## 8.4 Greenhouse gas and climate change

This section outlines the legislative and policy framework for the control of greenhouse gas (GHG) emissions and climate change. It provides an assessment of the contributions of the project to climate change, due to the release of GHG emissions during the construction and operation stages and provides recommended mitigation measures to reduce GHG emissions.

This section also identifies the current climate change projections for the Sydney region and NSW more broadly, and examines the potential impact of these on the project. Where possible, this section identifies appropriate risk management and mitigation measures that would be provided as part of the project design to build the resilience of project infrastructure to changing climate conditions.

### 8.4.1 Existing environment

GHGs, such as carbon dioxide, are emitted into the Earth's atmosphere as a result of natural processes (eg forest fires) and human activities (eg burning of fossil fuels to generate electricity). GHGs absorb and re-radiate heat from the sun, trapping heat in the atmosphere which then influences global temperatures.

Since the industrial revolution there has been an increase in the amount of GHGs emitted from human activities, which has increased the global concentration of GHGs in the atmosphere.

The most recently published Australian National Greenhouse Accounts estimate Australian GHG emissions for 2011 to be 563.1 Mt $CO_2$-e as reported under the Kyoto Protocol (DIICCSRTE, 2013b). For the year 2010 to 2011, the annual NSW State GHG emissions totalled 159 Mt $CO_2$-e (DIICCSRTE, 2013c). The transport sector contributes approximately 14 per cent of Australia's total GHG emissions, with approximately 90 per cent of these emissions attributed to the combustion of fuel for road transport (Maddocks et al, 2010). Reducing the contribution of emissions from road transport would therefore have a significant impact on emissions reduction for the transport sector, and Australia's overall emissions profile.

An increase in the global concentration of GHGs has led to an increase in the Earth's average temperature (surface temperature) and has contributed to the phenomenon of 'climate change'. The State of the Climate 2012 (CSIRO and the Australian Bureau of Meteorology (BOM), 2012) confirms the long term warming trend over Australia's land and oceans, showing that in Australia, each decade has been warmer than the previous since the 1950s. Other observed trends include an increase in record hot days, a decrease in record cold days, ocean warming, sea-level rise and increases in global GHG concentrations. Due to long lag times associated with climate processes, even if GHG emissions are mitigated and significantly reduced, the warming trend is expected to continue for centuries (Intergovernmental Panel on Climate Change (IPCC), 2007).

The IPCC Fifth Assessment Report (IPCC, 2013) states with high confidence that Australia is already experiencing impacts from recent climate change, including a greater frequency and severity of extreme weather events. Certain current and predicted climate events and trends pose a risk to road infrastructure, by way of physical damage, accelerated deterioration of assets and reduced network capacity and road safety (Maddocks et al, 2010). As a result, it is important to understand the most likely and 'worst case' implications of climate change on high-value infrastructure, such as the project.

The two key responses to climate change are:

- Climate change mitigation: Reducing the amount of GHG emissions emitted into the atmosphere.
- Climate change adaptation: Adapting or reducing vulnerability to the physical impacts of climate change.

The following sections are structured in two parts:

- An assessment of GHG emissions estimated to be generated by the project (climate change mitigation).
- A climate change risk assessment for the operation and maintenance of project infrastructure (climate change adaptation).

### 8.4.2 Policy and planning setting

Increasing public concern and debate regarding the likelihood and magnitude of climate change impacts in Australia has resulted in a number of national and state policy commitments, addressing both GHG mitigation and climate change adaptation. These are outlined in the following sections.

**GHG assessment**

GHG emission requirements and considerations are included in a growing number of legislative and policy mechanisms in Australia (State and Federal) and internationally.

The Kyoto Protocol to the United Nation Framework Convention on Climate Change (the Kyoto Protocol) (UNFCCC, 1998) was signed in 1997 and Australia ratified the protocol in December 2007. The Kyoto Protocol's objective is to reduce GHG emissions through setting reduction targets for GHG emissions produced by ratifying countries. These targets are set using the ratifying countries' 1990 baseline emissions. Australia has committed to a target of 108 per cent of 1990 emission levels by the end of 2012. In December 2012, Australia signed the Doha Amendment (UNFCCC, 2012) to the Kyoto Protocol, agreeing to a second commitment period, from 1 January 2013 until 2020.

