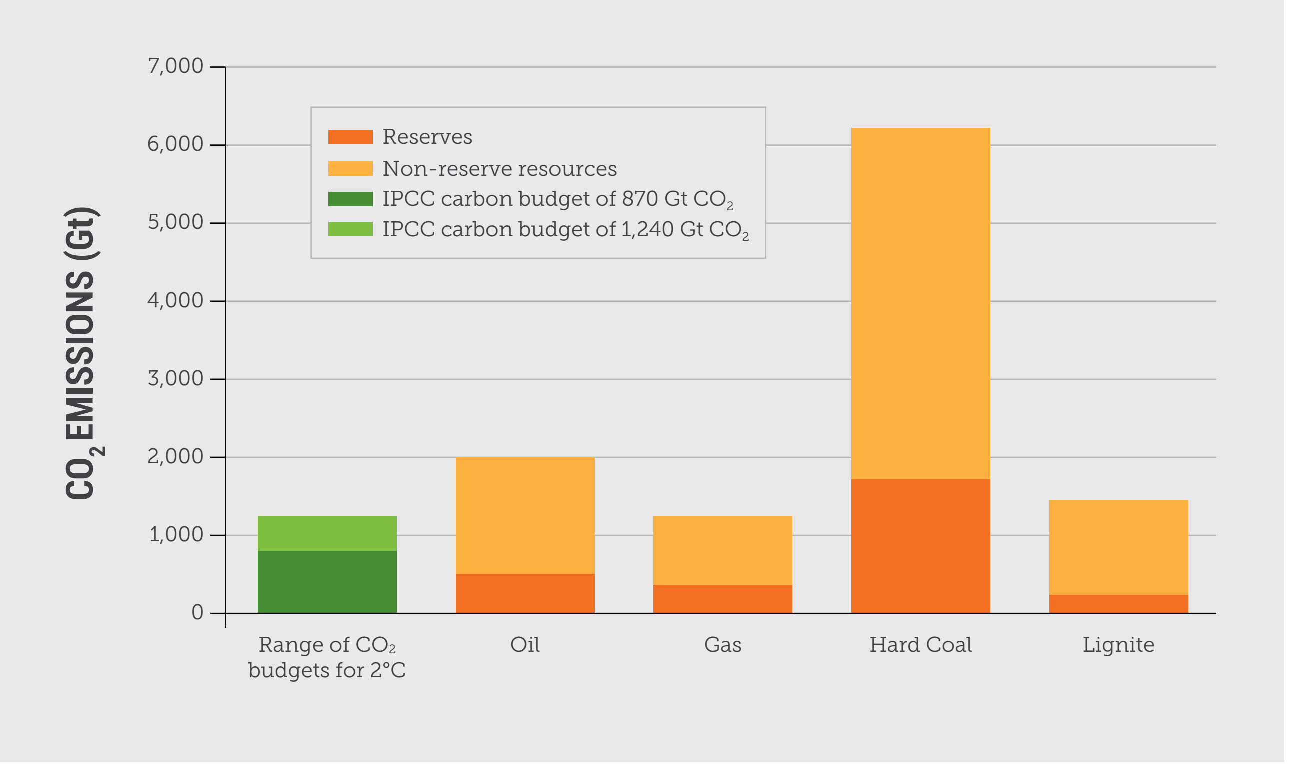


Figure 8: The combustion CO_2 emissions for oil, gas and coal (hard coal and lignite) resources and reserves. The range of carbon budgets between 2011 and 2050 that are approximately commensurate with limiting temperature rise to 2°C (870-1240 Gt CO_2) is also shown. **Source:** Adapted from McGlade and Ekins (2015).

"Coal is the fossil fuel with the greatest proportion that cannot be used; 88% of global reserves are unburnable."

