APPENDIX R

Greenhouse Gas Report

TABLE OF CONTENTS

LIST OF TABLES

LIST OF GRAPHS

LIST OF ATTACHMENTS

1 INTRODUCTION

The Dendrobium Mine is an underground coal mine situated in the Southern Coalfield of New South Wales (NSW) approximately 8 kilometres (km) west of Wollongong.

This Greenhouse Gas Assessment (GHG Assessment) forms part of an Environmental Impact Statement (EIS), which has been prepared to accompany a State Significant Infrastructure (SSI) Application for the Dendrobium Mine Extension Project (the Project) in accordance with Part 5 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

This GHG Assessment has been conducted as part of the EIS to evaluate the likely greenhouse gas emissions of the Project and their potential contribution to global climate change, and to consider climate change predictions relevant to the Project region.

1.1 DENDROBIUM MINE

Illawarra Coal Holdings Pty Ltd (Illawarra Metallurgical Coal [IMC]), a wholly owned subsidiary of South32 Limited (South32), is the owner and operator of the Dendrobium Mine. The Dendrobium Mine, Appin Mine and supporting operations are managed by IMC.

Development Consent DA 60-03-2001 for the Dendrobium Mine was granted by the NSW Minister for Urban Affairs and Planning under the EP&A Act in November 2001.

The Dendrobium Mine extracts coal from the Wongawilli Seam (also known as the No 3 Seam) within Consolidated Coal Lease (CCL) 768 using underground longwall mining methods. The Dendrobium Mine includes five approved underground mining domains, named Areas 1, 2, 3A, 3B and 3C. Longwall mining is currently being undertaken in Area 3B, with extraction largely complete in Areas 1, 2 and 3A.

The Dendrobium Mine has an approved operational capacity of up to 5.2 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal until 31 December 2030.

1.2 OVERVIEW OF THE PROJECT

IMC is seeking approval for the Project, which would support the extraction of approximately 31 million tonnes (Mt) of ROM coal from Area 5, within CCL 768. The life of the Project includes longwall mining in Area 5 up to approximately 31 December 2034, and ongoing use of existing surface facilities for handling of Area 3C ROM coal until 2041[1].

The Project would include the following activities:

- longwall mining of the Bulli Seam in a new underground mining area (Area 5);
- development of underground roadways from existing Dendrobium Mine underground areas (namely Area 3) to Area 5;
- use of existing Dendrobium Mine underground roadways and drifts for personnel and materials access, ventilation, dewatering and other ancillary activities related to Area 5;
- development of new surface infrastructure associated with mine ventilation and gas management and abatement, water management and other ancillary infrastructure;
- handling and processing of up to 5.2 million tonnes per annum (Mtpa) of ROM coal (no change from the approved Dendrobium Mine);
- extension of underground mining operations within Area 5 until approximately 2035;

[1] The Project does not include approved underground mining operations in the Wongawilli Seam in Areas 1, 2, 3A, 3B and 3C at the Dendrobium Mine and associated surface activities (such as monitoring and remediation). These activities will continue to operate in accordance with Development Consent DA 60-03-2001 (as modified).

- use of the existing Dendrobium Pit Top, Kemira Valley Coal Loading Facility, Dendrobium CPP and Dendrobium Shafts with minor upgrades and extensions until approximately 2041;
- transport of ROM coal from the Kemira Valley Coal Loading Facility to the Dendrobium CPP via the Kemira Valley Rail Line;
- handling and processing of coal from the Dendrobium Mine (including the Project) and IMC's Appin Mine (if required) to the Dendrobium CPP to 2041;
- delivery of coal from the Dendrobium CPP to Port Kembla for domestic use at the Port Kembla Steelworks and Liberty Primary Steel Whyalla Steelworks or export through the Port Kembla Coal Terminal (PKCT);
- transport of coal wash by road to customers for engineering purposes (e.g. civil construction fill) for other beneficial uses and/or for emplacement at the West Cliff Stage 3 and/or Stage 4 Coal Wash Emplacement;
- development and rehabilitation of the West Cliff Stage 3 Coal Wash Emplacement (noting that opportunities for beneficial use of coal wash would be maximised);
- continued use of the Cordeaux Pit Top for mining support activities such as exploration, environmental monitoring, survey, rehabilitation, administration and other ancillary activities;
- progressive development of sumps, pumps, pipelines, water storages and other water management infrastructure;
- controlled release of excess water in accordance with the conditions of Environmental Protection Licence (EPL) 3241 and/or beneficial use;
- monitoring, rehabilitation and remediation of subsidence and other mining effects; and
- other associated infrastructure, plant, equipment and activities.

A detailed description of the Project is provided in Section 4 of the main text of the EIS.

1.3 ONGOING DEMAND FOR METALLURGICAL COAL FOR STEELMAKING

The Project would primarily produce high quality metallurgical coal for steelmaking. Metallurgical coal is a raw material that is essential for the manufacture of 'virgin iron' and steel (also known as 'primary steelmaking' or 'integrated steelmaking'), with the other key raw material being iron ore. Metallurgical coal is used as a reducing agent in the steelmaking process. The carbon in the metallurgical coal is used to convert iron ore to molten iron in a blast furnace. The carbon dioxide by-product associated with the consumption of metallurgical coal in the blast furnace contributes to the greenhouse gas emissions associated with steelmaking (e.g. along with other emissions such as those associated with electricity consumption).

The Commonwealth Department of Agriculture, Water and Environment (DAWE) (2021) outlined the expected ongoing demand for steel and metallurgical coal in its Statement of Reasons for the Russel Vale Colliery (EPBC 2020/8702) within reference to advice from the Commonwealth Department of Industry, Science, Energy and Resources (DISER).

DAWE (2021) states that global demand for steel is not expected to peak until mid-century, as steel will support the global transition to a low carbon economy (e.g. as a substitute for more energy intensive concrete, in the construction of renewable energy infrastructure [wind farms, electricity infrastructure]):

> *200. Steel is and will be critical for supplying the world with energy, as it is an integral ingredient for energy transition, with solar panels, wind turbines, dams and electric vehicles all depending on it to varying degrees. Steel is the main material used in onshore and offshore wind turbines.*
>
> *201. Steel is also a fundamental building block for modern and developing economies. The construction of homes, schools, hospitals, bridges, cars and trucks rely heavily on steel. The DISER Advice notes that steel demand is driven by construction and infrastructure development.*
>
> *202. OECD modelling predicts that global steel demand is not expected to peak until mid- century, with a growth rate for steel demand from about 1.4% per annum to 1.1 %. Demand in mature economies will show zero to slightly negative growth rates over the period, while demand growth in emerging economies will be in the range 2.5% to 4%. Further, the modelling predicts that iron ore demand for steel making will peak in 2025- 2030.*

DAWE (2022) also outlines that alternative technologies for steelmaking (or developing alternative construction materials) that do not rely on the blast furnace method are unlikely to be operating at scale until the 2030s:

> *211. The 2020 IEA Iron and Steel Roadmap developed in conjunction with industry indicated that opportunities to reduce emissions from the* [steelmaking] *sector in the next 10 years will primarily rely on improvements in material efficiency (light weighting of steel requirements in buildings) greater recycling of steel and iron (electric arc furnace), energy efficiency and performance improvements. Additionally, alternatives to steel (such as carbon fibre, engineered timber) and new methods for making steel without metallurgical coal, using hydrogen or electrolysis (using electricity) are being developed and piloted globally. However, these methods are not currently projected to be operating at scale until the 2030s.*
>
> *212. The DISER Advice also notes that Direct Reduction Iron (ORI) and electric arc furnace technologies currently present technical and cost challenges and are not yet available at the scale needed to meet global demand for steel.*

This aligns with recent analysis by BlueScope in its consideration of alternative technologies to the blast furnace method for steelmaking, as well as alternatives to metallurgical coal as a reducing agent within a blast furnace, in its recent Scoping Report for the proposed Blast Furnace No 6 Reline (GHD, 2021). It concluded that a reline of its existing blast furnaces (i.e. No 6 Bast Furnace) to be the most technically feasible and economically viable option for steelmaking at Port Kembla while longer-term breakthrough low-emission technologies are developed:

> *In considering the options available to continue iron and steelmaking at PKSW, a range of alternative iron and steelmaking technologies were considered, including both mature and emerging technologies. Mature technologies that were considered included retrofitting the existing Basic Oxygen Steelmaking (BOS) building with Electric Arc Furnace (EAF) steelmaking or constructing a new EAF steelmaking facility on under-utilised land within PKSW.*
>
> *However, neither of these options was considered economically viable given Australia's high energy costs and insufficient availability of cost effective, quality scrap steel to support three million tonnes of flat steel production at Port Kembla.*
>
> *Consideration was also given to emerging technologies. A diverse range of hydrogen-based ironmaking technologies are currently being explored around the globe. These range from injection of hydrogen into existing blast furnace operations to manufacturing iron by a direct reduced iron (DRI) process utilising hydrogen as a fuel source. However, these technologies are in the early stages of development worldwide, with most at concept study, protype or demonstration stage. They are yet to be commercialised at the scale required at Port Kembla.*
>
> *Emerging technologies will also require significant capital and public policy support to reach commercial scale. For technologies based on the use of hydrogen, large-scale supply chains would need to be established to provide 'green' hydrogen from renewable sources at cost-competitive prices.*
>
> *Accordingly, at this point in time a reline is the most technically feasible and economically viable option for steelmaking at PKSW while longer-term breakthrough low-emission technologies are developed. Technology to reduce the greenhouse gas (GHG) emissions intensity of Blast Furnace – Basic Oxygen Furnace (BF-BOF) iron and steelmaking is proposed as part of the reline. BlueScope also has the capability and flexibility to adopt new technologies and iron making configurations in the medium to longer term, as and when they are technically and commercially ready.*

In regard to ongoing demand for metallurgical coal, DAWE (2022) concludes:

> *… demand for metallurgical coal in particular is likely to continue in circumstances where alternative steelmaking methods are not available at scale, and are not anticipated to be available until the 2030s, and steel is required for the construction of safe buildings, infrastructure and energy in developing economies.*

Similarly the NSW Government (2020) *Strategic Statement on Coal Exploration and Mining in NSW* states (emphasis added):

> *In the short to medium term, coal mining for export will continue to have an important role to play in NSW. In our immediate region of the world, as elsewhere, there has been a reduction in demand caused by the economic impacts of COVID-19. However, in the medium term, demand is likely to remain relatively stable. Some developing countries in South East Asia and elsewhere are likely to increase their demand for thermal coal as they seek to provide access to electricity for their citizens. Under some scenarios, this could see the global demand for thermal coal sustained for the next two decades or more.*
>
> ***The use of coal in the manufacture of steel (coking coal) is likely to be sustained longer as there are currently limited practical substitutes available.***

South32's analysis also indicated increased demand for metallurgical coal and steel under a global 1.5ºC increase scenario.

As a result of the limited practical substitutes available, it is expected that there will be continued demand for metallurgical coal for use in steelmaking using the blast furnace method over the life of the Project, notwithstanding the greenhouse gas emissions associated with the mining of coal and steelmaking process.

Consideration of alternative sources of metallurgical coal supply to the Port Kembla Steelworks (i.e. from other local mines or from interstate) are provided in Attachment 11 of the EIS.

1.4 GREENHOUSE GASES

1.4.1 Relevant Greenhouse Gases and Global Warming Potential

In the context of the Project, the most relevant greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

Greenhouse gas emissions are typically standardised by expression as a carbon dioxide equivalent (CO_2-e) based on their Global Warming Potential (GWP). The GWP is determined by the differing periods that greenhouse gases remain in the atmosphere and their relative absorption of outgoing infrared radiation. The GWP of CH_4 is 28 (i.e. one tonne of CH_4 emissions has 28 times the potential to contribute to global warming than one tonne of CO_2 emissions), while the GWP of N_2O is 265 as specified in section 2.02 of the Commonwealth *National Greenhouse and Energy Reporting Regulations 2008*.

To simplify greenhouse gas accounting, the emissions of these greenhouse gases (typically estimated in tonnes [t]) are converted to tonnes of carbon dioxide equivalent (t CO_2-e) before being summed to determine total greenhouse gas emissions. This can be expressed as:

$$t\ CO_2\text{-}e = (tonnes\ CO_2 \times 1) + (tonnes\ CH_4 \times)28 + (tonnes\ N_2O \times 265)$$

1.4.2 Greenhouse Gas Emission Scopes

The Greenhouse Gas Protocol (GHG Protocol) (World Business Council for Sustainable Development [WBCSD] and World Resources Institute [WRI], 2021) contains methodologies for calculating and assessing greenhouse gas emissions. The GHG Protocol provides guidance and standards for companies and organisations preparing greenhouse gas emissions inventories. It covers the accounting and reporting of the six greenhouse gases covered by the *Kyoto Protocol*, including the three greenhouse gases most relevant to the Project as described above.

Under the GHG Protocol, an entity's operational boundaries are established by identifying emissions associated with its operations, categorising them as direct or indirect emissions, and identifying the Scope of accounting and reporting for indirect emissions.

Three 'Scopes' of emissions (Scopes 1, 2 and 3) are defined for greenhouse gas accounting and reporting purposes and are described further below.

These scopes are also defined in the Commonwealth *National Greenhouse and Energy Reporting Act 2007* and the Commonwealth *National Greenhouse and Energy Reporting Regulations 2008,* which set the domestic statutory framework for greenhouse gas emission accounting in Australia (Sections 2 and 3).

Scope 1 – Direct Greenhouse Gas Emissions

Direct greenhouse gas emissions are defined as emissions that occur from sources that are owned or controlled by the entity (WBCSD and WRI, 2021). Direct greenhouse gas emissions are emissions that are principally the result of the following types of activities undertaken by an entity:

- Fugitive emissions (e.g. from underground mines).
- Generation of electricity, heat or steam – these emissions result from combustion of fuels in stationary sources (e.g. boilers, turbines and furnaces).
- Physical or chemical processing – most of these emissions result from the manufacture or processing of chemicals and materials (e.g. production of cement, ammonia and aluminium, or waste processing).
- Transportation of materials, products, waste, and employees – these emissions result from the combustion of fuels in mobile combustion sources (e.g. trucks, trains, ships, aeroplanes, cars, motorcycles and buses) owned/controlled by the entity.

Scope 2 – Electricity Indirect Greenhouse Gas Emissions

Scope 2 emissions are a category of indirect emissions that account for greenhouse gas emissions associated with the generation of purchased electricity consumed by the entity.

Purchased electricity is defined as electricity that is purchased or otherwise brought into the organisational boundary of the entity (WBCSD and WRI, 2021). Scope 2 emissions physically occur at the facility where the electricity is generated (WBCSD and WRI, 2021). Entities report the emissions associated with the generation of purchased electricity (consumed in equipment or operations owned or controlled by the entity) as Scope 2.

Scope 3 – Other Indirect Greenhouse Gas Emissions

Scope 3 emissions are those indirect emissions that are the consequence of the activities of an entity, but which arise from sources not owned or controlled by that entity. Some examples of Scope 3 emissions provided in the GHG Protocol are those from the extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services (WBCSD and WRI, 2021).

The GHG Protocol notes that reporting Scope 3 emissions can result in double counting of emissions. For example, greenhouse gas emissions from the consumption of coal to produce steel are the Scope 3 emissions of the mines approved to produce the coal, as well as the Scope 1 emissions of the businesses that consume the coal to produce the steel.

Given the indirect nature of Scope 3 emissions, in the context of the Project, Scope 3 emissions associated with the end use of coal are outside of IMC's control. Reductions in Scope 3 emissions for the Project would need to be related to reductions in product sold. The ongoing demand for metallurgical coal in the steelmaking process, and the ongoing demand for steel during the transition to a lower carbon economy is described above.

2 ASSESSMENT REQUIREMENTS

2.1 CONSIDERATION OF STATUTORY AND POLICY FRAMEWORK

EP&A Act

The Project is required to be assessed against the objects of the NSW EP&A Act, which includes the facilitation of Ecologically Sustainable Development (ESD). Consideration of the principles of ESD includes consideration of a development's impact to climate change, and the impact of climate change to the development. These matters are discussed in this GHG Assessment. A broad evaluation of the Project against the principles of ESD is provided in Section 8 of the EIS.

Resources and Energy SEPP

The *State Environmental Planning Policy (Resources and Energy) 2021* (the Resources and Energy SEPP) states the following in regard to greenhouse gas emissions:

> ***2.20 Natural resource management and environmental management***
>
> *(1) Before granting consent for development for the purposes of mining, petroleum production or extractive industry, the consent authority must consider whether or not the consent should be issued subject to conditions aimed at ensuring that the development is undertaken in an environmentally responsible manner, including conditions to ensure the following—*
>
> *…*
>
> *(c) that greenhouse gas emissions are minimised to the greatest extent practicable.*
>
> *(2) Without limiting subclause (1), in determining a development application for development for the purposes of mining, petroleum production or extractive industry, the consent authority must consider an assessment of the greenhouse gas emissions (including downstream emissions) of the development, and must do so having regard to any applicable State or national policies, programs or guidelines concerning greenhouse gas emissions.*

The Resources and Energy SEPP would have been relevant to the Project but for its SSI declaration.

Further consideration of the Resources and Energy SEPP as it relates to the Project is provided in Attachment 7 of the EIS.

Net Zero Plan Stage 1: 2020-2030 Implementation Update

The NSW Government has released the *NSW Climate Change Policy Framework* (NSW Government, 2016), which commits NSW to the 'aspirational long-term objective' of achieving net-zero emissions by 2050 (Section 3.3).

In March 2020, the NSW Government announced its *Net Zero Plan Stage 1: 2020–2030* (Department of Planning, Industry and Environment [DPIE], 2020a), which laid the foundation for NSW's action on climate change in the period 2020 to 2030 to reach the goal of net zero emissions by 2050. It forecast that NSW's greenhouse gas emissions would reduce by 35% compared to 2005 levels by 2030. In relation to mining, the *Net Zero Plan Stage 1: 2020–2030* states:

> *New South Wales' $36 billion mining sector is one of our biggest economic contributors, supplying both domestic and export markets with high quality, competitive resources. Mining will continue to be an important part of the economy into the future and it is important that the State's action on climate change does not undermine those businesses and the jobs and communities they support.*

In September 2021, DPIE released the *Net Zero Plan Stage 1: 2020–2030 Implementation Update* (DPIE, 2021b). It outlines an updated 2030 emissions reduction objective of 50% reduction below 2005 levels. In relation to assessment under the EP&A Act, the *Net Zero Plan Stage 1: 2020–2030 Implementation Update* states (emphasis added):

> *The emissions reduction projections do not assume, and the NSW Government does not intend, that all sectors of the NSW economy will abate at the same rate. The NSW Government's projections also find that the State is on track to achieve this objective on current policy settings. In light of this, the* ***NSW Government policy is that the NSW Government's objective set out in this Plan, to reduce emissions by 50% below 2005 levels by 2030, is not to be considered in the assessment or determination of development and infrastructure applications under the Environmental Planning and Assessment Act 1979****.*

Cumulative Impact Assessment Guidelines

In 2021, DPIE (2021a) released the *Cumulative Impact Assessment Guidelines for State Significant Projects* (the Guideline). The Guideline refers to cumulative impacts being assessed and managed at the "strategic-level" or "site-specific" level.