The Australian Government's climate change policies and regulations are managed by the Department of the Environment, and include:

- *The Energy Efficiency Opportunities Act 2006* (EEO Act).
- *The National Greenhouse and Energy Reporting Act 2007* (NGER Act).

The Australian Government has committed to a target of reducing carbon pollution by five per cent below 2000 emission levels by 2020 irrespective of what other countries do. The Government will review this position in 2015 at the Climate Summit in Paris as part of international negotiations regarding emissions reduction commitments prior to and post-2020.

The Australian Government's Direct Action Plan sets out how this five per cent reduction target will be achieved. The Emissions Reduction Fund Green Paper (Department of the Environment, 2013a), as part of the Direct Action Plan, aims to reduce Australia's GHG emissions by creating positive incentives to adopt better technologies and practices to reduce emissions.

In August 2013, the NSW State Government released the NSW Energy Efficiency Action Plan (Office of Environment and Heritage (OEH), 2013b), which provides a strategic management approach to improving energy efficiency, with a target for annual energy savings of 16,000 gigawatt-hours by 2020.

**Climate change risk assessment**

NSW 2021 – A Plan to Make NSW Number One (NSW Department of Premier and Cabinet, 2011) includes targets to minimise the impacts of climate change by ensuring that 'NSW is ready to deal with major emergencies and natural disasters' (Goal 28). In addition, the NSW Long Term Transport Master Plan (Transport for NSW, 2012a) promotes the need to ensure that transport infrastructure is 'able to withstand the predicted impacts of a changing climate'.

### 8.4.3 Assessment methodology

**GHG assessment methodology**

The methodology that has been used to develop the GHG inventory for the project has been based on relevant GHG reporting legislation and international reporting guidelines, including:

- The Greenhouse Gas Protocol A Corporate Accounting and Reporting Standard (World Council for Sustainable Business Development and World Resources Institute, 2005).
- *The National Greenhouse and Energy Reporting Act 2007*.
- Australian Standard AS ISO 14064.1:2006 Greenhouse Gas Part 1: Specification with guidance at the organisational level for quantification and reporting of greenhouse gas emissions and removals (Standards Australia, 2006).
- Australian National Greenhouse Accounts: National Greenhouse Accounts Factors (NGA Factors) (Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE), 2013a).
- Greenhouse Gas Assessment Workbook for Road Projects (the TAGG Workbook) (Transport Authorities Greenhouse Group (TAGG), 2013).

To calculate the GHG emissions associated with the construction, operation and maintenance of the project, the following steps were undertaken:

- Identify the assessment boundary and the sources of GHG emissions associated with the project (construction, operation and maintenance).
- Determine the quantity of each emissions source (fuel consumed, electricity, construction materials etc.) in line with the TAGG Workbook.
- Quantify the GHG emissions associated with each GHG source using equations specified in the NGA Factors (DIICCSRTE, 2013a).
- Present the GHG emissions associated with the project.
- Identify opportunities (mitigation measures) which may be implemented to reduce the GHG emissions associated with the project.

The TAGG Workbook provides a consistent methodology for estimating the GHG emissions for major activities that may contribute significantly to the overall emissions associated with a road project. The steps involved in undertaking a GHG assessment in accordance with the TAGG Workbook have been adopted for this assessment.

**Appendix N** provides a more detailed description of the GHG assessment methodology, including the calculation methods used to estimate the GHG emissions from liquid fuel combustion, electricity use, vegetation clearing, materials use and traffic use of the road post construction.

GHG emissions are reported in this assessment as tonnes of carbon dioxide equivalent ($tCO_{2}$-e).