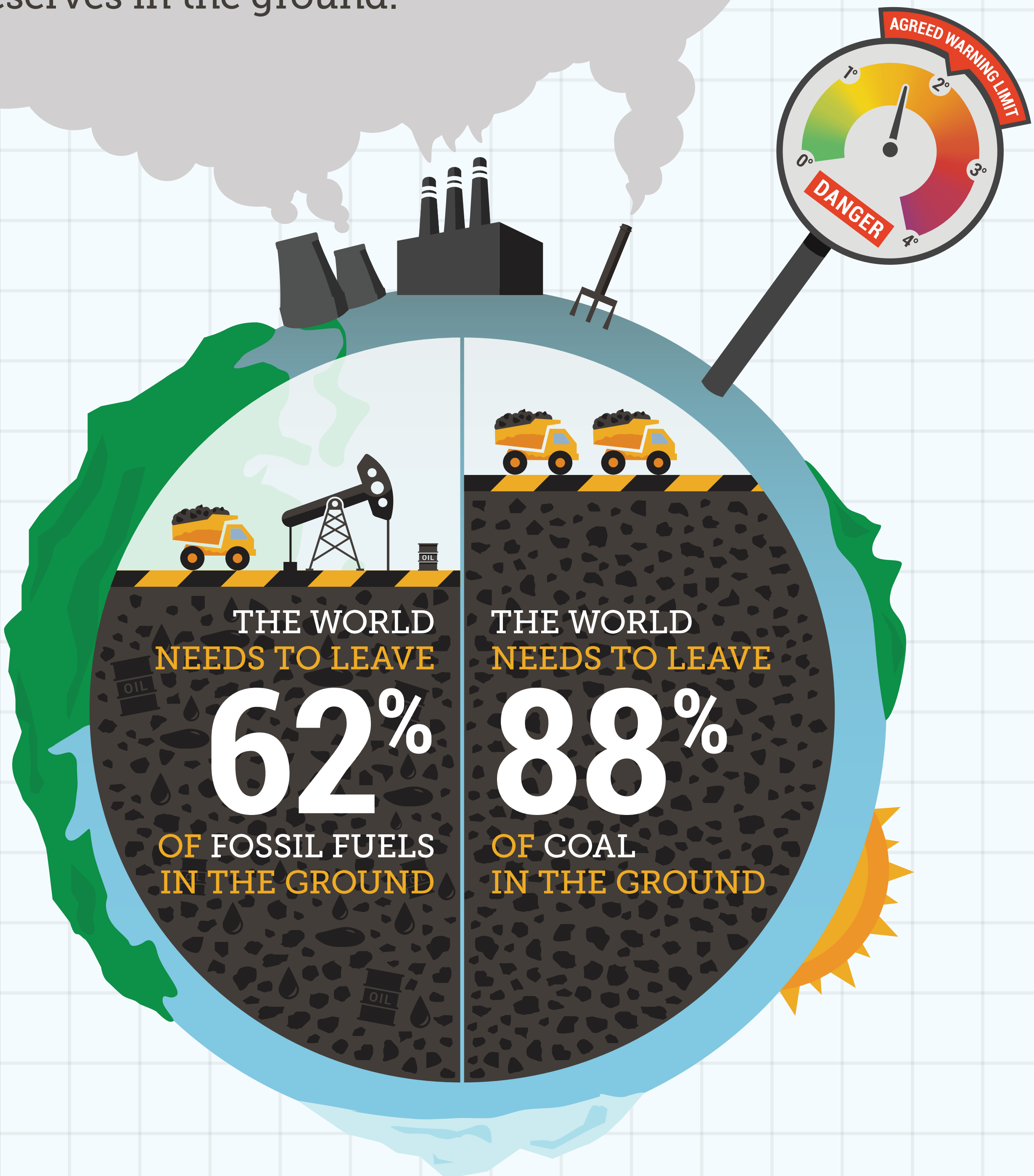
The analysis is based on the results of a sophisticated integrated assessment model that minimises whole-energy system costs for an assumed carbon budget (Anandarajah et al. 2011). The world's energy system is divided into 16 geographical regions, accounting for the various types of energy reserves and resources and where they are located. The minimisation of cost is based on the entire energy system, including the cost of resource extraction and production, conversion to products and use of those products by sectoral end-users. Infrastructure requirements are included in the analysis. Based on this approach, an economically-optimal (least cost) solution is generated by the model. The output gives the relative amounts of coal, oil and gas, and the geographical distribution, of the fossil fuels that can still be burned while avoiding a 2°C rise in global temperature. The remainder of the fossil fuels must then be left in the ground, unburned.