In the regard to cumulative assessment at the "strategic-level", the Guideline states:

> *The NSW Government has a comprehensive framework in place for assessing and managing cumulative impacts at the strategic-level. The framework includes a range of government legislation, strategies, plans, policies and guidelines (see examples at Appendix A) that have been developed over time to anticipate and respond to environmental, social and economic changes.*
>
> …
>
> *Further, the effective assessment and management of cumulative impacts is critical to protecting the things that matter to the community in NSW and ensuring ecologically sustainable development.*

Appendix A to the Guideline refers to strategic-level policy relating to climate change, including the *Climate Change Policy Framework* and *Net Zero Plan Stage 1:2020-2030* (as described above and in Section 3.3).

Cumulative global greenhouse gas emissions, and their contribution to global atmospheric greenhouse gas concentrations and associated climate change, is a clear example of an assessment issue that is managed at the "strategic-level" by relevant global, national and state-level legislation and policies (in addition to company and project-level plans). This is supported by the quotes above from the *Net Zero Plan Stage 1: 2020–2030 Implementation Update* that state that NSW Government policy does not intend that all sectors of the economy will abate greenhouse gas emissions at the same rate while the State achieves its emission reduction objectives, and that NSW's 2030 emission reduction objectives should not be considered in the assessment and determination of individual projects under the EP&A.

Sections 3.1 to 3.3 of this Report describe strategic-level policy framework relating to greenhouse gas emissions and climate change, while Section 3.4 describes South32's strategic framework.

2.2 SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS

The Secretary's Environmental Assessment Requirements (SEARs) for the Project (issued 23 December 2021) include the following in relation to greenhouse gases:

> *The EIS must address the following specific matters:*
>
> …
>
> ○ how the development has been designed to avoid or minimise, to the greatest extent practicable, impacts on:
>
> …
>
> - greenhouse gas emissions.
>
> …

This GHG Assessment and the independent peer review of the greenhouse gas emissions estimates and emission reduction measures, conducted by Palaris (2022) (Attachment 5 of the EIS), describe how greenhouse gas emissions for the Project would be avoided or minimised as far as practicable.

The SEARs also require:

> *The EIS must address the following specific matters:*
> …
>
> ***8. Greenhouse Gas** – including:*
>
> - *an assessment of the likely greenhouse gas emissions of the development;*
> - *analysis of how the development's greenhouse gas emissions would affect State and national greenhouse gas emission reduction targets;*
> - *a review of available best practice greenhouse gas emissions reduction measures available to the development;*
> - *details of proposed greenhouse gas emissions avoidance, mitigation and/or offset measures; and*
> - *an independent peer review of the greenhouse gas emission estimates and emission reduction measures, particularly targeting fugitive emissions from the development.*

This GHG Assessment has been prepared to satisfy the first four components of the above requirements and clause 2.20 of the Resources and Energy SEPP (notwithstanding the Project's declaration as SSI) and is supported by the *Dendrobium Mine Extension Project Air Quality and Greenhouse Gas Assessment* report prepared by Ramboll (2022) (Appendix I of this EIS).

The independent peer review of the greenhouse gas emissions estimates and emission reduction measures, conducted by Palaris (2022), are included in Attachment 5 of this EIS.

3 POLICY FRAMEWORK

3.1 GLOBAL

The international framework addressing greenhouse gas emissions, and the global response to climate change, commenced with adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992.

The UNFCCC has close to global membership, with 197 Parties (UNFCCC, 2022a). While a number of negotiating sessions are held each year, the largest is the annual Conference of the Parties (UNFCCC, 2022a). Two of the most important progressions of the UNFCCC were at the third Conference of the Parties (in 1997) and 21st Conference of the Parties (in 2015), with the adoption of the *Kyoto Protocol* and the *Paris Agreement*, respectively.

The *Kyoto Protocol* entered into force in 2005 and imposed limits on the greenhouse gas emissions of developed countries listed in Annex 1 to the UNFCCC, with an initial commitment period of 2008 to 2012 (UNFCCC, 2022b). The UNFCCC requires parties to submit national inventories of greenhouse gas emissions and report on steps taken to implement the *Kyoto Protocol* (UNFCCC, 2022b). The *Doha Amendment* to the *Kyoto Protocol* was adopted at the 18th Conference of the Parties (in 2012), which included a second commitment period of 2013 to 2020 (UNFCCC, 2022b). However, the *Doha Amendment* has not yet entered into force (UNFCCC, 2022b).

The goal of the *Paris Agreement* is to limit global temperature increases to well below 2 degrees Celsius (°C) above pre-industrial levels (UNFCCC, 2022b). In order to achieve that goal, Parties aim to reach peak global emissions as soon as possible, so as to (UNFCCC, 2022c):

> *… achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of the century.*

The *Paris Agreement* does not specify how global emissions reductions are to be achieved. It requires Parties to prepare, communicate and maintain nationally determined contributions (NDCs) and to pursue domestic measures to achieve them (UNFCCC, 2022c; UNFCCC, 2022d). The NDCs are to be communicated every five years, with each successive NDC to represent a progression beyond the previous NDC. Parties' first NDCs were submitted in 2015. New or updated NDCs will be progressively prepared and made available on the NDC Registry[2].

The greenhouse gas emissions associated with coal produced by the Project that is used domestically will be accounted for and managed in accordance with domestic law that has been adopted to implement Australia's NDCs. Greenhouse gas emissions produced by the end use of Project coal overseas would be accounted for and managed in accordance with the laws that have been adopted to implement the NDCs of the countries to which the coal is exported. At the 24th Conference of the Parties (in 2018), the Katowice Climate Package was agreed. The Katowice Climate Package contains, among other things, detailed guidance on the features of NDCs and the information each country should provide to improve transparency regarding NDCs, as well as highlighting the need to ensure that double counting of greenhouse gas emissions is avoided (UNFCCC, 2022e).

At the 26th Conference of the Parties in November 2021, the *Glasgow Climate Pact* was reached. The draft Pact reaffirms the long-term global goal to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels. The agreement also invites Parties to consider further actions to reduce non-carbon dioxide greenhouse gas emissions, including methane, by 2030 (UNFCCC, 2021a).

In the leadup to the 26th Conference of the Parties, in October 2021, the International Energy Agency (IEA) released three documents to inform the development of the *Glasgow Climate Pact*, these were:

- *Net Zero by 2050: A Roadmap for the Global Energy Sector* (IEA, 2021a);
- *World Energy Outlook 2021* (IEA, 2021b); and
- *Curtailing methane emissions from fossil fuel operations: Pathways to a 75% cut by 2030* (IEA, 2021c).

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[2] UNFCCC (n.d) *NDC Registry (Interim)*. Website: https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx

Where relevant, reference is made to these documents in the following sections of this report.

The IEA report *Curtailing methane emissions from fossil fuel operations: Pathways to a 75% cut by 2030* (IEA, 2021c) examines the methane emissions reductions that would be required to secure a 75% reduction in methane emissions from fossil fuel operations as envisioned in the *Net Zero by 2050 Roadmap* (IEA, 2021a), and describes that tackling methane emissions from fossil fuel operations "*represents one of the best near-term opportunities for limiting the worse effects of climate change because of its short-lived nature in the atmosphere and the large scope for cost-effective abatement, particularly in the oil and gas sector*."

Much of the IEA (2021c) report is necessarily focussed on the oil and gas industry, however, it also has a section on coal that states:

> *From a climate perspective, the methane intensity of a given coal mine should certainly be considered when deciding which assets should continue to produce. Furthermore, the potential of emissions to continue after the end of operations should also be considered, with a need for measures to ensure these are kept to a minimum.*

Further, with respect to coal mine methane mitigation measures, IEA (2021c) also states:

> *Higher concentration sources of methane can be captured if measures are planned prior to the start-up of mining operations. Degasification wells and drainage boreholes can capture methane in coal reservoirs, reducing the potential of leaks during production. This gas can then be used for small-scale power generation or, if concentrations are high enough, injected into a local gas grid. Where concentrations are low and there is no demand for gas in the area, methane can be combusted to reduce its climate impacts, either through open flares or enclosed combustion systems.*
>
> *For mines that are already in operation, ventilation air methane is often already captured and can be directed to processes such as blending or oxidation to make it usable as an energy source (e.g. for heating mine facilities or drying coal). Thermal or catalytic oxidation technologies are technically feasible at low CH_4 concentrations, between 0.25% and 1.25%, and can reduce methane emissions from most facilities by more than 50%.*

As the Dendrobium Mine is an existing metallurgical coal mine, and the Project would involve the continued extraction of metallurgical coal from deeper coal seams (with inherently higher gas contents), consideration is given later in this report to the potential feasibility of applying the methane mitigation measures described in IEA (2021c) over the life of the Project, and post mining.

3.2 NATIONAL

Australia's first NDC under the *Paris Agreement* communicates a greenhouse gas emissions reduction target of 26 per cent (%) to 28% below 2005 levels by 2030 and was updated in 2021 to include a target of net zero emissions by 2050 (DISER, 2021b).

Australia's first NDC is an unconditional, economy-wide target that represents a halving of emissions per capita by 2030 and reduction in emissions per unit of Gross Domestic Product (GDP) by 2030 of approximately 77 to 81% (DISER, 2021b).

3.2.1 Assessment

Australia's National Greenhouse Accounts are prepared by the DISER. The DISER publishes the greenhouse gas emission factors used in preparing the National Greenhouse Accounts. The *National Greenhouse Accounts Factors Australian National Greenhouse Accounts August 2021* (NGA Factors) (DISER, 2021a) is the latest such publication.

3.2.2 Reporting

The Commonwealth *National Greenhouse and Energy Reporting Act 2007* (NGER Act) is a national framework for reporting greenhouse gas emissions, energy production and energy consumption by corporations. The greenhouse gas emissions and energy data reported under the NGER Act is used by the Commonwealth Government in compiling Australia's national greenhouse gas emissions inventory to meet its reporting obligations under the UNFCCC.

Under the NGER Act, corporations that have operational control of facilities must report their greenhouse gas emissions and energy data if they meet the thresholds for reporting. The thresholds are:

a) emitting 25,000 t CO_2-e of greenhouse gas emissions or producing or consuming 100 terajoules (TJ) of energy (for an individual facility); or

b) emitting 50,000 t CO_2-e of greenhouse gas emissions or producing or consuming 200 TJ of energy (cumulatively for all facilities under the operational control of the corporation).

Reporting requirements of the NGER Act include both Scope 1 and Scope 2 emissions. To avoid the potential double counting of emissions, the NGER Act does not cover Scope 3 emissions.

Dendrobium Mine has triggered reporting under the NGER Act, and the following emissions and energy data were reported to the Clean Energy Regulator for the 2020 to 2021 reporting period:

- Scope 1 emissions – 234,807 t CO_2-e.
- Scope 2 emissions – 60,339 t CO_2-e.

IMC would continue to comply with its obligations under the NGER Act for the Project.

3.2.3 Mitigation

The Emissions Reduction Fund is the centrepiece of a suite of Commonwealth Government policies designed to incentivise business and other entities to adopt better technologies and practices to reduce greenhouse gas emissions (Commonwealth of Australia, 2017). The Emissions Reduction Fund is a $2.55 billion fund that purchases emission reductions and abatement through a Commonwealth Government procurement process. The Emissions Reduction Fund is underpinned by the Commonwealth *Carbon Credits (Carbon Farming) Act 2011*, which provides a framework for developing offset projects and the creation of Australian carbon credit units (ACCUs).

In February 2019, the Australian Government announced the Climate Solutions Package, which is a $3.5 billion plan to deliver Australia's 2030 emissions reduction target. As part of the package, a Climate Solutions Fund has been established to continue the work of the Emissions Reduction Fund with an additional $2 billion investment over 10 years. Approximately $200 million per year over ten years is expected to be allocated to abatement purchases through the Emissions Reduction Fund.

In addition, a range of policies including the Safeguard Mechanism (underpinned by the Commonwealth *National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015*), the Renewable Energy Target and the National Energy Productivity Plan have been implemented to help Australia meet its greenhouse gas commitments (Commonwealth of Australia, 2017).

The Safeguard Mechanism, which was established through the NGER Act, aims to ensure that greenhouse gas emission reductions purchased through the Emissions Reduction Fund are not undermined by increases in greenhouse gas emissions in other sectors. The Safeguard Mechanism sets a baseline level of emissions for facilities that emit over 100,000 t CO_2-e per year. If a facility exceeds its baseline level, it is generally required to surrender ACCUs, equivalent to the exceedance, to the Clean Energy Regulator. There are other mechanisms by which a facility can manage baseline exceedance, including applying for multi-year monitoring periods and exemptions for exceptional circumstances (i.e. natural disasters or criminal activity unrelated to the liable entity).

In 2021, the Australian Government detailed Australia’s Long Term Emissions Reduction Plan (the Plan), a range of policy initiatives to deliver net zero greenhouse gas emissions by 2050. The Plan is focused on reducing the cost of low emissions technology whilst increasing their availability nationwide. The Australian Government is committed to investing more than $20 billion in low emissions technology by 2030, including the Emissions Reduction Fund and Climate Solutions Fund. Other notable investments include $10 billion for the Clean Energy Finance Corporation to assist the private sector developing low emissions technology, over $1.4 billion to the Australian Renewable Energy Agency and over $1.2 billion supporting the developing of clean hydrogen (DISER, 2021c).

The Plan outlines eight critical pathways to achieving net zero greenhouse gas emissions, namely (DISER, 2021c):

- low emissions electricity (e.g., derived from renewable sources such as solar and wind);
- electrification (e.g., use of electrified vehicles instead of diesel or petrol);
- alternative fuels (e.g., hydrogen);
- energy storage (e.g., battery storage of solar-generated electricity);
- energy efficiency (e.g., use of more energy efficient appliances);
- carbon capture and storage;
- land-based solutions (e.g., storing carbon in soils and vegetation); and
- development of emerging technologies (e.g., livestock feed supplements to reduce emissions generated by livestock).

In order to implement these pathways, the Plan describes Australia's Technology Investment Roadmap, which will consist of annual Low Emissions Technology Statements. Each statement will include review and refinement of the Australian Government's priorities, goals and investment strategy for low emissions technologies, and report on progress towards current goals (DISER, 2021c). The 2020 and 2021 Low Emissions Technology Statements identify the following priority low emissions technologies (DISER, 2020; DISER, 2021d):

- clean hydrogen;
- ultra low-cost solar;
- energy storage;
- low emissions materials (steel and aluminium);
- carbon capture and storage; and
- soil carbon.

3.3 STATE

The NSW Government has released the *NSW Climate Change Policy Framework* (NSW Government, 2016), which commits NSW to the 'aspirational long-term objective' of achieving net-zero emissions by 2050. The NSW Climate Change Policy Framework endorses the *Paris Agreement* and includes an aspirational objective to implement policies consistent with the Commonwealth Government's plans for long-term greenhouse gas emissions reductions. It also includes an objective for NSW to be more resilient to climate change impacts (NSW Government, 2016).

In addition, the NSW Government has committed to halving the State's greenhouse gas emissions by 2030 (NSW Department of Planning and Environment [DPE], 2022a) (Section 3.3.3).

3.3.1 Assessment

Estimates of NSW' greenhouse gas emissions are prepared as part of Australia's National Greenhouse Accounts by the DISER. The NGA Factors published by the DISER includes NSW-specific emission factors used in preparing the National Greenhouse Accounts.

3.3.2 Reporting

In addition to the reporting of greenhouse gas emissions and energy consumption/production of individual facilities in NSW through reporting under the NGER Act (Section 3.2), and the Commonwealth Government's reporting of the State's greenhouse gas emissions via the National Greenhouse Accounts, the NSW Government has committed to additional reporting as part of the *Net Zero Plan Stage 1: 2020-2030*, including (DPIE, 2020a):

- State of the Environment Reports, which will describe the greenhouse gas emissions reductions achieved, greenhouse gas emissions forecasts and economic impact analyses.
- Annual recommendations from the NSW Climate Change Council, focused on potential improvements to the programs described in the *Net Zero Plan Stage 1: 2020-2030*, opportunities for further greenhouse gas emissions reductions and reducing the cost of living in NSW.
- Reports from the NSW Chief Scientist and Engineer every second year on emerging technologies that can reduce greenhouse gas emissions and are commercially competitive.

3.3.3 Mitigation

The *NSW Climate Change Policy Framework* is being implemented in part through the Climate Change Fund, through which the NSW Government is investing $1.4 billion for the period 2017 to 2022 to improve energy affordability and reliability, help households and businesses save money and improve climate change resilience in communities across NSW (DPE, 2022b).

The DPIE published the *Net Zero Plan Stage 1: 2020-2030* in March 2020, which describes how, over the next decade, the NSW Government intends to work towards its objective of achieving net zero emissions by 2050 (DPIE, 2020a). The *Net Zero Plan Stage 1: 2020-2030* sets out greenhouse gas emissions mitigation measures relevant to electricity generation, transport, agriculture, stationary energy (excluding electricity generation), fugitive emissions, industrial processes, waste and land use (DPIE, 2020a).