### GHG assessment boundary

The assessment boundary defines the scope of GHG emissions and the activities to be included in the GHG assessment. The TAGG Workbook considers the GHG assessment boundary of a road project to include all emissions sources that can be impacted by decisions made by designers, constructors, managers and/or operators of the road.

Emissions sources are categorised into three different scopes to delineate between 'direct emissions' from sources that are owned or controlled by the project and 'indirect emissions' that are a consequence of project activities but occur at sources owned or controlled by another entity. The three scopes are:

- **Scope 1** – direct emissions: GHG emissions generated by sources owned or controlled by the project, eg emissions generated by the use of diesel fuel by project-owned construction plant, equipment or vehicles.
- **Scope 2** – indirect emissions: GHG emissions from the generation of purchased electricity in project-owned or controlled equipment or operations. These GHG emissions are generated outside of the project's boundaries, eg the use of purchased electricity from the grid.
- **Scope 3** – indirect upstream emissions: GHG emissions generated in the wider economy due to third party supply chains as a consequence of activity within the boundary of the project, eg GHG emissions associated with the offsite mining, production and transport of materials used in construction or maintenance of the road.

GHG emissions associated with the project are assessed in terms of Scope 1, Scope 2 and Scope 3 emissions.

### Climate change risk assessment methodology

The climate change risk assessment provided in this report has been undertaken in line with the following relevant standards and current guidelines:

- The risk assessment approach set out in AS/NZS ISO 31000:2009 Risk management – Principles and guidelines and ISO/IEC 31010 Risk management – Risk assessment techniques. Both build upon AS/NZ 4360:2004 Risk management and its application to climate change risks.
- The climate change projections used in this assessment have been derived and collated in accordance with AS 5334:2013 Climate change adaptation for settlements and infrastructure.
- The climate change impacts have been integrated into risk management in line with the methods recommended in Climate Change Impacts and Risk Management: A Guide for Business and Government (DEH, 2006) and Climate Change in Australia: Technical Report, Chapter 6: Application of Climate Projections in Impact and Risk Assessments (CSIRO and BOM, 2007).

The following key steps were undertaken to complete the climate change risk assessment (DEH, 2006 and AS 5334:2013):

- Identification of key climate variables (such as temperature, rainfall, extreme events) and the climate variability that differentiates regional climate zones.
- Identification of potential climate change scenarios, based on the latest climate science, that broadly identify how each climate variable may change over the design life of the project.
- Identification of climate-based risks that may impact on the project, as a result of climate change.
- Assessment of potential impacts of priority climate change risks based on the consequence and likelihood of each risk.
- Recommendation of broad actions to mitigate climate risks.

An assessment of the risk of climate change requires an understanding of the current climate using historical data for comparison with future climate scenarios. In order to assess the risk to the project posed by climate change, the current climate science and model projections have been investigated for the following parameters.

**Time slices**

Given the expected design life of road infrastructure, the proposed construction timeframe for the project and the available climate data, the time periods which were selected for assessment are 2030 and 2070. Climate change projections for 2030 were identified as appropriate for assessment of short term impacts of climate change on the project (around 10 years after opening to traffic). Although the project life is anticipated to be 100 years, much of the available climate change modelling only projects impacts up to the year 2070. Climate change projections for 2070 are relevant to the longer term operation and maintenance stages of the project.

Projections for 2050 have been used to inform the climate risk assessment, where data for 2030 or 2070 was not available.

**Emissions scenarios**

GHG emission scenarios estimate the quantity of GHG that may be released into the atmosphere in the future. The GHG emission scenarios used in this climate change risk assessment are A1B (moderate emissions) and A1FI (high emissions) as set out by the IPCC (2000). According to the Garnaut Climate Change Review (Maunsell, 2008), the A1B scenario provides the best estimate of annual warming over Australia relative to the climate of 1990. Projections for 2030 are therefore reported for the moderate A1B climate scenario. Scenario projections developed as part of the Garnaut Climate Change Review indicate potential emission paths greater than the A1FI high emissions scenario, suggesting that the increase of GHG emissions since 2000 was greater than that projected in the most fossil-fuel intensive A1FI emissions scenario. On this basis and adopting the precautionary principle, projections for 2070 are reported for the higher A1FI climate science scenario.