The results of the integrated assessment model show that to meet the budget, coal is the fossil fuel with the greatest proportion that cannot be used; 88% of global reserves are unburnable (Figure 9). Oil is the fossil fuel with the least proportion that cannot be used, with 35% of reserves unburnable. Just over half – about 52% - of the known reserves of gas are unburnable. Application of CCS technology does not alter the mix very much. The fraction of unburnable coal reserves reduces only slightly to 82%, while 33% of oil and 49% of gas reserves are unburnable. Of the coal that can be burned to stay within the budget, about three-quarters is hard coal (often called "black coal" in Australia) and only one-quarter is lignite ("brown coal") (McGlade and Ekins 2015).

"Over half of the known reserves of gas are unburnable."

WHAT IS OUR CARBON BUDGET?

To have just a break-even, 50:50 chance of staying **below 2°C** of global warming, we must keep most of the world's fossil fuel reserves in the ground.



AT THE CURRENT RATE

We will blow our carbon budget within the next **two decades** or even sooner.

Figure 9: Carbon Budget Report 2015.

The analysis yields some interesting results regarding non-conventional fossil fuels. For example, to meet the carbon budget, the open-pit mining of natural bitumen (tar sands; Figure 10) in Canada must be reduced rapidly over the next five years to near zero. With or without CCS, 99% of the Canadian natural bitumen resources are unburnable if we are to keep global temperature rise below 2°C. Similarly, none of the Arctic Ocean oil and gas resources is exploitable in any of the scenarios that meet the policy target. This means that all Arctic resources are unburnable; any exploitation of any of the resources in that region is incompatible with effective action on climate change.

“Tar sands mining in Canada must be reduced rapidly to near zero over the next five years.”

Figure 10: Tar sands in Alberta, Canada.

“Any exploitation of Arctic fossil fuels resources is incompatible with effective action on climate change.”

4. THE CHALLENGE FOR AUSTRALIA

The calculation of the world's unburnable fossil fuel reserves presents especially serious challenges for Australia, given our focus on coal both for domestic consumption and as an export commodity. To put the nature of this challenge into perspective, it is useful to compare Australia's known coal reserves and resources with the global carbon budget based on the 2°C warming limit.

Australia's coal reserves are estimated to be 76 billion tonnes, of which 39 billion tonnes are black (hard) coal and 37 billion tonnes are brown coal (lignite) (Geoscience Australia 2010). If all of the reserves were exploited and burned, 128 billion tonnes CO_2 would be emitted to the atmosphere (Department of Environment 2014). These emissions represent 11.5% the global carbon budget from 2012 for a 50% probability of meeting the 2°C warming limit and 19.0% of the budget for a 75% probability. Our total resources of coal are much higher (estimated to be 308 billion tonnes, with 114 billion tonnes of black coal and 194 billion tonnes of lignite (Geoscience Australia 2009), which is equivalent to 454 billion tonnes CO_2 if all of the resources were burned (Department of Environment 2014). These resources are very large in the context of the total global carbon budget from 2012, comprising 40.8% of the budget for a 50% probability of meeting the 2°C warming limit, and 67.6% of the budget for a 75% probability. In summary if all of Australia's coal was burned, it would consume two-thirds of the global carbon budget based on a 75% chance to meet the 2°C warming limit.

The McGlade and Ekins (2015) analysis breaks down the global estimates of unburnable fossil fuels into geographical regions, with Australia in the "OECD Pacific" group which also includes South Korea, Japan and New Zealand. The estimates for this group are essentially equivalent to the estimates for Australia alone because South Korea and Japan have negligible fossil fuel resources. Furthermore, Australia's fossil fuel resources are far greater than those of New Zealand.

"If all of Australia's coal was burned, it would consume two-thirds of the global carbon budget based on a 75% chance to meet the 2°C warming limit."

"It is estimated that over 90% of Australian coal reserves cannot be burned."

Based on the McGlade and Ekins (2015) analysis, without CCS it is estimated that the unburnable fossil fuels for the OECD Pacific group (i.e., primarily Australia) are 46% of oil reserves, 51% of gas reserves and 95% of coal reserves. The most optimistic application of CCS technology from 2025 onwards does not diminish these daunting figures by much; 37% of oil reserves are unburnable; 56% of gas and 93% of coal. In summary, it is estimated that over 90% of Australia's coal reserves cannot be burned (for example, Figure 11), compared to the global average of 82% of coal reserves that cannot be burned.