The NSW Government outlines a number of greenhouse gas mitigation strategies in the *Net Zero Plan Stage 1: 2020-2030*, including (DPIE, 2020a):

- A $450 million Emissions Intensity Reduction Program to support businesses in transitioning their process, plant and equipment to low greenhouse gas emissions alternatives.
- A further $450 million from the Commonwealth's Climate Solutions Fund to support land managers, farms and other businesses to implement low-cost greenhouse gas emissions reduction actions.
- Development of Renewable Energy Zones to connect investors with communities who wish to diversify their electricity supply with renewable energy.
- Establishment of an Energy Security Safeguard and expansion of the Energy Efficiency Program to improve energy efficiency.
- Development of an Electric Vehicle Infrastructure and Model Availability Program to increase the uptake of electric vehicles in NSW.
- Development of a Primary Industries Productivity and Abatement Program to support landowners and primary producers in commercialising low-emissions technologies and maximising their revenue from carbon offset programs.
- Investment in a Coal Innovation Program focused on providing incentives for capturing and reusing methane released from underground mines, and commercialising emerging technologies that can reduce fugitive emissions from hard-to-mitigate mines.
- Establishment of policies regarding organic waste management and development of waste to energy facilities to reduce the amount of methane generated from decomposing organic material.
- Development of a Green Investment Strategy to facilitate growth in the environmental goods and services sector and attract new investors.

Notably, the *Net Zero Plan Stage 1: 2020-2030* (DPIE, 2020a) states the following:

> *New South Wales' $36 billion mining sector is one of our biggest economic contributors, supplying both domestic and export markets with high quality, competitive resources. Mining will continue to be an important part of the economy into the future and it is important that the State's action on climate change does not undermine those businesses and the jobs and communities they support.*

This illustrates that the State of NSW is adopting an approach to emissions reduction that balances both socio-economic factors and emissions reduction opportunities for the long-term benefit of the State.

3.3.4 Adaptation

The NSW Government acknowledges that changes to climate due to global greenhouse gas emissions are unavoidable and NSW must adapt to these climatic changes by building resilience (DPE, 2022a; NSW Government, 2021).

It is further acknowledged that responsibility for adapting to climate change and building resilience is shared between private entities and governments (DPE, 2022c), consistent with the roles and responsibilities of governments, businesses and the community in regard to climate change adaptation in Australia agreed by the Council of Australian Governments (COAG) in 2012 (COAG, 2012).

Role of Government

The NSW Government (DPE, 2022c) states it will help NSW to adjust to a changing climate by:

- *Supporting local adaptation actions.*
- *Managing climate change risks to its own assets and services.*
- *Removing market, regulatory and governance barriers to the private sector and local government adapting effectively.*
- *Reducing climate change impacts on health and wellbeing.*
- *Managing impacts on natural resources, ecosystems and communities.*

The *Select Council on Climate Change Meeting Communique 16 November 2012* (COAG, 2012) describes that one of the key roles of government in climate change adaptation is to set the right conditions to facilitate adaptation by private entities. This means governments must ensure that policies and regulatory arrangements that facilitate climate change adaptation do not distort market signals and incentives for private entities (COAG, 2012). This is reinforced in the 'Guiding principles for the management and allocation of climate change risks' (COAG, 2012), which states:

> *Public actions and policies should be carefully targeted and should not undermine the incentives for, or capacity of, the private sector to individually manage risk.*

Governments should also ensure climate change risk is appropriately recognised by private entities and the responsibility for management of such risks is apportioned and communicated effectively (COAG, 2012).

The NSW *Climate Change Policy Framework* (NSW Government, 2016) (Section 3.3) outlines the NSW Government's commitments regarding reducing greenhouse gas emissions and building resilience in NSW. In line with the above, the *Climate Change Policy Framework* and the subsequent *Net Zero Plan Stage 1: 2020-2030* (DPIE, 2020a) (Section 3.3.3) are focused on programs and strategies that incentivise participation by businesses, rather than requiring participation.

3.4 SOUTH32

Sustainability is a core focus of South32, with sustainable work practices embedded in its operations. South32's sustainability policy aligns with international benchmarks, particularly the International Council on Mining and Metals. The policy is also informed by the United Nations Sustainable Development Goals and the United Nations Global Compact Ten Principles. Specifically, they focus on reducing carbon emissions and avoiding and managing climate change risks, sustainable development and eradicating modern slavery.

3.4.1 Mitigation

South32 supports the objectives of the *Paris Agreement* and is committed to assisting in achieving these goals. Upon its inception in 2015, South32 announced its goal to achieve net zero carbon emissions by 2050, as well as a short-term target to keep its group-wide Scope 1 emissions below its FY15 baseline, which has been met. In 2021, South32 set a new company-wide decarbonisation target to achieve a 50% reduction in Scope 1 and 2 emissions by 2035 (South32, 2021a) and committed to the implementation of a range of mitigation measures and strategies to achieve its decarbonisation target. General mitigation themes include (South32, 2021a):

- reducing emissions through efficiency projects and low-carbon energy;
- applying low-carbon design to reduce carbon intensity; and
- trialling technology solutions for existing operations.

The approach to decarbonisation is aligned with a hierarchy focused on emissions avoidance, mitigation and offsetting:

- Avoidance: low-carbon design and technology to avoid emissions;
- Mitigation: reducing emissions through efficiency projects and low-carbon energy; and
- Offsetting: using high-quality carbon credits to offset residual and hard to abate emissions.

Specific greenhouse gas mitigation measures and reduction strategies South32 is implementing internationally, nationally and within NSW are detailed below. It should be noted the decarbonisation target is company-wide, and applies to the portfolio of South32's assets, which may reduce emissions at varying speeds to meet this company-level target. Similar to the approach outlined by the NSW Government regarding its implementation plan for achieving emission reduction objectives (Section 2.1), which states that different sectors of the NSW economy will reduce emissions at different rates, it is expected that various components of South32's operations will decarbonise at different rates.

South32 is taking a range of initiatives to mitigate Scope 1 and 2 emissions throughout its portfolio of assets. These initiatives are summarised below.

As the largest aluminium smelter in the southern hemisphere, the Hillside Aluminium facility in South Africa is the largest contributor to South32's global Scope 1 and 2 emissions (~56%) (South32, 2021a). The bulk of these emissions are associated with purchased electricity. As such, South32 is completing a feasibility study for the deployment of AP3XLE energy efficiency technology at the facility. To materially reduce the Scope 2 emissions of the facility, South32 is also investigating alternate, lower-carbon energy sources for the South African electricity grid with Eskom, the South African public electricity company, government and other potential partners.

The AP3XLE technology is also currently being deployed at South32's Mozal Aluminium Smelter in Mozambique.

South32 has also completed a pre-feasibility study to incorporate low-carbon design initiatives at the Taylor Deposit in Hermosa, Arizona.

Worsley Alumina, in Western Australia, is the largest contributor to South32's national Scope 1 and 2 emissions. South32 has completed low-carbon fuel switching trials at the facility, and has completed a pre-feasibility study for the conversion of a coal-fired boiler to natural gas. A pre-feasibility study of mud-washing at the facility is also underway, which will reduce water, steam and energy consumption at the facility.

At the Cannington zinc-lead-silver mine in Queensland, South32 has installed an off-grid solar photovoltaic system and is trialling light battery electric vehicles.

IMC's Dendrobium Mine and Appin Mine comprise South32 operations in NSW. While a range of mitigation and management measures are employed to optimise fuel and electricity usage (Section 4.2.2), fugitive emissions of coal seam gas are the most significant contributor to Scope 1 emissions.

In recognition of this, South32 is focused on increasing the efficiency of gas drainage and assessing technologies for abating ventilation air methane.

Gas is drained from coal seams before and after mining activity. The captured gas is piped to the surface and either supplied to a third-party provider to generate electricity (as occurs at the Appin Mine) or destroyed through flaring which converts the methane into carbon dioxide (proposed for the Project) (i.e. 28 times reduction in CO_{2-e} emissions).

Appin is currently mining in a relatively homogenous gas environment with consistent gas composition and content. The majority of the coal mine waste gas released is collected and removed ahead of and during the progressive longwall mining activities using an underground gas pipeline network. In the case of Appin Mine, these volumes are delivered to the Appin and Tower power stations adjacent to Appin Mine surface facilities, operated by a third party (energy generation company EDL) to provide power to the NSW state grid. Coal mine waste gas in excess to volumes used to generate electricity is destroyed through flaring which converts the methane into carbon dioxide. Gases which are not captured in these pipelines are removed through closely monitored ventilation systems.

Appin is also targeting an increase in post drainage capture efficiency through increased in-seam drilling. Studies are underway to evaluate drilling methods to increase post-drainage capture, as well as identify additional pre-drainage targets.

Dendrobium is currently mining in an area with lower fugitive emissions, currently comprising ~6% of the total Scope 1 emissions from IMC. Due to the higher emissions at Appin Mine, IMC's decarbonisation focus is directed to Appin Mine where the most material abatement opportunities exist to lower overall emissions at IMC. The gas content of the seams currently mined by the Dendrobium operations is sufficiently low that it is not required to be drained and flared. However, IMC is currently seeking approval for a gas management plant for the Dendrobium Mine to reduce emissions through the capture, drainage and flaring of gas from the approved Area 3C mining domain.

In addition, IMC has worked in partnership with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) since 2014 on ventilation air methane capture and recovery, consistent with the IEA's (2021c) recommendations. The partnership has resulted in CSIRO patenting a number of ventilation air methane abatement and utilisation technologies. IMC and CSIRO are completing a pilot plant scale trial of CSIRO's 'VAMMIT' technology at Appin Mine. Following completion of the pilot plant scale trial, anticipated in 2022, a commercial scale VAMMIT trial is planned at Appin Mine, which if successful may be applicable for use at other mines (Attachment 1).

Specific mitigation and management measures to be adopted for the Project (i.e. Area 5) are provided in Section 4.2.2.

4 ESTIMATED PROJECT GREENHOUSE GAS EMISSIONS

4.1 GREENHOUSE GAS EMISSIONS ESTIMATION METHODOLOGY

Project direct and indirect greenhouse gas emissions have been estimated by Ramboll (2022) (Appendix I of this EIS) using data provide by IMC and published emission factors from the NGA Factors (DISER, 2021a), where possible. The emission estimates have been peer reviewed by Palaris (see Attachment 5 of the EIS).

The energy contents, emission factors and activity data used to estimate the Project's greenhouse gas emissions are summarised in Sections 8.2 to 8.4 of Appendix I of this EIS.

4.2 PROJECT GREENHOUSE GAS EMISSIONS

A summary of key potential greenhouse gas emissions sources considered for the Project is provided in Table 1. The greenhouse gas emissions for the Project estimated by Ramboll (2022) are summarised in Table 2.Ramboll (2022) considered other minor emissions sources, however deemed them to be below the materiality threshold for inclusion in the assessment. These include employee travel, waste disposal and vegetation clearing. Greenhouse gas emissions for the Project have been calculated in accordance with the requirements of the NGER Act.

Table 1
Summary of Key Potential Project Greenhouse Gas Emissions

Component	Direct Emissions	Indirect Emissions	
	Scope1	Scope 2	Scope 3
Electricity consumption for the processing of ROM coal and other on-site uses	N/A	Emissions from the consumption of purchased electricity used at the Project.	Upstream emissions from the extraction, production and transport of fuel burned for the generation of electricity consumed, and the electricity lost in delivery in the transmission and distribution network.
Diesel consumption (including during decommissioning)	Emissions from the combustion of diesel at the Project.	N/A	Upstream emissions attributable to the extraction, production and transport of diesel consumed at the Project.
Fugitive emissions	Fugitive emissions – venting mine ventilation air, flaring of pre- and post- gas drainage and post mining fugitive emissions from stockpiled coal.	N/A	N/A
Natural gas consumption	Emissions from the coal dryer at the Project.	N/A	Upstream emissions from the attributed to the extraction, production and transport of natural gas consumed at the Project.
Coal reject and ROM and product coal transport	Emissions from the transportation of coal and coal reject to West Cliff, PKCT and Dendrobium CPP.	N/A	N/A
Use of product coal	N/A	N/A	Downstream third-party emissions from the use of product coal from the Project.

After: Ramboll (2022).

Table 2
Summary of Greenhouse Gas Emissions Estimates

Component	Estimated Greenhouse Emissions (Mt CO_2-e)			
	Scope 1		Scope 2	Scope 3
	No Flaring	Flaring		
Annual Average (during longwall mining in Area 5)	1.4	1.0	0.07	9.2
Maximum Annual Value	1.7	1.2	0.09	12.5
Total for Project Life	14.3	11.0	1.2	75.8

After: Ramboll (2022).

Note: Mt CO_2-e = Million tonnes of carbon dioxide equivalent.

It is acknowledged that the existing Dendrobium Mine Safeguard Mechanism baseline value may change over time in accordance with the provisions of the NGER Act and the applicable rules and regulations (Clean Energy Regulator, 2020b) (e.g. production adjusted baseline to reflect the Dendrobium Mine and the Project). Notwithstanding, it is anticipated that IMC's implementation of various mitigation measures to minimise the overall generation of greenhouse gas emissions from the Project (Section 4.2.2) would result in greenhouse gas emissions being maintained within any varied Safeguard Mechanism baseline emissions value. Otherwise, IMC would be required to purchase or surrender ACCUs for any exceedance of the relevant baseline value.

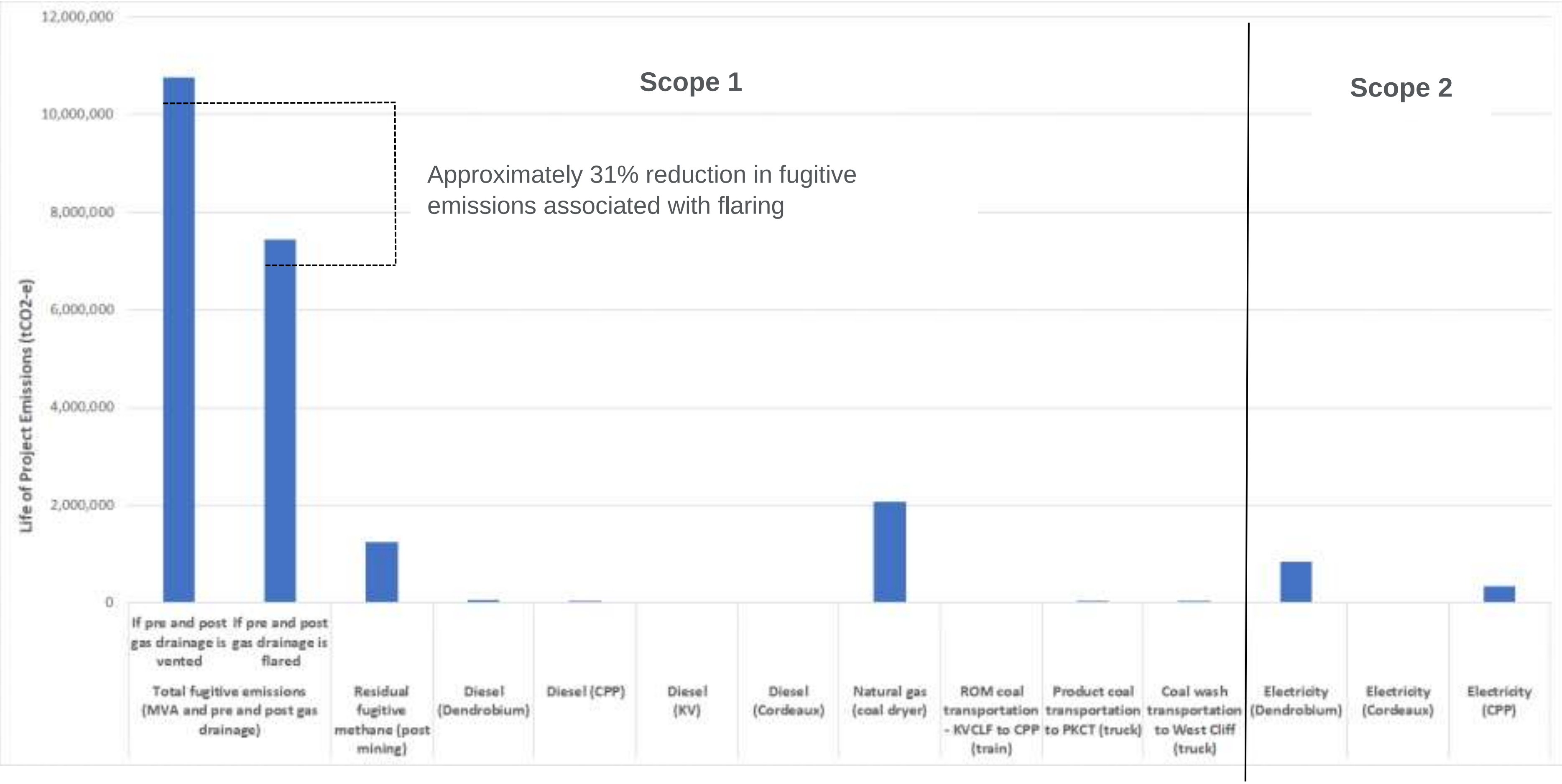
The estimated Project greenhouse gas emissions, disaggregated by key greenhouse gas emissions source (e.g. fugitive sources, diesel combustion, etc.), is provided in Appendix I of this EIS and summarised in Graph 1 (for estimated life of Project Scope 1 and 2 emissions).

Discussion of the greenhouse gas emissions intensity of the Project is provided in Section 4.2.1, and details of the Project's relative greenhouse gas contribution at a global, national and state level is provided in Sections 4.2.4 and 5.4.

4.2.1 Greenhouse Gas Emissions Intensity

The estimated Scope 1 and 2 greenhouse gas emissions intensity of the Project emissions during longwall mining in Area 5 is between approximately 0.22 to 0.47 t CO_2-e per tonne of ROM coal (t CO_2-e/t ROM coal) for Scope 1 emissions only, and between approximately 0.24 to 0.49 t CO_2-e/t ROM coal for Scope 1 and 2 emissions combined. This compares with other coal mining operations in the Illawarra region recently approved by the NSW Independent Planning Commission, with the Tahmoor South Project having Scopes 1 and 2 emissions intensity of 0.57 t CO_2-e/t ROM coal (abated) and 0.79 t CO_2-e/t ROM coal (unabated), and the Russell Vale Underground Expansion having an emissions intensity of 0.38 t CO_2-e/t ROM coal (DPE, 2022e).

Graph 1: Breakdown of Life of Project Scope 1 and 2 Greenhouse Gas Emissions by Source



4.2.2 Mitigation and Management Measures

Scope 1 carbon emissions from underground mines are predominantly from the release of gases from the underground coal seams during mining. These gases are known as fugitive emissions. The amount of fugitive emissions can vary greatly between mining areas, based on the surrounding rock strata, depth and seam. The largest proportion (~94%) of these emissions at IMC is from the Appin underground mine due to its relatively high gas and methane content. At Appin Mine, the methane split is approximately 13% pre-drainage capture, 30% post drainage capture and 57% ventilation air methane (VAM) which is not captured. Dendrobium is currently mining in areas of relatively low gas, however these areas will be exhausted by 2024 at currently approved production rates and the Project is proposing to extract from Area 5 with a higher gas concentration compared to Areas 1, 2, 3A and 3B. IMC is proposing gas drainage and flaring to mitigate gas from future mining at Dendrobium, including the Project.