### 8.4.4 Assessment of potential impacts

**GHG assessment**

The GHG emission source data used to estimate the GHG emissions associated with construction, operation and maintenance of the project is provided in **Appendix N**. Assumptions have been made, where necessary, to provide a quantitative estimate of emissions.

Activities that would generate GHG emissions during construction of the project include:

- The combustion of diesel fuel for earthworks and construction activities using construction plant and equipment onsite.
- The combustion of diesel fuel for use in project vehicles.
- The combustion of diesel fuel for the transport of construction materials to site, and the transport of spoil from site.
- Electricity consumption to power construction plant, such as road headers, and project site offices.
- Clearance of vegetation.
- The embodied energy of construction materials, associated with the offsite mining and production of materials to be used in construction of the project.

**Construction GHG emissions**

It is estimated that the construction of the project would generate approximately 535,500 t $CO_2$-e. The breakdown of emissions by scope is provided in **Figure 8-12** and summarised as:

- 230,300 t $CO_2$-e direct Scope 1 GHG emissions.
- 69,800 t $CO_2$-e indirect Scope 2 GHG emissions.
- 235,400 t $CO_2$-e indirect Scope 3 GHG emissions.

The GHG emissions results from key emissions sources associated with construction are shown in **Table 8-32** and **Figure 8-12**. Detailed GHG assessment results are provided in **Appendix N**.

**Table 8-32 Construction GHG emissions results**

| Emissions source | | Scope 1 | Scope 2 | Scope 3 | Total | % of total emissions |
|---|---|---|---|---|---|---|
| Fuel use (diesel) – mobile plant and equipment | | 95,638 | - | 7,261 | 102,899 | 19.22% |
| Fuel use (diesel) – transport of materials and waste to / from site | | 103,863 | - | 7,885 | 111,748 | 20.87% |
| Fuel use (petrol) – project light vehicles | | 14,777 | - | 1,170 | 15,947 | 2.98% |
| Vegetation clearance | | 16,048 | - | - | 16,048 | 3.00% |
| Electricity consumption | | - | 69,782 | 15,240 | 85,022 | 15.88% |
| Construction materials | Concrete | - | - | 168,012 | 168,012 | 31.38% |
| | Cement | - | - | 451 | 451 | 0.08% |
| | Steel | - | - | 19,304 | 19,304 | 3.60% |
| | Aggregate | - | - | 191 | 191 | 0.04% |
| | Asphalt | - | - | 1,450 | 1,450 | 0.27% |
| | Copper | - | - | 9,656 | 9,656 | 1.80% |
| | Plastic | - | - | 1,655 | 1,655 | 0.30% |
| | Water | - | - | 3,055 | 3,055 | 0.58% |
| Total | | 230,326 | 69,782 | 235,380 | 535,488 | 100% |
| % total | | 43% | 13% | 44% | 100% | |

The results demonstrate that the majority of GHG emissions, associated with the construction of the project, are attributed to indirect Scope 3 emissions (44 per cent), closely followed by direct Scope 1 emissions (43 per cent).

The embodied energy associated with the indirect offsite mining and production of materials which would be used for the construction of the project contributes the largest proportion of indirect Scope 3 emissions, accounting for 87 per cent of Scope 3 emissions (**Figure 8-13**). Concrete and, to a lesser extent, steel would contribute significantly to the emissions associated with construction materials. The high proportions of emissions associated with these materials are attributed not only to the quantity required for the construction of the project, but also the emissions-intensive processes involved in the extraction and production of these materials.