These estimates, however, contain large uncertainties. The modelled geographical distribution of unburnable fossil fuels is based on several critical assumptions out to 2050, such as the total future demand for energy in different regions, the future costs of mining and energy extraction, the relative costs of different energy technologies, and the local costs of alternatives. All of these factors are difficult to predict into the future with a high degree of certainty. In addition, the analysis does not include factors such as regulation of local air pollution (e.g., in China), which would favour coal reserves with lower sulfur content and higher energy density (i.e., some Australian reserves).

Figure 11: Tarrawonga coal mine adjacent to Leard State Forest in NSW.

> "Tackling climate change makes it highly unlikely that any new Australian coal resources would ever be developed."

In terms of coal specifically, uncertainties include:

- the level of global demand given improvements in energy efficiency and the falling cost of alternative renewables;
- the impact on the global market of changes in energy policy in China (e.g., peaking thermal coal use) and perhaps India;
- potential restrictions on coal usage in a post-Paris climate agreement; and
- the cost of developing new coal resources that typically require expensive new rail and port facilities (Carbon Tracker 2014a, 2014b).

In summary, it is likely that the fraction of Australia's unburnable coal is larger than the global average, but it is not clear by how much, given the large uncertainties in the geographical distribution analysis and the future of the global coal market.

Effectively tackling climate change, that is, meeting the 2°C warming limit, makes it highly unlikely that any of Australia's potential coal resources beyond the reserves already being exploited would ever be developed. This includes the Galilee Basin deposits, which in general have high costs of development and contain relatively low-grade coal. Such resources, if developed, would very likely become stranded assets in a world that is rapidly cutting carbon emissions. These resources are in a similar category to the natural bitumen deposits in Canada or the oil and gas resources under the Arctic Sea. They are unburnable; any exploitation of them is almost certain to be incompatible with effective action on climate change.

In contrast to the challenges that the global carbon budget presents for Australia's coal industry, observing the 2°C warming limit opens up many opportunities for the Australian economy (ClimateWorks Australia and the ANU 2014). For example, many of Australia's coal-fired power plants are nearing the end of their lifetimes, and, simultaneously, the costs of renewable energy technologies such as solar PV (Figure 12) and wind continue to fall. Replacing our ageing coal stations with modern, clean renewables could help Australia meet its share of the carbon budget with little or no economic cost, or, more likely, with economic benefits (Climate Council 2014). Rapid innovation on energy efficiency and conservation technologies would also yield significant economic benefits (The Climate Institute 2013; ATSE 2014; ClimateWorks Australia 2015).

Figure 12: Solar Panels in Sydney.

"Exploitation of Australia's Galilee Basin coal deposits is incompatible with effective action on climate change."

As for export coal, the recent boom since the early 2000s was driven by inflated prices, largely in the Chinese market, and as coal prices continue to fall towards their long-term average, the coal export industry is much less profitable. In addition, scenarios of the future show that we can build an Australian economy that remains a large exporter of primary products and minerals but on a low-carbon basis. This scenario requires rapid change in the energy sector away from fossil fuels to 50% renewables by 2030 (ClimateWorks Australia and the ANU 2014).

5.
URGENCY: GETTING ON WITH THE JOB NOW

With the carbon budget rapidly running out, it is extremely urgent that global emissions track downward. The trajectory to 2050 needed to stay within budget for the 2°C policy target is highly sensitive to the year in which global emissions reach their maximum. If emissions peak this year, the maximum rate of emission reduction thereafter would be about 5.3% per year (Figure 13). That is already a daunting task. But if the peaking year does not occur until 2020, now only five years away and itself a formidable challenge, the maximum rate of emission reduction thereafter becomes 9.0% per year and the global economy needs to be essentially decarbonised by 2040-2045 (WBGU 2009). These are global average emission rates, and the rate of emission reduction by OECD (wealthy) countries such as Australia would need to be significantly higher to allow poorer countries to develop.

If there is any chance to meet the 2°C warming limit, it is clear that new investment in fossil fuels, especially in coal, needs to be reduced to zero as soon as possible. This is evident in the McGlade and Ekin (2015) analysis showing that only 12% of the world's coal reserves - and only 18% with the

"It is extremely urgent that global emissions start tracking downward this decade."