Therefore, IMC's decarbonisation plans are focused on reducing fugitive emissions by increasing the efficiency of gas drainage and assessing technologies for reducing ventilation air methane.

For the Project, which involves longwall mining in the Bulli Seam in Area 5, a review of best practice emission reduction technologies were reviewed by IMC and peer reviewed by Palaris (Attachment 5). For the Project it is proposed:

- Best practice abatement technology for fugitive emissions would be implemented by maximising the capture of gas via effective Inseam Drainage of the Bulli Seam prior to longwall extraction (pre-drainage), cross measure drainage of the underlying Wongawilli Seam during longwall extraction (post-drainage) and flaring of methane, thereby converting methane to carbon dioxide and lowering the global warming potential by a factor of 28.
- Further opportunities to maximise gas capture via pre-drainage of the underlying Wongawilli Seam and management of goaf gas would be investigated, and implemented if technically feasible and commercially viable.

This is predicted to reduce fugitive GHG emissions by approximately 3.3 Mt CO_2-e or 31% over the life of the Project, which is a significant and material reduction (Graph 1).

In addition, IMC would investigate the use of alternative fuels for surface and underground equipment for the Project.

Additional abatement measures for fugitive emissions have been considered, but are not considered reasonable or feasible for inclusion in the Project. This includes:

- Combustion of gas to generate electricity: While this technology is used at the Appin Mine, it requires a relatively homogenous gas resource at 75-95% methane, and notwithstanding, requires periodic gas enrichment from the state gas network to feed the electricity generation plant. By comparison, the Area 5 gas content is lower in methane content and less homogenous, and as such, would require gas enrichment which is not available in the Metropolitan Special Area. Accordingly, this option is not considered viable for the Project.
- Ventilation Air Methane (VAM): In partnership with CSIRO, IMC is supporting the development of VAM abatement technology at the Appin Mine. This project is at the pre-feasibility stage of a full-scale demonstration plant, following the trial of pilot plants over the last three years. The use of VAM abatement by the Project is deemed unviable because of the unavailability of proven and cost effective VAM technologies suitable for the Project. However, if the technology is successful at Appin, it may be considered at the Dendrobium Mine, with the associated development of infrastructure required to implement VAM abatement at Dendrobium would be subject to separate assessment and approval. Accordingly, VAM abatement does not form part of the Project.

The existing *Dendrobium Mine Air Quality and Greenhouse Gas Management Plan* (IMC, 2021) describes a number of greenhouse gas abatement measures and mining efficiency improvement projects which would continue to be implemented for the Project, including:

- maintaining plant and equipment to optimise reliability and efficiency;
- upgrading equipment and processes to optimise efficiency and reduce energy consumption, if opportunities arise; and
- operational practices (e.g. optimising the utilisation of available plant).

Energy use (electricity consumption and diesel usage) for the Project would continue to be recorded through direct measurement and/or invoicing.

Greenhouse gas and energy data would continue to be accounted for and reported in compliance with legislative and other requirements (e.g. the NGER Act).

The existing *Dendrobium Mine Air Quality and Greenhouse Gas Management Plan* (IMC, 2021) would be reviewed and updated accordingly to address the Project. IMC would continue to assess and implement energy and greenhouse gas management initiatives during the life of the Project.

If required by legislation, IMC would offset greenhouse gas emissions.

4.2.3 The Project's Relative Greenhouse Gas Emissions Contribution

The estimated greenhouse gas emissions of the Project can be considered in the context of global greenhouse gas emissions associated with anthropogenic sources.

To gain an understanding of the Project in the context of the global coal market (all types) and global greenhouse gas emissions, the Project's annual coal production volume can be compared to the current global coal demand and the Project's greenhouse gas emissions can be compared to total estimated anthropogenic greenhouse gas emissions. The International Energy Agency estimates the current global coal demand to be in the order of 5,000 Mt of coal per annum (International Energy Agency, 2020). The proposed peak production rate of the Project of 5.2 Mt represents approximately 0.1% of the current estimated global coal demand.

Comparison of the Project's annual average Scope 1 emissions during longwall mining (approximately 1 to 1.4 Mt CO_2-e) (Table 2) to the total anthropogenic greenhouse gas emissions globally (excluding land use change) in 2019 of approximately 51.5 gigatonnes of carbon dioxide equivalent (United Nations Environment Programme, 2021) indicates that the Project's Scope 1 emissions would contribute approximately 0.002% in the context of cumulative global emissions.

Further, comparison of the annual average Scope 3 emissions during longwall mining of customer entities combusting coal produced by the Project (approximately 9.3 Mt CO_2-e) (Table 2) to the total anthropogenic greenhouse gas emissions globally (excluding land use change) in 2019 suggests these emissions would be approximately 0.018% of global anthropogenic emissions.

4.2.4 Project Influence on State and National Greenhouse Gas Reduction Targets

Unlike a new development such as a new coal mine or new gas-fired power station, the Project represents a continuation and extension of an existing coal mine that has been operating in the Illawarra region since approximately 2002.

As the NSW and Federal Governments regularly review the current and proposed production of minerals (including coal production) as part of normal budgetary processes, the Dendrobium Mine's current metallurgical coal production, and its projected future production would be accounted for in NSW by the Mining, Exploration and Geoscience (MEG) within Regional NSW, and Federally by the DISER. If the Project is not currently included within these State and National projections, it is anticipated that it would be included in future, should it be approved.

Further, under the NGER Act, the Dendrobium Mine is already reporting its Scope 1 emissions (Section 3.2.3). It is anticipated that IMC's implementation of various mitigation measures to minimise the overall generation of greenhouse gas emissions from the Project (Section 4.2.2) would result in greenhouse gas emissions being maintained within any varied Safeguard Mechanism baseline emissions value. Otherwise, IMC would be required to purchase ACCUs for any exceedance of the baseline value.

Steel manufacturing facilities in Australia that are already using Dendrobium metallurgical coal (or any additional Dendrobium metallurgical coal consumed by these facilities) would likely replace coal already being combusted from other mines (or become less viable, with associated significant potential socio-economic implications for NSW and Australia), and therefore the Scope 1 emissions of these steel manufacturing facilities would be unchanged by the Project. These manufacturing facilities (e.g. Port Kembla Steelworks) are also required to report their Scope 1 emissions in accordance with the NGER Act, and comply with the requirements of the Clean Energy Regulator.

Therefore, it follows that, should the Project be approved, any Project metallurgical coal combusted in NSW (i.e. at BlueScope, Port Kembla) or elsewhere in Australia (e.g. Liberty Primary Steel Whyalla Steelworks, South Australia), would have no influence on State or National Greenhouse Gas Reduction targets, given these major facilities are of national economic significance, and therefore would be accounted for within State and National greenhouse gas reduction targets.

Based on the estimated emissions for the Project, its Scope 1 and 2 emissions represent:

- Between 0.08% and 0.32% of Australia's 2005 inventory and between 0.09% and 0.33% of Australia's 2019 inventory (i.e. range based on minimum estimated annual emissions during longwall mining with flaring, and maximum annual emissions during longwall mining with no flaring [i.e. the conservative worst-case]).
- Between 0.28% and 1.1% of NSW' 2005 inventory and between 0.34% and 1.3% of NSW' 2019 inventory. Based on a 50% reduction in NSW emissions compared to the 2005 inventory by 2030, the Project's base case scope 1 and 2 emissions would represent between 0.56% and 2.2% of the 2030 emissions inventory objective.

When considering the Project represents a continuation of the existing greenhouse gas emissions of the Dendrobium Mine, the Project would incorporate reasonable and feasible greenhouse gas mitigation measures (Section 4.2.2), the relatively minor contribution of the Project's Scope 1 and 2 emissions to Australian and NSW inventories, and the national and state-level strategic policies being implemented to reduce cumulative greenhouse gas emissions, approval of the Project is expected to have no material influence on State and National greenhouse gas reduction targets, while delivering significant economic and employment benefits to NSW.

In addition, and notwithstanding the requirements of the SEARS, the *Net Zero Plan Stage 1: 2020–2030 Implementation Update* relevantly states that (Section 2.1) it is "*NSW Government policy is that the NSW Government's objective set out in this Plan, to reduce emissions by 50% below 2005 levels by 2030, is not to be considered in the assessment or determination of development and infrastructure applications under the Environmental Planning and Assessment Act 1979.*"

5 POTENTIAL IMPACTS OF CLIMATE CHANGE

Consideration of the potential implications of climate change involves complex interactions between climatic, biophysical, social, economic, institutional and technological processes.

Although scientific understanding of climate change has improved, projections are still subject to a wide range of uncertainties such as (CSIRO and Bureau of Meteorology [BoM], 2015):

> *…scenario uncertainty, due to the uncertain future emissions and concentrations of greenhouse gases and aerosols; response uncertainty, resulting from limitations in our understanding of the climate system and its representation in climate models; and natural variability, the uncertainty stemming from unperturbed variability in the climate system.*

The sources for climate change projections considered for the Project include:

- The *Working Group 1 Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC) (IPCC, 2021).
- Climate Change in Australia, produced by CSIRO and BoM (Dowdy *et al.*, 2015).
- An Interactive Climate Change Projections Map (Illawarra region), which has been produced by the NSW government (AdaptNSW, 2022) and informed by data collected by NARCliM (2015).
- OEH's (2014) *Illawarra Climate Change Snapshot* (Attachment A).

The Climate Change in Australia report presents climate change projections for Australia. The NARCliM Project presents climate change projections for NSW and ACT only.

5.1 CLIMATE CHANGE PROJECTIONS GLOBALLY

The IPCC has completed a number of comprehensive assessments of potential climate change, which include projections for both the 'near-term', focused on the period 2021 to 2040, and 'long-term', focused on the period 2081 to 2100. Summaries of relevant climate projections from the *Working Group 1 Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC, 2021) are provided below.

It is noted that the Working Group's 1, 2 and 3 contributions to the Sixth Assessment Report of the IPCC have been released, with the final Synthesis Report due in September 2022.

- **'Near-term' climate projections –** projections indicated global mean surface temperatures are likely to increase by 0.4 to 1.1°C based on the range of all climate scenarios and relative to the reference period of 1995 to 2014 (IPCC, 2021).
- **'Long-term' climate projections –** global mean surface temperatures are projected to increase by 1.3 to 2.7°C under the SSP2-4.5[3] climate scenario and 2.5 to 4.9°C under the SSP5-8.5[4] climate scenario relative to the reference period of 1995 to 2014 (IPCC, 2021).

Climate projections suggest that many changes in the climate system are likely to become larger in direct relation to increasing incremental global warming, with a warmer climate likely to intensify very wet and very dry weather and climatic events and seasons, noting the frequency is dependent on location (IPCC, 2021).

Extreme climatic events (e.g. hot extremes [including heatwaves], heavy rainfall events and droughts) are projected to be more frequent if global warming reaches 1.5°C above pre-industrial levels, and even more frequent if global temperatures are raised to 2°C above pre-industrial levels for some regions (IPCC, 2021).

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[3] Intermediate greenhouse gas emissions scenario whereby emissions are assumed to remain at 2015 levels until mid-century.
[4] High greenhouse gas emissions scenario whereby emissions are assumed to roughly double from 2015 levels by 2050.

5.2 CLIMATE CHANGE PROJECTIONS FOR AUSTRALIA

In Australia, the climate is generally projected to become warmer and drier. Climate change may result in changes to rainfall patterns, runoff patterns and river flow.

Two greenhouse gas global emissions scenario projections for annual average rainfall in the East Coast South sub-cluster of 'Eastern Australia' for 2030 and 2090 (relative to 1995) are presented in Table 3 based on Climate Change in Australia, produced by CSIRO and BoM (Dowdy *et al.*, 2015).

It is noted that the RCP8.5 scenario (worst-case) illustrated in Table 3 is a scenario where minimal greenhouse gas emissions controls are introduced, and hence does not reflect the measures currently being pursued by Parties to the *Paris Agreement*.

Table 3
Climate Change Projections for the East Coast South Sub-cluster, Eastern Australia – Percentage Change in Rainfall (relative to 1995)

Period	2030	2090	
	RCP4.5	RCP4.5	RCP8.5
Summer	+1	0	+11
Autumn	-3	-1	-2
Winter	-5	-8	-17
Spring	-1	-6	-8
Annual	-3	-2	-3

Source: After Dowdy *et al.* (2015).
RCP4.5: Emissions scenario assuming a slow reduction in emissions that stabilises CO_2 concentration at about 540 ppm by 2100.
RCP8.5: Emissions scenario assuming an increase in emissions leading to a CO_2 concentration of about 940 ppm by 2100.

5.3 CLIMATE CHANGE PROJECTIONS FOR NEW SOUTH WALES

The Project is located within the Illawarra Region of the AdaptNSW Project domain. AdaptNSW projections are based on NARCliM data which is generated using the Weather Research and Forecasting Model, which has been demonstrated to be effective in simulating temperature and rainfall in NSW and provides a good representation of local topography and coastal processes (Evans and McCabe, 2010).

Mean temperatures in the Illawarra Region are projected to rise by 0.62°C by 2030 and 1.9°C by 2070 (AdaptNSW, 2022). Summer and spring will experience the greatest changes in temperatures, with maximum temperatures increasing by 2.14°C and 2.17°C by 2079.

Changes to annual rainfall are predicted to vary across the Illawarra Region, with rainfall projected to increase in autumn and decrease in winter (AdaptNSW, 2022) (Table 4).

Table 4
Climate Change Projections for the Illawarra Region, NSW – Percentage Change in Rainfall

Period	2020-2039	2060-2079
Summer	+1.5	+10.9
Autumn	+5.6	+15.1
Winter	-4.9	-6.6
Spring	-1.5	-1.3
Annual	-0.4	+6.5

Source: After AdaptNSW (2022).
Note: Projections based on IPCC high emissions A2 scenario and relative to 1990-2009 baseline period.

The AdaptNSW (2022) and Dowdy *et al.* (2015) rainfall projections are quite variable, particularly for the 2079/2090 forecast. As shown in Table 3, Dowdy *et al.* (2015) project a generally drier climate, whereas Table 4 indicates that AdaptNSW (2022) projects a wetter climate.

The AdaptNSW projections use data provided by NARCliM, which is based on the IPCC high emissions A2 scenario, which projects an increase in global warming by approximately 3.4°C by 2100. The A2 scenario is similar to the RCP8.5 scenario (worst-case) modelled by Dowdy *et al.* (2015), in terms of changes in global mean temperature, and hence does not reflect the measures currently being pursued by Parties to the *Paris Agreement*.

The potential implications of climate change on local groundwater and surface water resources are considered in the Project Groundwater Assessment (Watershed HydroGeo Pty Ltd [Watershed HydroGeo], 2022) and the Project Surface Water Assessment (Hydro Engineering & Consulting, 2022), respectively.

Over the life of the Project, it is anticipated that such climatic modelling for Australia, NSW and various regions will be updated many times as international greenhouse gas emissions mitigation measures are adjusted based on the uptake of less carbon-intensive technology and as climate science continues to evolve.

The OEH (2014) has also produced the *Illawarra Climate Change Snapshot* (Attachment A) which provides climate change projects specific to the Illawarra. In addition to temperate and rainfall changes (described above), it projects the region is expected to experience (Appendix A):

- An increase in hot days (days over 35°C) per year.
- A decrease in cold days (days below 2°C) per year.
- Changes in projected severe fire weather that are relatively small (up to 1 more day per year of severe fire weather).

5.4 POTENTIAL IMPACTS OF THE PROJECT TO GLOBAL CLIMATE CHANGE

Biological diversity, or 'biodiversity', is considered to be the number, relative abundance, and genetic diversity of organisms from all habitats (including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are a part) and includes diversity within species and between species as well as diversity of ecosystems (Lindenmayer and Burgman, 2005).

Many natural ecosystems are considered to be vulnerable to climate change. Patterns of temperature and rainfall are key factors affecting the distribution and abundance of species (Preston and Jones, 2006). Projected changes in climate will have diverse ecological implications. Habitat for some species will expand, contract and/or shift with the changing climate, resulting in habitat losses or gains, which could prove challenging, particularly for species that are threatened.

"*Anthropogenic Climate Change*" is listed as a key threatening process under the NSW *Biodiversity Conservation Act 2016*, and *Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases* is listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999*.

It is acknowledged that (subject to the efficacy of national and international greenhouse gas abatement measures) all sources of greenhouse gas emissions will contribute in some way towards the potential global, national, state and regional effects of climate change.

5.4.1 Project Contribution to Global Climate Change

The Project's contribution to global climate change effects would be proportional to its contribution to global greenhouse gas emissions. Greenhouse gases directly generated at the Project (i.e. Scope 1 emissions) and indirect emissions associated with the on-site use of electricity (i.e. Scope 2 emissions) have together been estimated as summarised in Table 2, and would be negligible in the context of global greenhouse gas emissions (Section 4.2.4).

5.5 POTENTIAL IMPACTS OF CLIMATE CHANGE ON THE PROJECT

Due to the inherent uncertainties associated with the climate change projections described in Sections 5.1 to 5.3, the potential impacts of climate change on the Project cannot be determined with a high degree of confidence.

Notwithstanding, the projections presented in Sections 5.1 to 5.3 indicate average temperatures are likely to rise in the Project area, and extreme temperature events may increase in frequency. This suggests that bushfire activity may become more prevalent in the region, due to the potential of prolonged dry periods.

In addition, rainfall has the potential to both increase and decrease, particularly seasonally, with heavier rainfall events likely to become more frequent.

5.5.1 Key Risks and Mitigations

The potential for increased bushfire activity in the region poses risks to both the Project workforce and Project infrastructure. The Project's Preliminary Hazard Analysis assesses a number of fire-related hazards (including those related to bushfires) and describes the relevant existing and proposed preventative measures.

Bushfire Management Plans have been prepared by the Illawarra Bush Fire Management Committee (2016) and Wollondilly/Wingecarribee BMFC (2016). These plans include a range of measures to reduce the potential for the ignition of bushfires. Key mitigation measures include minimising and controlling ignition sources and developing evacuation strategies. Prolonged dry periods and strong winds particularly increase the potential for a bushfire. The degree of the potential impact of a bushfire is dependent on the climatic conditions and the amount of fuel available.