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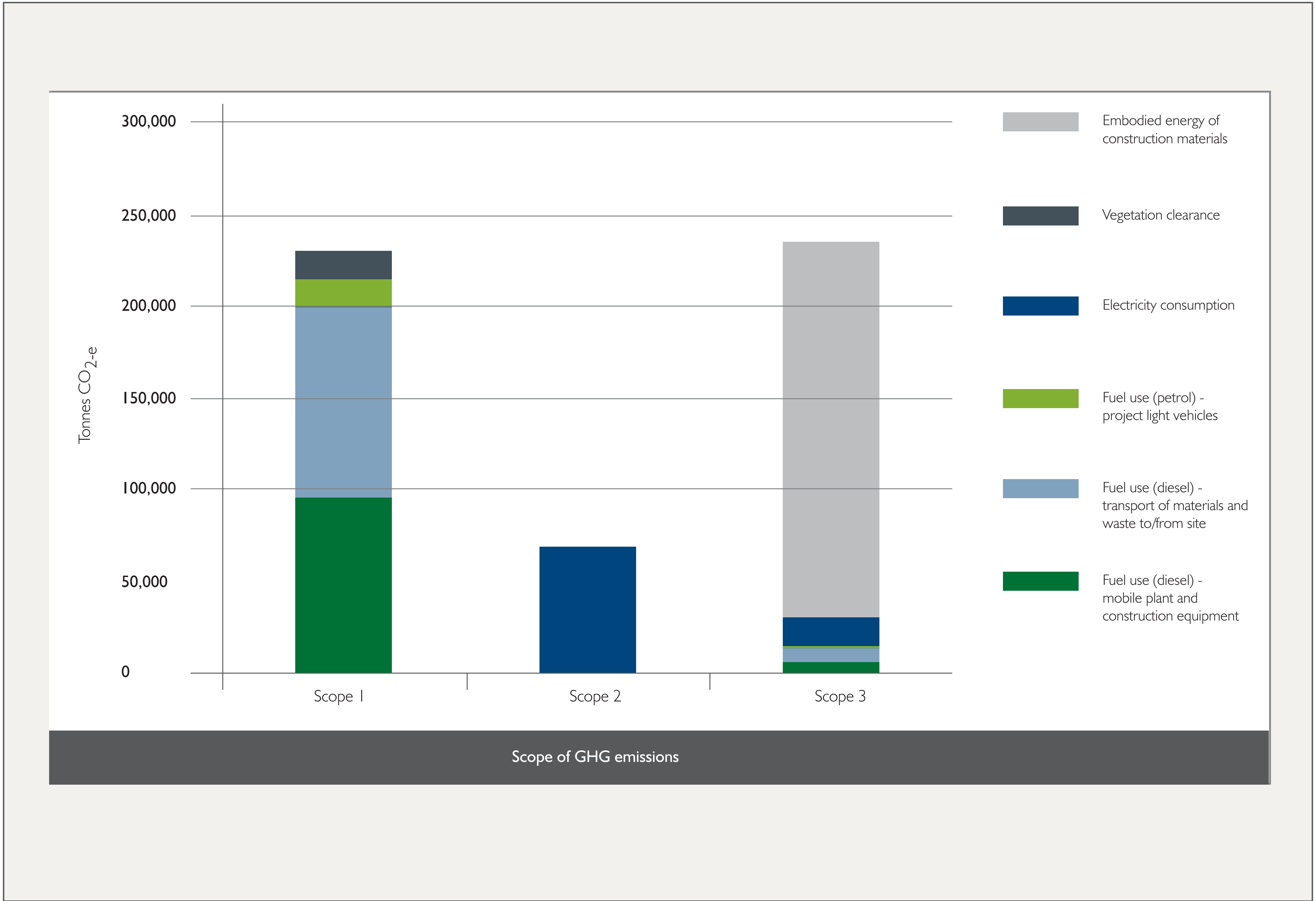


**Figure 8-12 Construction greenhouse gas emissions by scope and emissions source**

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Diesel fuel to operate construction equipment on site and for the transport of materials and waste to and from site would also contribute a major source of GHG emissions for the construction of the project, accounting for around 40 per cent of the total emissions.

The moderately high proportion of indirect emissions (16 per cent of the total GHG emissions) associated with the consumption of electricity is attributed to the use of road headers and lighting and ventilation requirements during the construction of the tunnel.