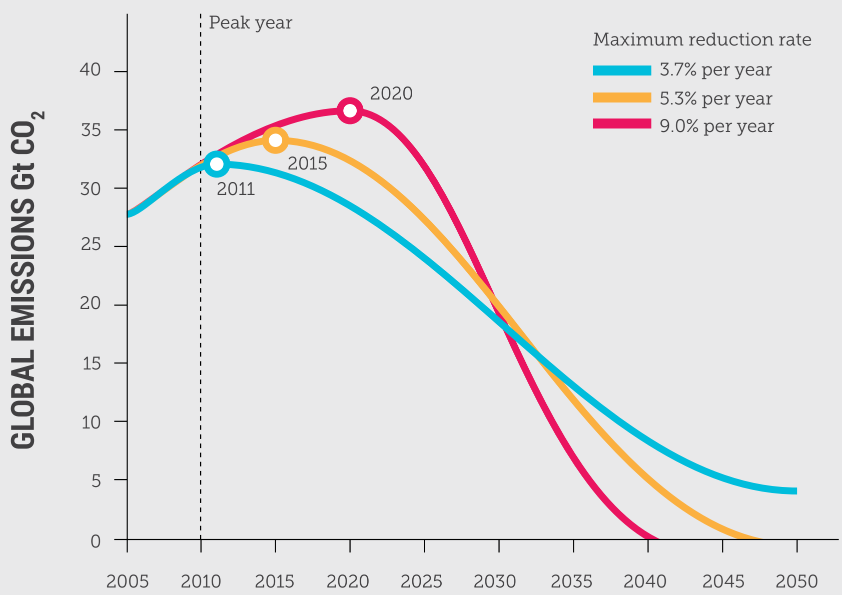


Figure 13: Three emission trajectories based on the budget approach and giving a 67% probability of meeting the 2°C guardrail. **Source:** Adapted from WBGU 2009.

“There is no time to lose; now is the time to get on with the job.”

application of CCS technology - can be burned between now and 2050. It is likely that much, if not all, of the infrastructure needed to burn a rapidly diminishing allowable amount of coal already exists so any new investment in coal infrastructure is very likely to be incompatible with the climate policy target. In fact, some existing coal infrastructure may need to be retired before its planned lifetime is reached.

This year countries world-wide are setting emission reduction targets for the period after 2020. For instance, the United States government has said they will reduce emissions by 26%-28% by 2025 relative to 2005 levels (UNFCCC 2015), and they are on track to meet their reduction target of 17% by 2020. Australia's bipartisan commitment is currently a 5% reduction by 2020 based on 2000 levels, and a commitment to move to 15-25% if certain factors exist (Climate Change Authority 2014). The Australian government has indicated they will make a post-2020 commitment by June this year.

While targets and timetables are not the best way of measuring future effort as noted above (and shown by the differing baselines and reduction targets used by the US and Australia), historically this is how major countries have made commitments. The Climate Change Authority (2014) recently assessed Australia's commitments to determine what Australia's target should be in light of the carbon budget and significant progress being made internationally. Australia's current emission reduction target was found to be too low and out of step with our allies and trading partners. The Authority concluded that climate science, international action and economic factors all justify stronger action, and recommended Australia move to emissions reduction target of 15% below 2000 levels by 2020. They also recommended a 40-60% reduction below 2000 levels by 2030 (Climate Change Authority 2014). Both of these targets would be more in line with the carbon budget approach.

In summary, the carbon budget is a far more powerful approach to informing climate change policy than the more traditional targets-and-timetables method. The budget approach is simpler, and progress (or lack thereof) is easier to monitor. It focuses attention on the end game, that is, to decarbonise the global economy by around mid-century. This, in turn, emphasises the need for immediate investment decisions as well as strenuous mitigation actions. The carbon budget approach is consistent with a multitude of possible deep decarbonisation pathways, allowing for flexibility, ingenuity, innovation and rapid technological and institutional advances, but it does emphasise that fossil fuel usage must be phased out well before reserves, let alone resources, are exhausted. But most of all, the rapid decrease in the remaining carbon budget underscores the need for urgency. There is no time to lose; now is the time to get on with the job.

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