A safety management system at the Dendrobium Mine has been established to manage risks to health and safety in accordance with the requirements of the *Work Health and Safety (Mines and Petroleum Sites) Act 2013* and the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014*. A waste management plan is also in place.

The potential implications of climate change have been considered in the Project Groundwater Assessment (Watershed HydroGeo, 2022) and the Project Surface Water Assessment (Hydro Engineering & Consulting, 2022).

It is recognised that international measures to 'decarbonise' global economies may alter the future demand for and/or supply of coal. Expected global trends are factored into coal price forecasts considered in the Project Economic Assessment (Ernst & Young, 2022). The Economic Assessment also includes sensitivity analysis for variations in export coal prices and the social cost per tonne of carbon emissions. The sensitivity analysis shows that the Project would still generate a substantial net benefit to NSW under all scenarios considered (Ernst & Young, 2022).

Resilience to potential climate change will be a consideration for IMC when designing infrastructure for the Project.

5.5.2 Adaptive Management

IMC would implement an adaptive management approach to climate change impacts throughout the life of the Project, consistent with South32's sustainability policy.

This would include conducting climate change risk assessments in consideration of the DPIE's *Climate Risk Ready NSW Guide* (DPIE, 2020b) and implementing appropriate risk treatment strategies. Potential climate change risks to be assessed would include the example risks provided in the Climate Risk Assessment Tool described in Appendix C of the DPIE's *Climate Risk Ready NSW Guide* (DPIE, 2020b).

South32 also conducts ongoing risk assessments for each of its global operations to understand resilience to climate change, which would continue during the Project.

6 EVALUATION AND SUMMARY

The Project's contribution to global climate change effects would be proportional to its contribution to global greenhouse gas emissions.

The Project's Scope 1 and Scope 2 emissions have together been estimated at approximately 0.5 to 1.8 Mt CO_2-e per year during operations, which represents between approximately 0.34% and 1.3% of the estimated total greenhouse gas emissions in NSW from 2019 and approximately 0.09% and 0.33% of Australia's greenhouse gas emissions from 2019.

The estimated annual average Scope 3 emissions due to the combustion of coal produced by the Project by its customers would be approximately 0.018% of the total anthropogenic greenhouse gas emissions globally (excluding land use change) in 2019.

If the Project does not proceed, global demand for coal could be satisfied by other sources and, therefore, there would not likely be a corresponding reduction in global greenhouse emissions in the atmosphere due to the use of coal.

An evaluation of the merits of the Project is provided in Section 9 of the EIS main text.

In relation to greenhouse gas emissions, climate change and the principles of ecologically sustainable development, it is noted that:

- Sustainability is a core focus of South32, as exemplified by the company-wide goal (that is, not specific to each operation) to achieve a 50% reduction in Scope 1 and 2 emissions by 2035 and reach net zero by 2050.
- IMC has been proactive with regard to greenhouse gas mitigation, as evidenced by its Appin Mine gas drainage and methane power generation initiatives, Appin Mine commitment to increase post drainage capture through increased drilling and partnership with the CSIRO since 2014 developing ventilation air methane capture and recovery technologies, including the current pilot plant scale trial of CSIRO's VAMMIT technology at Appin Mine.
- Greenhouse gas emissions estimates for the Project (Scopes 1, 2 and 3) have accounted for uncertainty by adopting conservative assumptions.
- The assessment of greenhouse gas emissions of the Project allows the effective integration of social, economic and environmental considerations in the decision-making process for the Project.
- The focus of IMC's emission reductions has related to the Appin Mine, as it has accounted for ~94% of IMC's emissions.
- While capture and destruction or utilisation of ventilation air methane has been determined not to be viable for the Project, IMC would implement a suite of mitigation measures to minimise the Project's Scope 1 and Scope 2 greenhouse gas emissions, including extensive pre- and post- gas drainage and flaring of captured gas, which are consistent with industry best practice.
- IMC is also committed to investigating additional methods to increase gas drainage efficiencies, such as targeting additional coal seams for pre-drainage, as well as goaf capture.
- Valuation of potential impacts of Project Scope 1 and Scope 2 greenhouse gas emissions has been incorporated into the Economic Assessment (Ernst & Young, 2022) for the Project.
- The Project would benefit current and future generations through:
  - approximately $148.2 million (net present value) in royalties, $24.9 million in payroll tax to the State of NSW and $3.5 million in council rates and land taxes – noting a range of uncertainty analyses (e.g. variations in discount rate, coal price and exchange rate) indicate benefits would still be delivered to NSW under economic scenarios considered in the Economic Assessment (Ernst & Young, 2022);
  - the continuation and expansion of Dendrobium Mine employment (up to 700 operational employees);

  - a range of positive flow-on effects of the Project, including continuation and expansion of local spend by the Project workforce and continuation and expansion of community contributions Ernst & Young (2021); and
  - annual contributions to the community by the Dendrobium Community Enhancement Program (DCEP), per saleable tonne of coal.
- The greenhouse gas emissions associated with the combustion of portions of Project product coal overseas will be addressed and regulated by customer countries, under their NDCs. Those NDCs reflect national priorities, including in respect of sustainable development.
- When considering the Project represents a continuation of the existing greenhouse gas emissions of the Dendrobium Mine, the Project would incorporate reasonable and feasible greenhouse gas mitigation measures that are estimated to reduce the predicted Project greenhouse gas emissions by approximately 31%. The relatively minor contribution of the Project's Scope 1 and 2 emissions to Australian and NSW inventories, and the national and state-level strategic policies being implemented to reduce cumulative greenhouse gas emissions, approval of the Project is expected to have no material influence on State and National greenhouse gas reduction targets.

In relation to Australian and NSW laws and policies, it is noted that IMC would continue to comply with its obligations to report greenhouse gas emissions and energy consumption/production under the NGER Act.

IMC has considered the key potential climate change risks to the Project (particularly increased frequency of bushfires) in the design of the Project, and would continue to assess climate change risks on an ongoing basis via implementation of an adaptive management approach.

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ATTACHMENT A

OEH (2014) ILLAWARRA CLIMATE CHANGE SNAPSHOT

New South Wales
Climate change snapshot

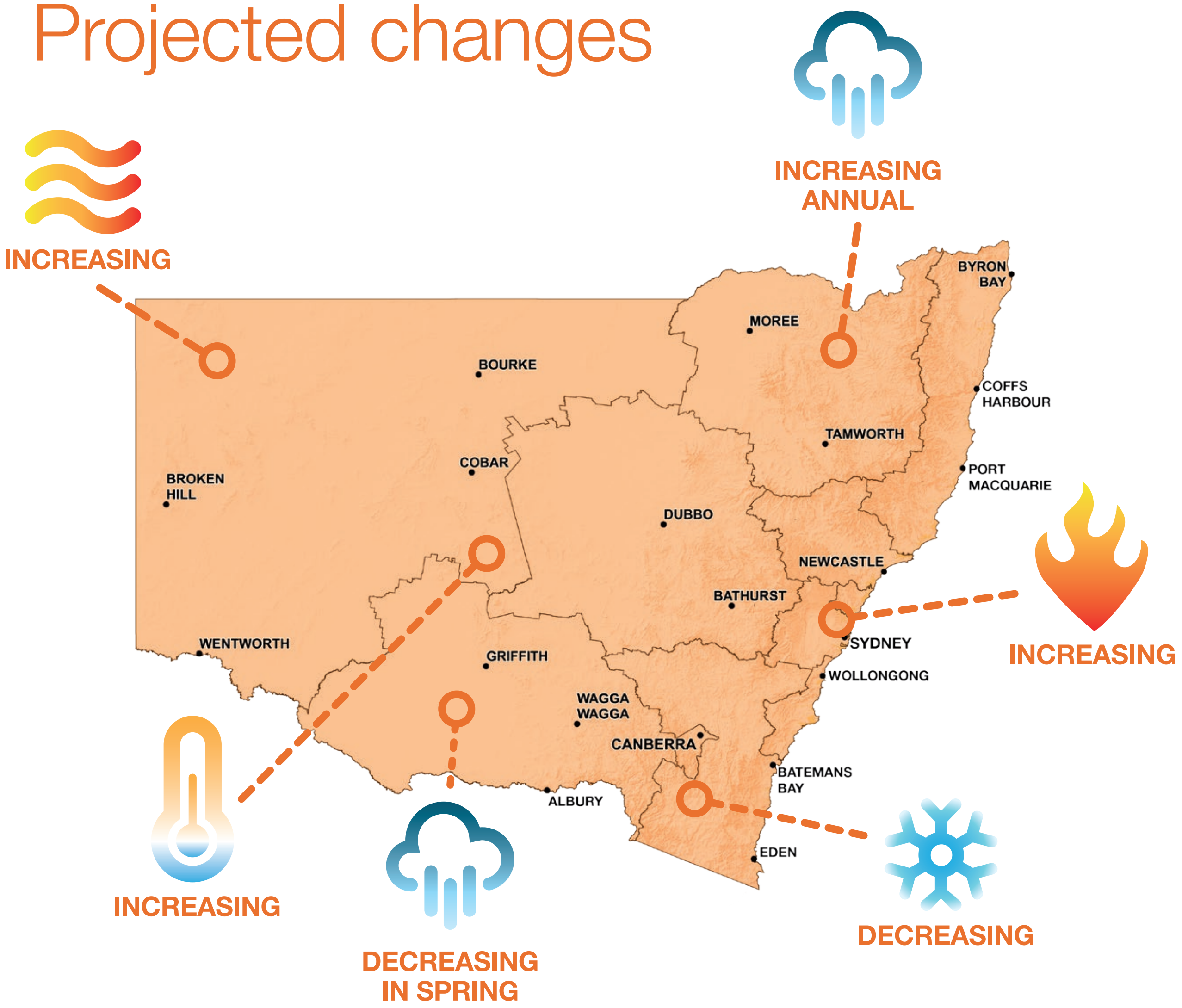
Overview of **New South Wales** climate change

According to long-term (1910–2013) observations, air temperatures have been increasing since the 1950s, with the highest temperatures on record being experienced in recent decades. The rate of change has also increased, with mean temperatures rising by 0.5°C per decade since 1990, compared to about 0.1°C per decade during the 1950s to 1980s.

NSW is projected to continue to warm in the near future (2020–2039) and far future (2060–2079). The warming is projected to average about 0.7°C in the near future, increasing to about 2.1°C in the far future. There are not many differences across the state in the projected increases in average temperatures with all regions becoming warmer. The warming projected for NSW is large compared to natural variability in temperature.

NSW currently experiences considerable rainfall variability across regions, seasons and from year-to-year and this variability is also reflected in the projections.

Projected changes



Projected **temperature** changes	
Maximum temperatures are projected to increase in the near future by 0.4 – 1.0°C	Maximum temperatures are projected to increase in the far future by 1.8 – 2.6°C
Minimum temperatures are projected to increase in the near future by 0.0 – 0.5°C	Minimum temperatures are projected to increase in the far future by 1.4 – 2.6°C
The number of hot days will increase	The number of cold nights will decrease
Projected **rainfall** changes	
Rainfall is projected to decrease in spring and winter	Rainfall is projected to increase in summer and autumn
Projected **Forest Fire Danger Index (FFDI)** changes	
Average fire weather is projected to increase in summer and spring	Number of days with severe fire danger is projected to increase in summer and spring

Regional snapshots

NSW and ACT Regional Climate Modelling project (NARCliM)

The climate change projections in this snapshot are from the NSW and ACT Regional Climate Modelling (NARCliM) project. NARCliM is a multi-agency research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW. NSW Government funding comes from the Office of Environment and Heritage (OEH), Sydney Catchment Authority, Sydney Water, Hunter Water, NSW Office of Water, Transport for NSW, and the Department of Primary Industries.

The NARCliM project has produced a suite of twelve regional climate projections for south-east Australia spanning the range of likely future changes in climate. NARCliM is explicitly designed to sample a large range of possible future climates.

Over 100 climate variables, including temperature, rainfall and wind are available at fine resolution (10km and hourly intervals). The data can be used in impacts and adaptation research, and by local decision makers. The data is also available to the public and will help to better understand possible changes in NSW climate.

Modelling overview

The NARCliM modelling was mainly undertaken and supervised at the Climate Change Research Centre. NARCliM takes global climate model outputs and downscales these to provide finer, higher resolution climate projections for a range of meteorological variables. The NARCliM project design and the process for choosing climate models has been peer-reviewed and published in the international scientific literature (Evans et. al. 2014, Evans et. al. 2013, Evans et. al. 2012).

Go to climatechange.environment.nsw.gov.au for more information on the modelling project and methods.

Interpreting climate projections can be challenging due to the complexities of our climate systems. ‘Model agreement’, that is the number of models that agree on the direction of change (for example increasing or decreasing rainfall) is used to determine the confidence in the projected changes. The more models that agree, the greater the confidence in the direction of change.

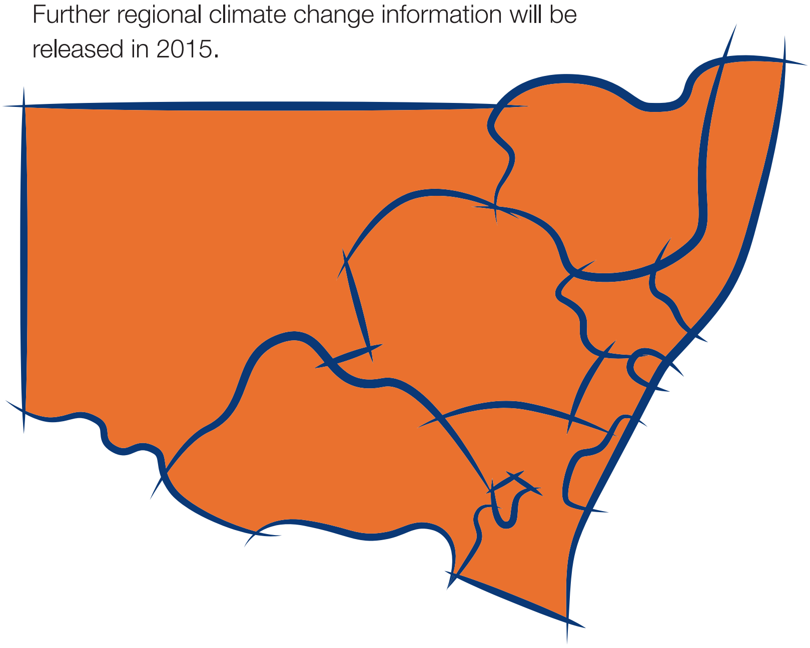
In this report care should be taken when interpreting changes in rainfall that are presented as the average of all of the climate change projections, especially when the model outputs show changes of both wetting and drying. To understand the spread of potential changes in rainfall the bar charts should be considered along with the maps provided in this document. Help on how to interpret the maps and graphs in this report is provided in Appendix 1.

Summary documents for each of the state planning regions of NSW are available and provide climate change information specific to each region.

The snapshots provide descriptions of climate change projections for two future 20-year time periods: 2020–2039 and 2060–2079.

1. The climate projections for 2020–2039 are described in the snapshots as **NEAR FUTURE, or as 2030**, the latter representing the average for the 20-year period.
2. The climate projections for 2060–2079 are described in the snapshots as **FAR FUTURE, or as 2070**, the latter representing the average of the 20-year period.

Further regional climate change information will be released in 2015.



Introduction

This snapshot presents a summary of climate change projections for NSW. It outlines some key characteristics of the state, including its current climate, before detailing the projected changes to the state's climate in the near and far future.

Topography and hydrography

Situated in the mid-latitudes of eastern Australia, NSW covers an area of more than 800,000 km^2, and has just over 2000 km of coastline.

The Great Dividing Range is an elevated region of undulating terrain and broad plains which includes the Snowy Mountains, with Mount Kosciuszko (2228 m), Australia's highest peak. The eastern side of the Great Dividing Range forms a steep escarpment with densely forested areas. The mountainous areas of the range and surrounding elevated areas include the Southern Highlands, Central Tablelands and the Northern Tablelands. The western side of the Range is less steep, ending in a series of hills and valleys which include much of the state's fertile agricultural land.

The western plains cover almost two-thirds of the state. These vast plains covered by riverine sediment are almost entirely flat.

The coastal rivers of NSW rise in the Great Dividing Range and flow eastwards to the sea. These rivers are short, navigable at their lowest reaches and subject to flooding during high rainfall periods. The inland rivers rise on the other side of the range and flow westwards, with most of these rivers eventually combining into the Murray–Darling River network which flows to the sea in South Australia.

Population and settlements

NSW is Australia's most populous state with over 73 per cent of the NSW population living in major cities. Between 1961 and 2011, the population of NSW almost doubled from 3.9 million to 7.2 million people. Population growth has been greatest in Metropolitan Sydney, as well as the Central Coast, Lower Hunter and Illawarra. Population growth has also been seen in coastal areas and in larger inland centres like Albury, Orange, Wagga Wagga and Tamworth (Department of Planning & Environment 2014).

The state's population is projected to reach 9.2 million people by 2031, with 64 per cent of this population (5.9 million), residing in Metropolitan Sydney. Population growth is projected to be larger in places near Metropolitan Sydney, such as the Central Coast, Wollongong, Newcastle and Port Stephens, coastal areas such as Tweed Heads and Port Macquarie, areas to the north and east of Canberra and the ACT, and regional centres such as Tamworth, Bathurst and Wagga Wagga (Department of Planning & Environment 2014).

Natural ecosystems

The diversity of NSW landscapes is evident in the wide variety seen in the state's bioregions. The Border Ranges of northern NSW is the most biologically diverse area in the state and includes subtropical rainforest, wet sclerophyll forest, mountain headlands, rocky outcrops and transition zones between forests. The Brigalow Belt, located in inland northern NSW, is another important area for biodiversity. It has large tracts of eucalypt woodlands and is a stronghold for endemic invertebrates. These two locations have been identified on the list of Australia's 15 National Biodiversity Hotspots[1].

1. www.environment.gov.au/topics/biodiversity/biodiversity-conservation/biodiversity-hotspots/national-biodiversity-hotspots

Climate of NSW

The climate of NSW is highly variable. The north-east of the state is dominated by summer rainfall, with relatively dry winters. Conversely the south of the state experiences regular rainfall from cold fronts and cut-off lows traversing south-eastern Australia during the winter.