The total estimated GHG emissions from construction of the project are approximately 535,500 t $CO_2$-e, which equates to 0.10 per cent of the national GHG inventory for the year 2010 to 2011 and 0.34 per cent of the NSW GHG inventory for 2010 to 2011, as discussed in **Section 8.4.1**.

### Operation and maintenance GHG emissions

Activities that would generate GHG emissions during the operation and maintenance stages of the project include:

- Road infrastructure operation: the use of electricity for powering tunnel lighting and ventilation, communications systems, control systems, computer and safety systems, electronic signage and other associated electrical systems.
- Road infrastructure maintenance: diesel fuel use for the operation of maintenance equipment and the use of materials for maintaining the road pavement.
- Vehicles using the project tunnel during operation: use of the tunnel during operation by traffic currently utilising the Pennant Hills Road alignment between the northern interchange with the M1 Pacific Motorway and the southern interchange with the Hills M2 Motorway (the operational traffic impact footprint) and the potential reduction of traffic volumes on Pennant Hills Road.

The estimated GHG emissions that would occur due to the operation and maintenance of the project, throughout its anticipated design life of 100 years, are presented in **Table 8-33**. These have been calculated according to the GHG assessment methodology summarised in **Section 8.4.3**, and the assumptions and inputs presented in **Appendix N**.

**Table 8-33 Operation and maintenance GHG emissions results**

| Emissions source | | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|---|
| **Operation** | | | | | |
| Electricity consumption | | - | 18,391 | 4,016 | 22,408 |
| **Maintenance** | | | | | |
| Fuel use (diesel) – mobile plant and equipment | | 5,611 | - | 426 | 6,037 |
| Maintenance materials | Cement | - | - | 772 | 772 |
| | Steel | - | - | 18 | 18 |
| | Aggregate | - | - | 400 | 400 |
| Total maintenance emissions | | 5,611 | - | 1,616 | 7,227 |

Annual use of electricity for powering tunnel lighting and ventilation, communications systems, control systems, computer and safety systems, electronic signage and other associated electrical systems would incur 18,400 t $CO_2$-e indirect Scope 2 emissions and 4,000 t $CO_2$-e indirect Scope 3 emissions per year.

Emission estimates for the use of fuel and materials for the maintenance of the road pavement are based on the replacement of five per cent of the concrete pavement every 50 years, with only the top concrete layer requiring replacement (in accordance with 'typical' maintenance activities given in the TAGG Workbook).

The use of fuel and materials to undertake maintenance activities would result in around 5,600 t $CO_2$-e direct Scope 1 emissions and 1,600 t $CO_2$-e indirect Scope 3 emissions. The total quantity of GHG emissions associated with the above road maintenance activities would be approximately 7,200 t $CO_2$-e.

**Operational road use emissions**

GHG emissions generated during operation and maintenance of the project (eg lighting, ventilation and major road maintenance) are relatively small in comparison with indirect GHG emissions associated with the fuel consumption of vehicle traffic utilising the road.

To assess the indirect Scope 3 GHG emissions associated with fuel combustion of vehicle traffic utilising the project, and to evaluate any potential GHG emissions savings as a result of the project, road use was considered for two scenarios:

- The base case 'without project' scenario, assessing the future operational performance of Pennant Hills Road in its current condition.
- The 'with project' scenario, including the future operational performance of Pennant Hills Road as well as the operational performance of the project tunnel.

Traffic volumes were modelled for the years 2019 (the project opening year) and 2029 (the project opening plus ten years) as part of the traffic and transport assessment provided in **Section 7.1** and **Appendix E**. These future years were chosen as they provide an indication of road network performance immediately after the project opening (2019), and once traffic patterns have become accustomed to any changes brought about by the project (2029).

The base case scenario ('without project') was also assessed for these years in order to provide a baseline for comparison of GHG emissions. The results, detailed in **Table 8-34** and **Appendix E** indicate that the 'without project' scenario would generate around:

- 243,500 t $CO_2$-e for the year 2019
- 309,900 t $CO_2$-e for the year 2029.