The coast of NSW is influenced by the warm waters of the Tasman Sea, which moderate temperatures and provide moisture for abundant rainfall. Moist onshore winds deposit considerable precipitation on the steeply rising terrain of the Great Dividing Range. The ranges enhance rainfall near the coast and contribute to a strong east to west reduction in annual rainfall across much of the state. The dry north-west of the state receives most of its highly variable rainfall in very irregular, high intensity, rainfall events. Sporadic rainfall events can occur over the arid north-west at any time of the year but are more likely in summer. Annual average rainfall varies from less than 200 mm in the north-west of NSW, to more than 1800 mm along the north-east coast.

Very high temperatures are regularly recorded in the arid north-west of NSW and sub-freezing temperatures are frequently observed in the southern alpine regions. Afternoon sea breezes usually moderate the summer temperatures along the coast.

Temperature

Cooler temperatures occur along the Great Dividing Range, with more moderate temperatures experienced along the coast. Temperatures get progressively hotter moving inland and towards the far north-west of the state. Annual average temperatures (calculated from 1961-1990) range from about 4°C in the Snowy Mountains to over 20°C in the far north-west and parts of the far north coast (Figure 1).

In the summer, average temperatures range from 28–30°C in the state's north-west to 10–12°C in the Snowy Mountains. In winter, average temperatures range from 14–16°C on the far north coast to –2 to 0°C in the Snowy Mountains.

In summer, average maximum temperatures range from over 34-36°C in the state's north-west to 14–16°C in the Snowy Mountains.

In winter, the average minimum temperature ranges from –6 to –4°C in the Snowy Mountains, to 8–10°C along the far north coast near Byron Bay

Temperature extremes

Temperature extremes, both hot and cold, occur infrequently but can have major impacts on health, infrastructure and our environment. Changes to temperature extremes often result in greater impacts than changes to average temperatures.

Average temperature 1961-1990

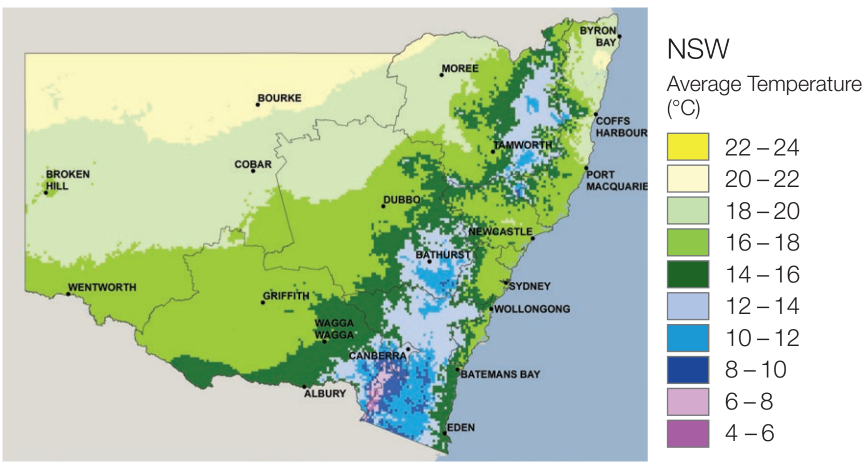


Figure 1: Map of average annual temperatures across NSW, 1961–1990 (Source: Bureau of Meteorology).




Hot days

Generally, the number of hot days (maximum temperatures above 35°C) in NSW increases as you move further inland. Near the coast there are on average fewer than 10 hot days per year, while inland in north-western NSW there are more than 80 hot days each year. On average, there are few hot days along parts of the Great Dividing Range, the Snowy Mountains and near Coffs Harbour on the far north coast where the mountains are closest to the coast.

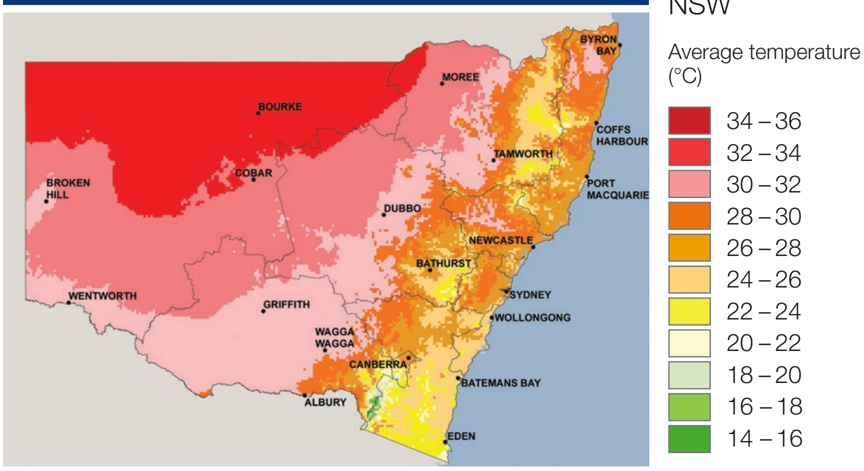
Cold nights

The number of days per year with minimum temperatures below 2°C varies considerably across New South Wales. The Great Dividing Range has a considerable influence on the distribution of cold nights across NSW.

On the eastern side of the range, in proximity to the coast, the number of cold nights ranges from fewer than 10 to about 30 nights per year near the escarpment. Along the range, the number of cold nights is notably higher, with the Snowy Mountains experiencing up to 220 cold nights per year. From the western slopes of the range the number of cold nights gradually decreases with distance inland, with fewer than 10 cold nights per year in the far west of the state.

For NSW as a whole, 2013 was the warmest year on record for maximum temperatures, and the third-warmest for average temperature. All years from 1997 to 2013 were warmer than the 1961-1990 average, an unprecedented sequence in the historical records. Since the start of this century, all years have recorded an annual average temperature more than 0.5°C warmer than the 1961-1990 average. The hottest year on record for NSW was 2009 when the average temperature was 1.37°C above the 1961-1990 average.

b) Summer maximum temperature



b) Winter minimum temperature

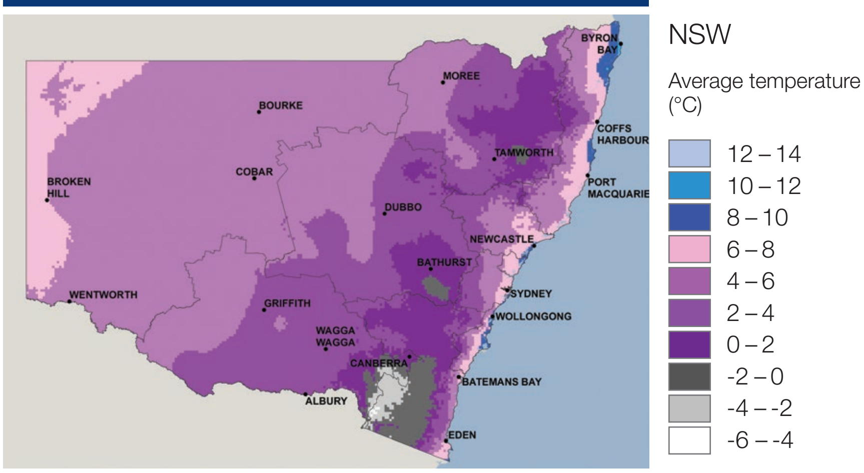


Figure 2: Maps of a) average summer daily maximum temperature and b) average winter daily minimum temperature for 1961–1990, based on gridded AWAP (www.csiro.au/awap/) temperature data.

Rainfall

Average annual rainfall varies considerably across NSW, ranging from 1600–2400 mm on the far north coast and parts of the Snowy Mountains, to less than 200 mm along the NSW – South Australia border. Large parts of eastern NSW experience annual rainfall of 400–800 mm per year, while much of the west typically experiences 200–400 mm per year. The coastal strip east of the Great Dividing Range typically receives over 800 mm of rainfall per year.

The north-east of NSW gets most of its rainfall in summer, with autumn rainfall also considerable, but experiences relatively dry winters. In contrast, in the south of the state winter rainfall dominates. Over a significant part of NSW the distribution of rainfall is fairly even.

The long term rainfall record (1900-2013) shows that NSW has experienced considerable variation in rainfall with periods of both wetter and drier conditions. During much of the first half of the 20th century the state experienced dry conditions. From the 1950s to the 1990s there was more inter-annual variability with many wet years and many dry years. The first decade of the 21st century saw a long period of below average rainfall during the Millennium Drought. This dry period ended with two of the wettest years on record for Australia (2010-2011), with 2010 being the third wettest year on record for NSW.

Climate classes*

Summer Dominant
Marked wet summer & dry winter
- More than 1200
- 650 – 1200
- 350 – 650

Summer
Wet summer & low winter rainfall
- More than 1200
- 650 – 1200
- 350 – 650

Uniform
Uniform rainfall
- More than 800
- 500 – 800
- 250 – 500

Winter
Wet winter & low summer rainfall
- More than 800
- 500 – 800
- 250 – 500

Winter Dominant
Marked wet winter & dry summer
- More than 800
- 500 – 800
- 250 – 500

Arid
Low rainfall
- More than 350

Figure 3: Major seasonal rainfall zones of Australia[2].

2. Bureau of Meteorology 2014, Seasonal rainfall zones of Australia, Product Code IDCJCM0002, Australian Bureau of Meteorology, Melbourne, viewed October 2014, http://archive.today/DWzJ. *Based on a median annual rainfall and seasonal incidence. The seasonal incidence is determined from the ration of the median rainfall November to April and May to October. Based on a 100 year period from 1900–1999. © Commonwealth of Australia 2008.

Fire weather

The risk of bushfire in any given region depends on four ‘switches’. There needs to be enough vegetation (fuel), the fuel needs to be dry enough to burn, the weather needs to be favourable for fire to spread, and there needs to be an ignition source (Bradstock 2010). All four of these switches must be on for a fire to occur. The Forest Fire Danger Index (FFDI) is used in NSW to quantify fire weather. The FFDI combines observations of temperature, humidity and wind speed with an estimate of the fuel state.

Long-term observations of FFDI come from daily measurements of temperature, rainfall, humidity and wind speed at only a small number of weather stations in Australia, with 17 stations located in NSW and the ACT (Lucas 2010). Although these stations are spread fairly evenly across the state, there are no stations in alpine regions.

The annual average FFDI for the period 1990–2009 ranges from 3.3 in Coffs Harbour to 21.2 in Tibooburra. The highest average FFDI occurs in summer and spring and the lowest is usually in winter.

Fire weather is classified as ‘severe’ when the FFDI is above 50, and most of the property loss from major fires in Australia has occurred when the FFDI reached this level (Blanchi et al. 2010). FFDI values below 12 indicate low to moderate fire weather, 12-25 high, 25-49 very high, 50-74 severe, 75-99 extreme and above 100 catastrophic.

Severe fire danger days are more likely to occur in summer and spring months. Tibooburra (20 days) and Wilcannia (12 days) record considerably more sever fire weather days each year than other stations. Severe fire weather conditions are estimated to occur at least once a year at all stations except Lismore and Coffs Harbour.

Baseline average FFDI and days with severe FFDI in NSW

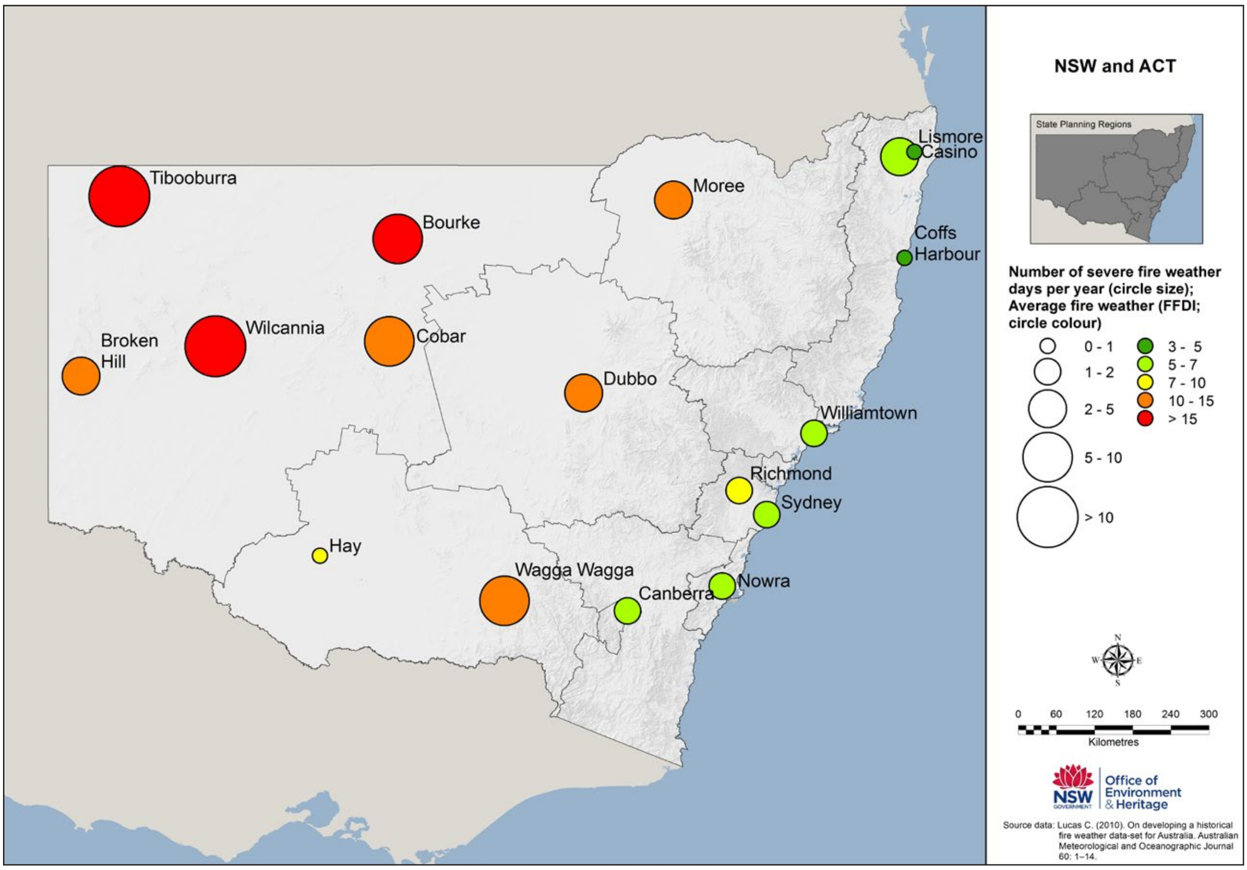


Figure 4: Baseline mean FFDI values and severe fire weather days (FFDI>50) for meteorological stations within NSW.

Temperature

Climate change projections are presented for the near future (2030) and far future (2070), and are compared to the baseline modelled climate (1990–2009). The projections are based on simulations from a suite of twelve climate models run to provide detailed future climate information for NSW and the ACT.

Temperature is the most reliable indicator of climate change. Across NSW all of the models agree that average, minimum and maximum temperatures are all increasing (Figure 5).

Summary temperature

Maximum temperatures are projected to increase in the near future by 0.7°C

Maximum temperatures are projected to increase in the far future by 2.1°C

Minimum temperatures are projected to increase by near future by 0.7°C

Minimum temperatures are projected to increase by far future by 2.1°C

The greatest increases are projected for the north-west of the state in summer

There are projected to be more hot days and fewer cold nights

Projected statewide climate changes

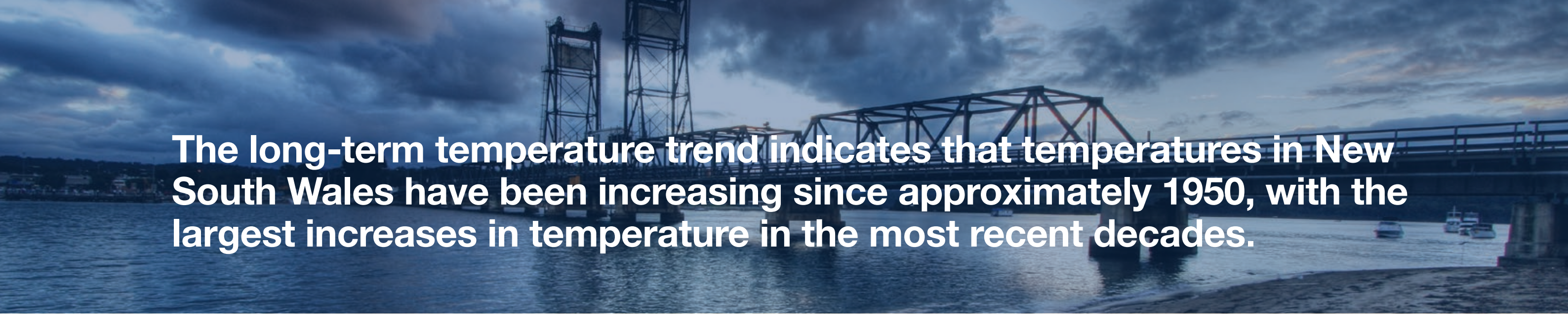
NSW is expected to experience an increase in all temperature variables (average, maximum and minimum) for the near future and an even greater increase in the far future.

Maximum temperatures are projected to increase by 0.7°C in the near future and up to 2.1°C in the far future (Figure 5b). Summer and spring will experience the greatest change with maximum temperatures increasing by up to 2.4°C in the far future (Figure 5b). Increased maximum temperatures are known to impact human health through heat stress and increasing the number of heatwave events.

Minimum temperatures are projected to increase by 0.7°C in the near future and up to 2.1°C in the far future (Figure 5c). Increased overnight temperatures (minimum temperatures) can have a significant effect on human health especially during heatwaves.

The greatest increases in average temperatures are projected for the north-west of the state during summer.

Increases in temperatures are projected to occur across all of the state (Figures 6–9).



The long-term temperature trend indicates that temperatures in New South Wales have been increasing since approximately 1950, with the largest increases in temperature in the most recent decades.

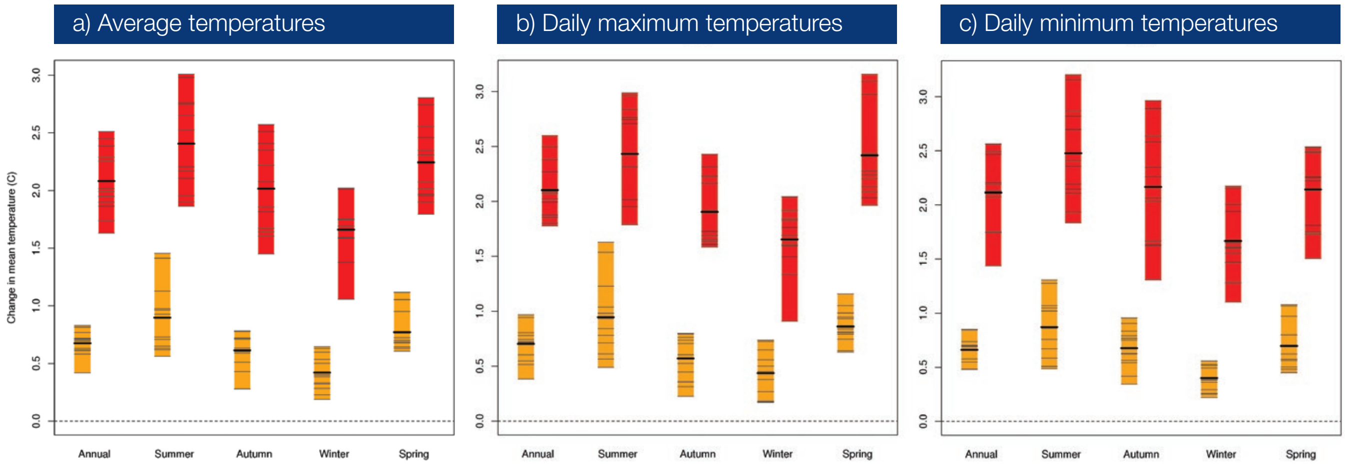


Figure 5: Projected changes in air temperature for NSW, annually and by season (2030 yellow; 2070 red): a) average, b) daily maximum, and c) daily minimum. (Appendix 1 provides help with how to read and interpret these graphs).

Near future change in maximum temperature

Figure 6: Near future (2020–2039) change in annual mean maximum temperature, compared to the baseline period (1990–2009).

Far future change in maximum temperature

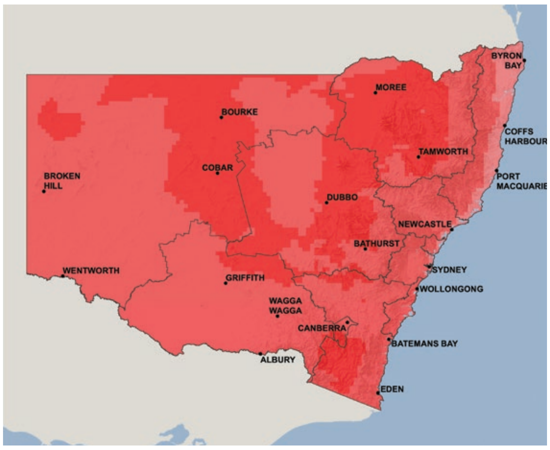


Figure 7: Far future (2060–2079) change in annual mean maximum temperature, compared to the baseline period (1990–2009).

Near future change in minimum temperature

Figure 8: Near future (2020–2039) change in annual mean minimum temperature, compared to the baseline period (1990–2009).

Far future change in minimum temperature

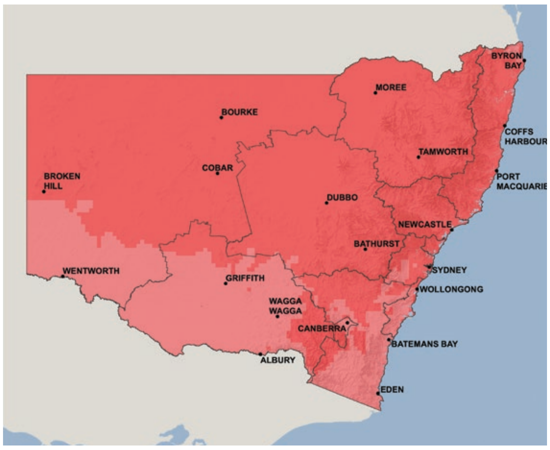
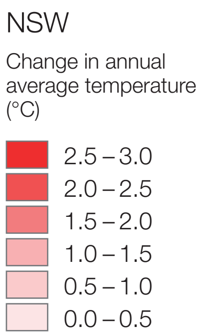


Figure 9: Far future (2060–2079) change in annual mean minimum temperature, compared to the baseline period (1990–2009).



Hot days

DAYS PER YEAR ABOVE 35°C

The number of hot days in NSW increases with distance inland, ranging from no days in the more mountainous parts of the state, fewer than 10 days per year near the coast and more than 80 hot days per year in the far north-west. International and Australian experiences show that prolonged hot days increase the incidence of illness and death – particularly among vulnerable population groups such as people who are older, have a pre-existing medical condition or who have a disability. Seasonal changes in hot days could have significant impacts on bushfire danger, infrastructure development and native species diversity.

Projected statewide climate changes

NSW is expected to experience more hot days in the near future and the far future (Figure 10).

There are however significant regional differences in the projected changes to the number of hot days.

The greatest change is projected for north-western NSW with an additional 10–20 hot days in the near future increasing to over 40 additional hot days per year by 2070 (Figures 11 and 12). Currently this part of the state experiences between 50 and 80 hot days each year. These projections suggest that by 2070 parts of north-western NSW may see one third of the year with temperatures above 35°C.

Areas east of the Great Dividing Range and along the coast experience fewer hot days than inland regions. Along parts of the coast and Ranges the number of hot days is projected to increase by up to an additional 20 days per year by 2070.

These increases in hot days are projected to occur mainly in spring and summer although in the far future hot days are also extending into autumn (Figure 10).

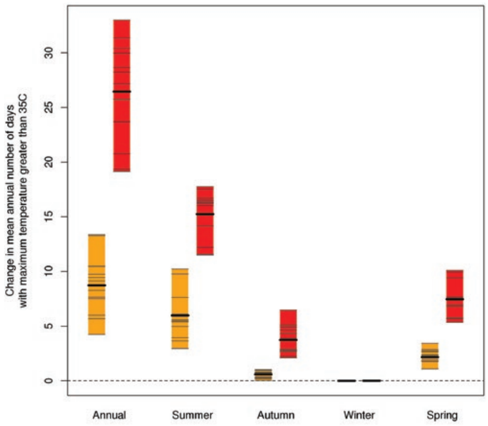


Figure 10: Projected changes in the number of hot days (with daily maximum temperature of above 35°C) for NSW, annually and by season (2030 yellow; 2070 red). (Appendix 1 provides help with how to read and interpret these graphs).

Near future change in days per year above 35°C

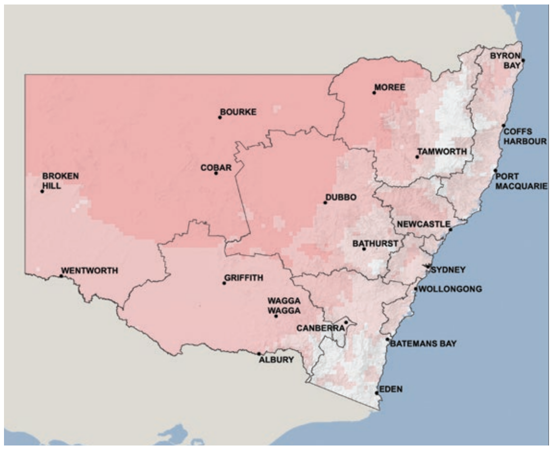


Figure 11: Near future (2020–2039) projected changes in the number of days per year with maximum temperatures above 35°C.

Far future change in days per year above 35°C

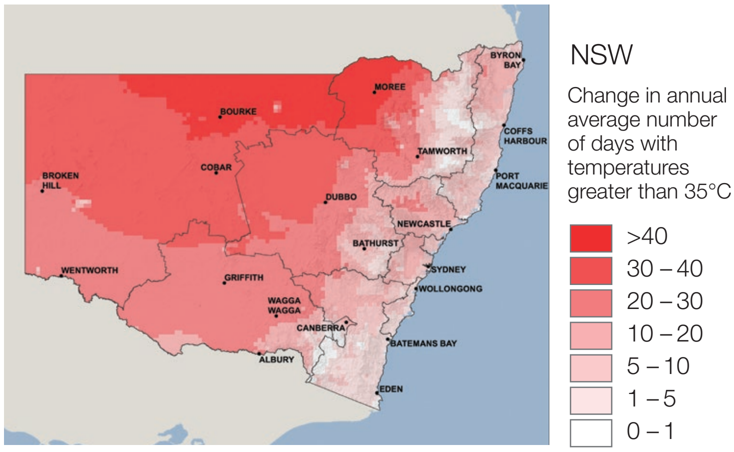
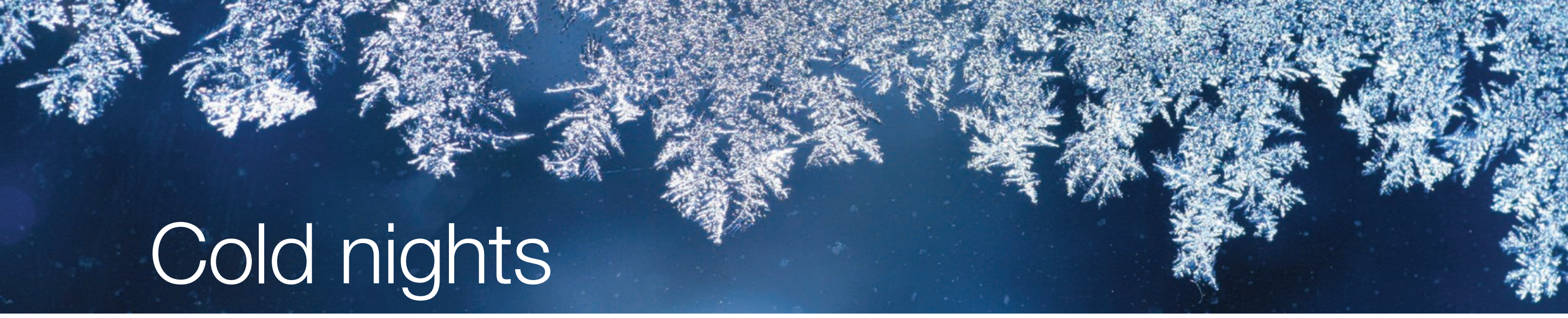


Figure 12: Far future (2060–2079) projected changes in the number of days per year with maximum temperatures above 35°C.



Cold nights

DAYS PER YEAR BELOW 2°C

Most of the emphasis on changes in temperatures from climate change has been on hot days and maximum temperatures, but changes in cold nights are equally important in the maintenance of our natural ecosystems and agricultural/horticultural industries; for example, some common temperate fruit species require sufficiently cold winters to produce flower buds.

Projected statewide climate changes

NSW is expected to experience fewer cold nights in the future. The changes will occur across all seasons, with the largest decreases during winter and spring (Figure 13).

The greatest changes are projected to occur along the Great Dividing Range including the Snowy Mountains, with 10–20 fewer cold nights in the near future, and over 40 fewer cold nights by 2070 (Figures 14 and 15). This is a considerable reduction in cold nights for our Alpine regions, with the potential to impact our natural ecosystems, snow tourism and industry.

Minor changes are projected for coastal NSW and the far west. Approximately 5–10 fewer cold nights are projected for the western slopes and plains (Figures 14 and 15).

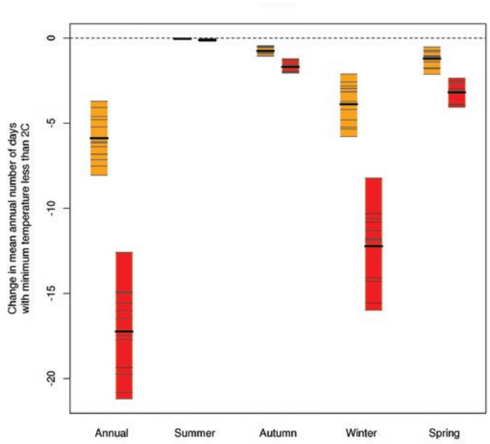


Figure 13: Projected changes in the number of low temperature nights for the NSW, annually and by season (2030 yellow; 2070 red). (Appendix 1 provides help with how to read and interpret these graphs).

Near future change in number of cold nights (below 2°C) per year

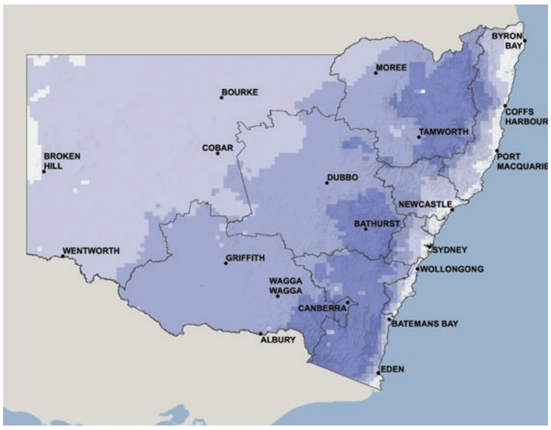


Figure 14: Near future (2020–2039) change in the number of days per year with minimum temperatures below 2°C, compared to the baseline period (1990–2009).

Far future change in number of cold nights (below 2°C) per year

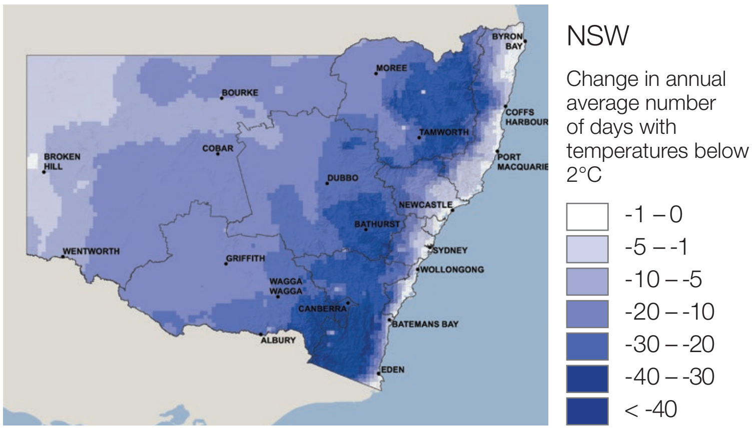


Figure 15: Far future (2060–2079) change in the number of days per year with minimum temperatures below 2°C, compared to the baseline period (1990–2009).

Rainfall

Changes in rainfall patterns have the potential for widespread impacts. Seasonal shifts in rainfall can impact native species' reproductive cycles as well as impacting agricultural productivity; for example crops that are reliant on winter rains for peak growth.

Rainfall changes are also associated with changes in the extremes, such as floods and droughts, as well as secondary impacts such as water quality and soil erosion that occur as a result of changes to rainfall intensity.

Modelling rainfall is challenging due to the complexities of the weather systems that generate rain. 'Model agreement', that is the number of models that agree on the direction of change (increasing or decreasing rainfall) is used to determine the confidence in the projected change. The more models that agree, the greater the confidence in the direction of change.

Care should be taken when interpreting changes in rainfall from averaging climate change projections when the model outputs project changes of both wetting and drying. To understand the spread of potential changes in rainfall the bar charts should be considered along with the maps provided in this document. Single model outputs are available for download from the Adapt NSW website.

Rainfall is projected to decrease in spring and to increase in autumn

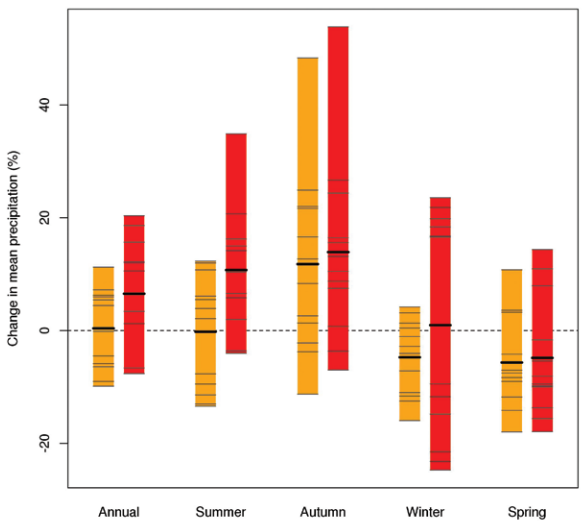


Figure 16: Projected changes in mean rainfall for NSW, annually and by season (2030 yellow; 2070 red) compared to the period (1990–2009). (Appendix 1 provides help with how to interpret these graphs).

Projected statewide climate changes

Across NSW and the ACT the majority of models (9 out of 12) agree that spring rainfall will decrease in the near future and far future. However there are important regional variations in the changes in spring rainfall.

NSW currently experiences considerable rainfall variability across regions, seasons and from year-to-year and this variability is also reflected in the projections (Figures 17 and 18).

Spring rainfall is projected by the majority of models to decrease in the near and far future for inland regions west of the Great Dividing Range, and in southern NSW (Murray Murrumbidgee and the South East and Tablelands regions) (Figures 17 and 18). In contrast spring rainfall is projected by the majority of models to increase along the coast north from Newcastle to the Queensland border.

Autumn rainfall is projected by the majority of models to increase across NSW in the near future and the far future (Figure 16).

Projected changes in summer and winter rainfall vary across the state.

Seasonal projections for the near future span both increases and decreases for summer (–13% to +12%), autumn (–11% to +48%), winter (–16% to +4%), and spring (–18% to +11%). By 2070 the projections are: summer (–4% to +35%), autumn (–7% to +54%), winter (–25% to +24%), and spring (–18% to –14%) (Figure 16).

Projections for the state's annual average rainfall range from a decrease (drying) of 10% to an increase (wetting) of 11% by 2030 and still span both drying and wetting scenarios (–8% to +20%) by 2070.