The difference between total GHG emissions generated in the 'without project' and 'with project' scenarios was used to calculate the net GHG emissions savings attributable to operation of the project. **Table 8-34** indicates that the 'with project' scenario would generate less GHG emissions when compared to the base case 'without project' scenario, including around:

- 196,400 t $CO_2$-e for the year 2019 for the 'with project' scenario, resulting in a net reduction of GHG emissions of 47,100 t $CO_2$-e when compared to the 'without project' scenario for 2019
- 241,300 t $CO_2$-e for the year 2029 for the 'with project' scenario, resulting in a net reduction of GHG emissions of 68,600 t $CO_2$-e when compared to the 'without project' scenario for 2029.

**Table 8-34 Scope 3 operational road use GHG emissions results**

| Route | GHG emissions Without project | | With project | | GHG savings Difference between scenarios | |
|---|---|---|---|---|---|---|
| | 2019 | 2029 | 2019 | 2029 | 2019 | 2029 |
| Pennant Hills Road | 243,497 | 309,900 | 146,148 | 178,287 | -97,349 | -131,613 |
| Project tunnel | 0 | 0 | 50,230 | 63,039 | 50,230 | 63,039 |
| Totals | 243,497 | 309,900 | 196,379 | 241,327 | -47,119 | -68,574 |

Note: negative values indicate a savings in GHG emissions for the project compared to the 'without project' scenario.

The results demonstrate the benefits of road tunnel usage in urban areas, where travel along a more direct route at higher average speeds, results in a reduction of GHG emissions generated by road users. The GHG assessment results indicate the project would reduce GHG emissions by around 19 per cent in 2019 and around 22 per cent in 2029. The predicted reduction in GHG emissions as a result of the project is due to an improvement in vehicle fuel efficiency for most sections of Pennant Hills Road as well as the operational efficiency of the project tunnels. Vehicle fuel efficiency is anticipated to improve as part of the project based on:

- Increased average speeds on Pennant Hills Road due to reduced levels of congestion.
- Increased average speeds as a result of the operational efficiency of the project tunnels, which would minimise the number of intersections and the frequency of stopping.
- Reduced length of travel between the Hills M2 Motorway and the M1 Pacific Motorway.

The GHG emission saving of 47,100 t $CO_2$-e in the project opening year (2019) would represent around 0.008 per cent of the Australian National inventory and 0.03 per cent of the NSW inventory for the year 2010 to 2011 as discussed in **Section 8.4.1**.

Construction and operation of the project would generate GHG emissions, however, GHG emissions savings relative to the base case 'without project' scenario would result in an overall GHG emissions reduction for the project. **Figure 8-13** shows the cumulative GHG emissions and savings, from project construction commencing in 2015, to the operational road use of the project in 2029. **Figure 8-13** demonstrates that GHG emissions savings as a result of improved road performance of the project would offset emissions generated during construction by approximately 2027. The cumulative emissions savings shown in **Figure 8-13** exclude the annual contributions of operational emissions associated with project tunnel electricity use as emissions savings beyond 2029 were not able to be estimated. Emissions from major road maintenance are also excluded from **Figure 8-13** as these emissions are expected to occur on a 50 year basis, which would occur beyond the timeframe for which traffic volumes have been assessed.

Mitigation and management measures to reduce GHG emissions for the project are provided in **Section 8.4.5**.