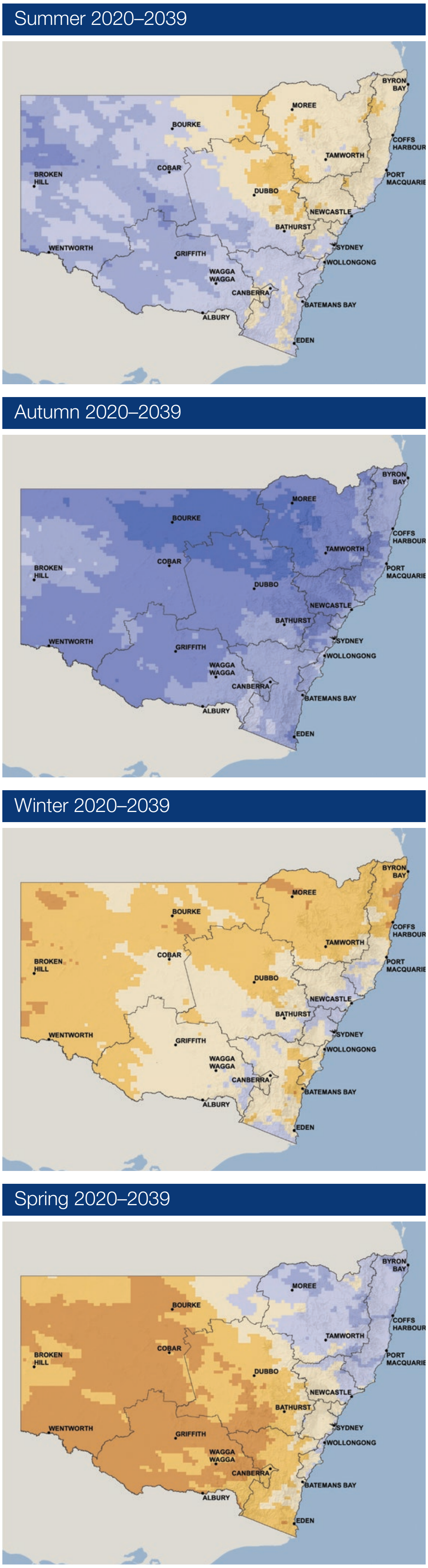


Figure 17: Near future (2020–2039) projected changes in mean rainfall by season compared to the baseline period (1990–2009).

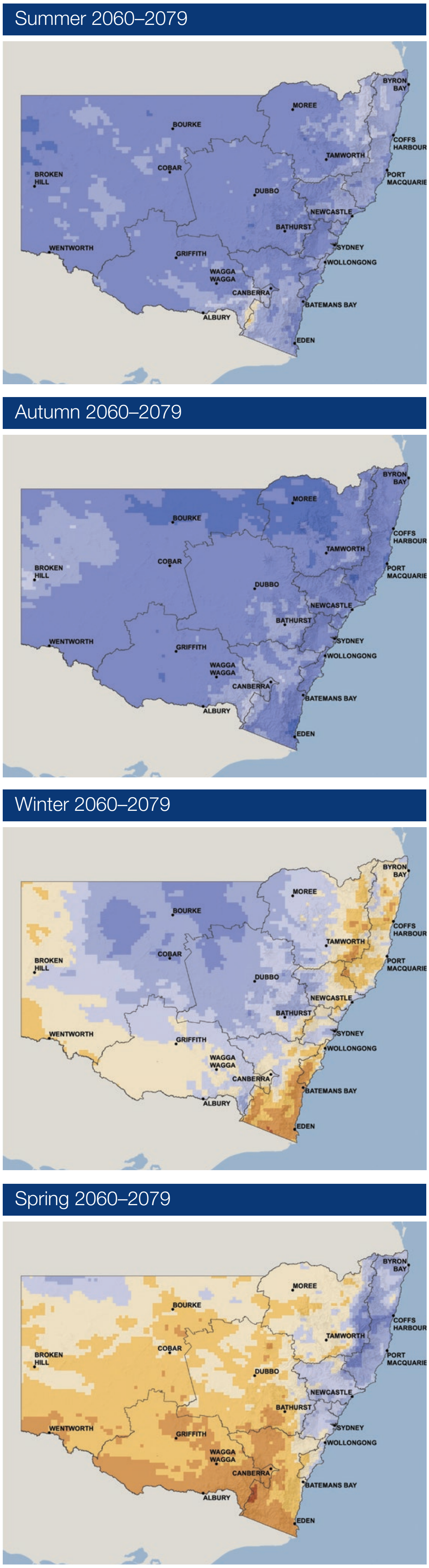
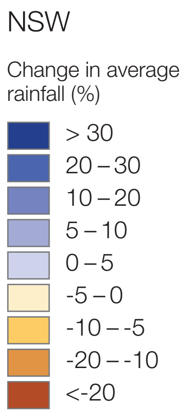


Figure 18: Far future (2060–2079) projected changes in mean rainfall by season compared to the baseline period (1990–2009).



North-east NSW

The north-east of the state is projected to have decreases in rainfall in summer and winter by 2030. By 2070 the majority of models project a decrease in winter rainfall along the coast and an increase in winter rainfall inland.

The north-east is projected to have increases in rainfall during autumn and spring by 2030.

By 2070 the north-east is projected to have increased rainfall in autumn and summer, and spring (along the coast).

North-west NSW

The north-west of the state is projected to have increases in summer and autumn rainfall in the near and far future and decreases in spring rainfall in the near and far future.

The north-west is projected to see decreases in winter and spring rainfall in the near future. Decreases in spring rainfall persist but by 2070 changes in winter rainfall patterns are less certain.

South-east NSW

The south-east of NSW is projected to have increases in summer and autumn rainfall with greater increases by 2070.

The south-east is projected to see decreases in winter and spring rainfall, with greater declines by 2070, particularly along the south coast in winter.

South-west NSW

The south-west of the state is projected to have increases in rainfall during summer and autumn in the near and far future, while spring rainfall decreases.

Winter rainfall decreases in the near future but changes in winter rainfall patterns in the far future are more variable.

Greater Metropolitan Region

Projected changes in rainfall across the Greater Metropolitan Region (Sydney, Newcastle and Wollongong) vary. More detail on the projected changes to rainfall in these areas is provided in the local snapshots for the Sydney Metropolitan, Hunter, Illawarra and Central Coast regions.

Fire weather

The Bureau of Meteorology issues Fire Weather Warnings when the FFDI is forecast to be over 50. High FFDI values are also considered by the Rural Fire Service when declaring a Total Fire Ban.

Average FFDI values are often used to track the status of fire risk. These values can be used when planning for prescribed burns and help fire agencies to better understand the seasonal fire risk. The FFDI is also considered an indication of the consequences of a fire if one was to start – the higher the FFDI value the more dangerous the fire could be.

FFDI values below 12 indicate low to moderate fire weather, 12-25 high, 25-49 very high, 50-74 severe, 75-99 extreme and above 100 catastrophic.

Average fire weather and severe fire weather days are projected to increase in summer and spring

Projected statewide climate changes

NSW is projected to experience an increase in average and severe fire weather in the future (Figures 19 and 20).

The increases in average and severe fire weather are projected to occur mainly in summer and spring. The western region has the greatest increases in the state, and these increases occur across all seasons (Figures 21 and 22).

Models mainly project a relatively small change in severe fire weather for coastal regions, the south-east and the Southern Tablelands.

Autumn is projected to have a decrease in mean fire weather across large parts of the state and a decrease in severe fire weather in the east of the state. As fire weather measurements take into account rainfall, it is likely that the decrease in FFDI during autumn is due to projected increases in autumn rainfall (compare Figures 17 and 18 with Figures 21 and 22).

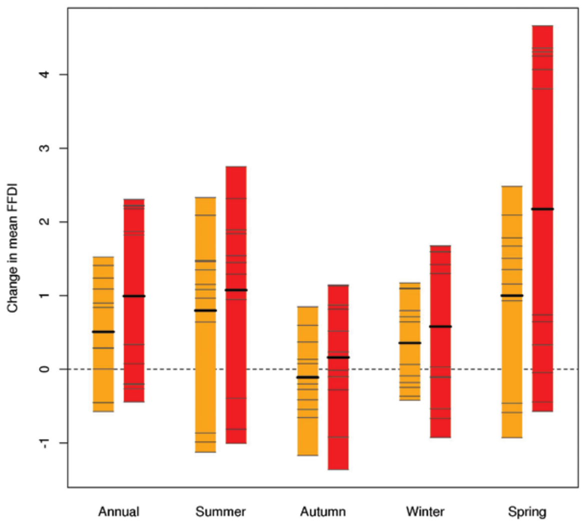


Figure 19: Projected changes in the mean daily forest fire danger index (FFDI) for NSW annually and by season (2030 yellow; 2070 red). (Appendix 1 provides help with how to read these graphs).

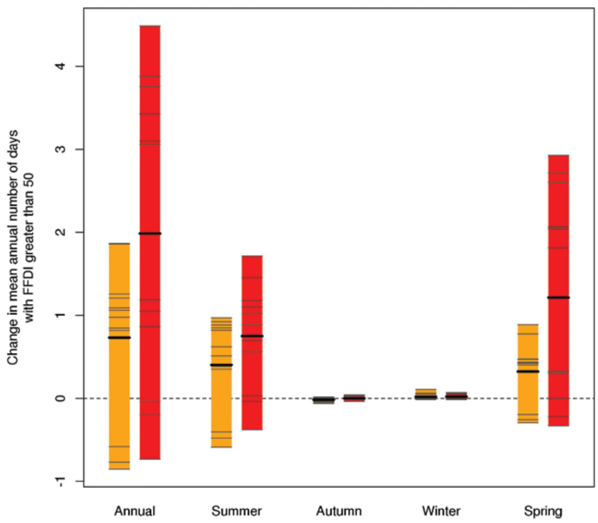


Figure 20: Projected changes in mean annual number of days with a forest fire danger index (FFDI) greater than 50 for NSW, annually and by season (2030 yellow; 2070 red). (Appendix 1 provides help with how to read these graphs).

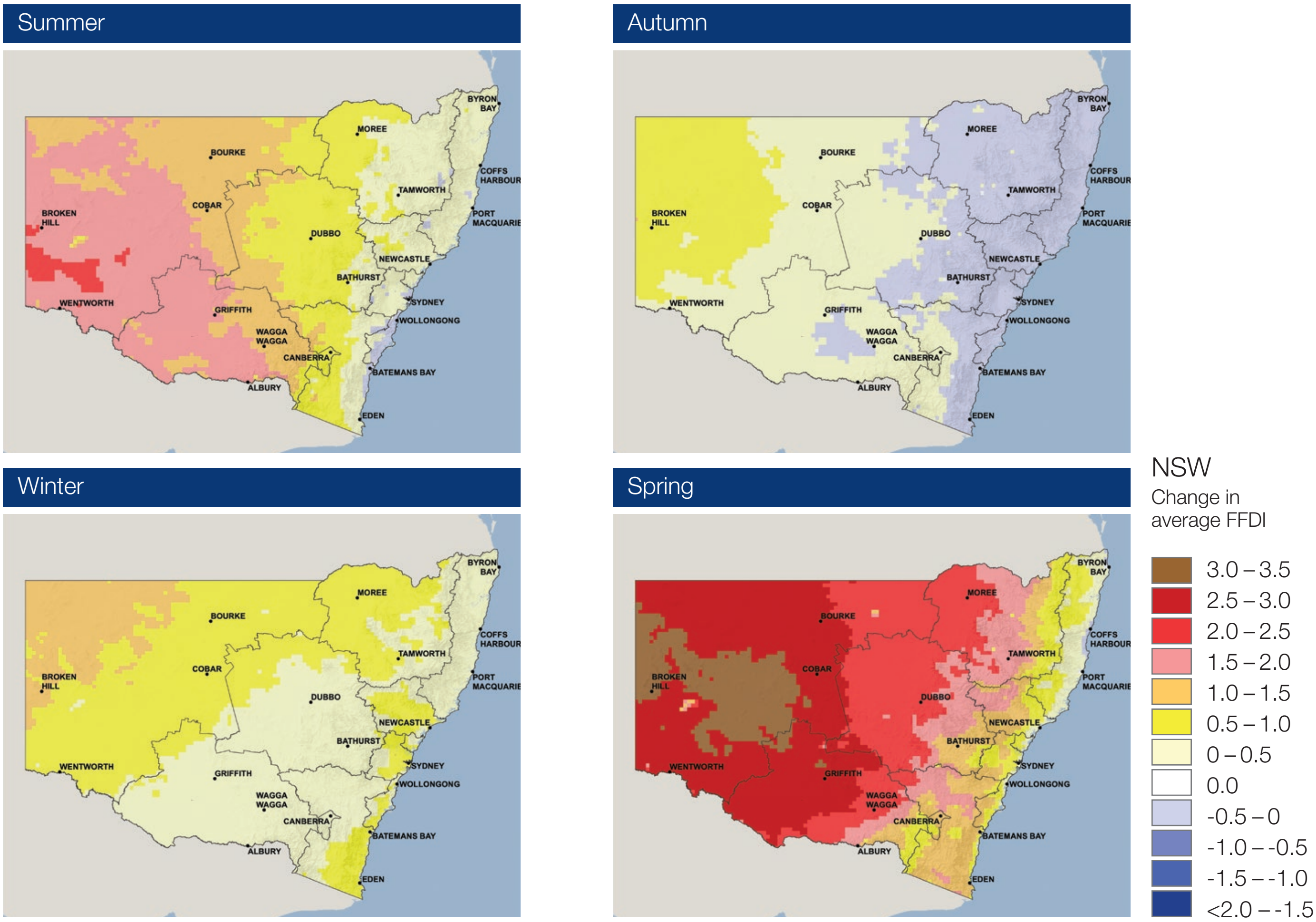


Figure 21: Far future (2060–2079) projected changes in average daily FFDI, compared to the baseline period (1990–2009).

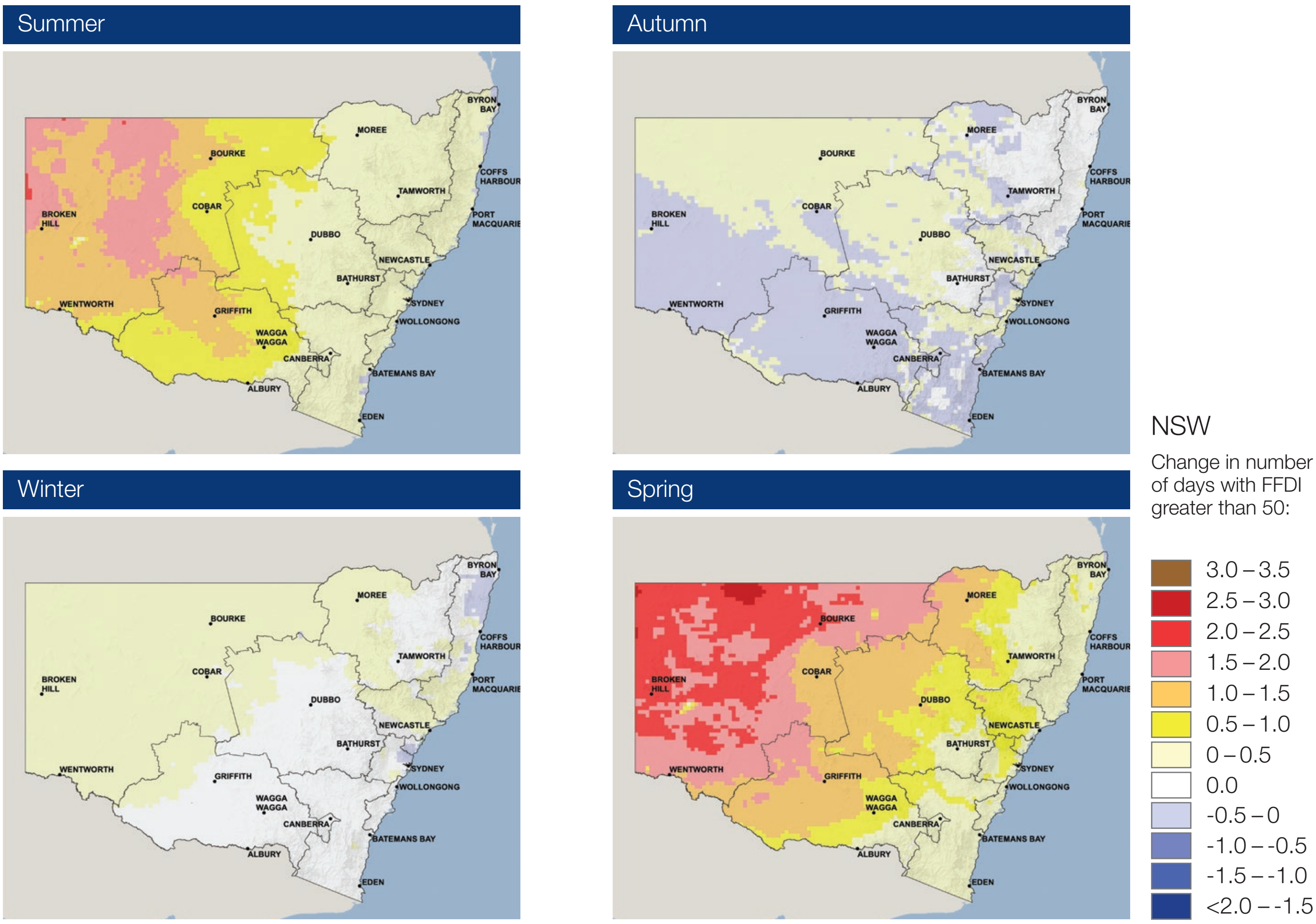


Figure 22: Far future (2060–2079) projected changes in average annual number of days with a FFDI greater than 50, compared to the baseline period (1990–2009).

Appendix 1 Guide to reading the maps and graphs

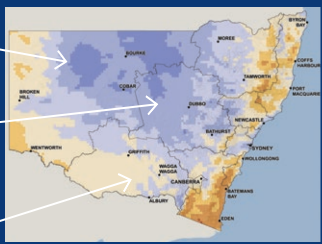
This document contains maps and bar graphs of the climate change projections. The maps present the results of the twelve models as an average of all twelve models. The bar graphs show projections averaged across the entire state and do not represent any particular location within the state. The bar graphs also show results from each individual model. See below for more information on what is displayed in the maps and bar graphs.

How to read the maps

The maps display a **10km** grid.

NSW has been divided into State Planning Regions and each region has a Local Snapshot report.

The colour of each grid is the **average of all 12 models** outputs for that grid.



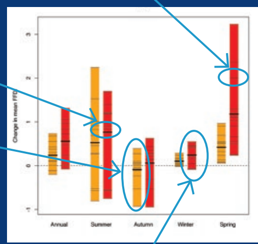
How to read the bar graphs

The thin grey lines are the **individual models**. There are 12 thin lines for each bar.

The thick line is **the average of all 12 models** for the region.

The length of the bar shows the **spread of the 12 model values** for the region

Each line is the **average for** the region. They do not represent a single location in the region.



Note: The yellow bars represent the near future (2020–2039), while the red bars represent the far future (2060–2079).

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