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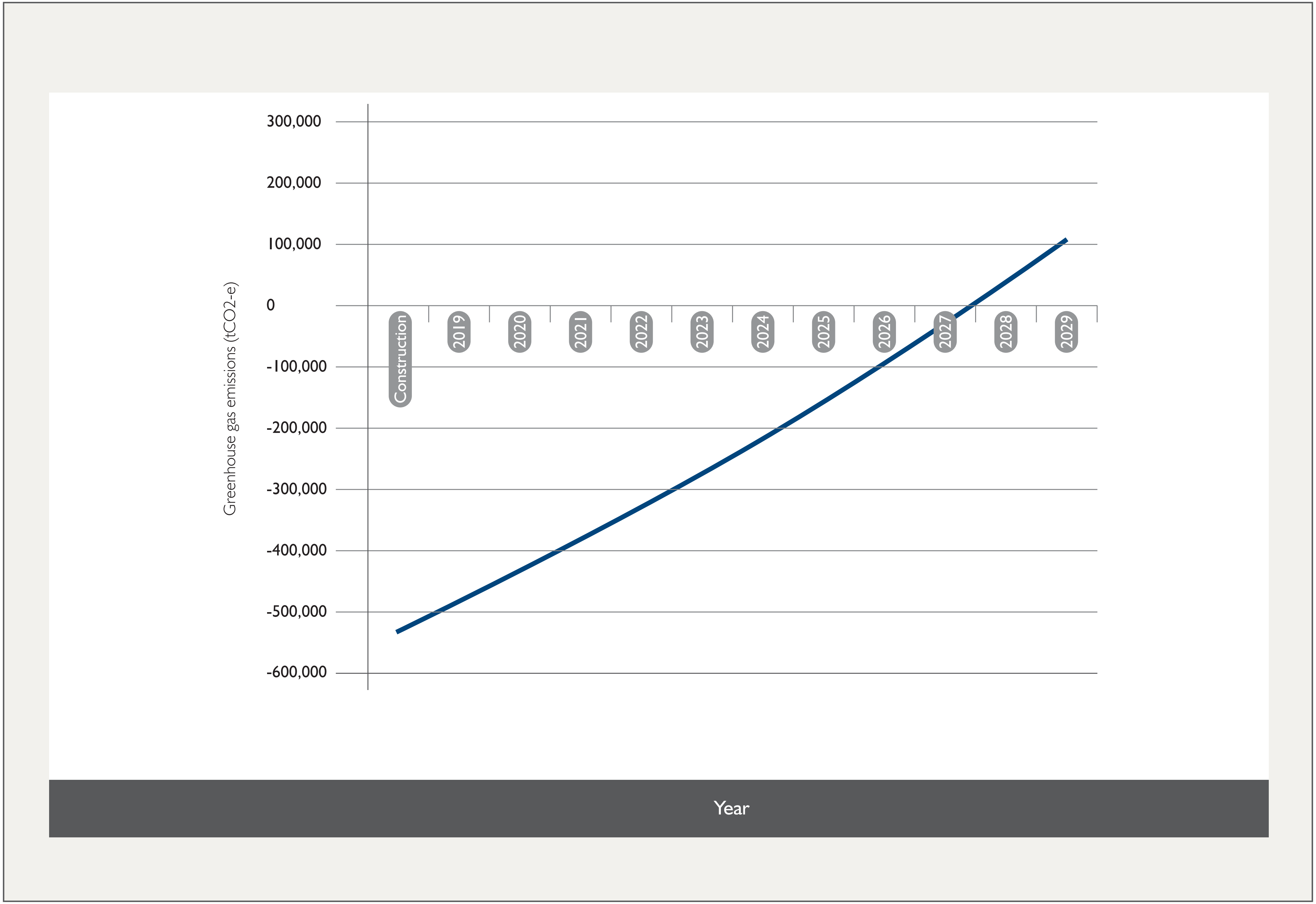


**Figure 8-13 Greenhouse gas emissions savings**

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## Climate change risk assessment

### *Key climate variables*

Climate differs from region to region due to changes in influencing factors such as geographical location, latitude, physical characteristics, variable patterns of atmosphere, ocean circulation and in some cases, human interaction (IPCC, 2007). Consequently, climate change and the associated impacts can be expected to vary from region to region. The climate change assessment provided in this section is based on projections for the Sydney region. Projections for NSW more broadly are provided where data specific to the Sydney region was unavailable.

This assessment is based on the following factors regarding the broader context and nature of the project:

- The inland location of the project reduces the risk of impacts from sea level rise, however inland areas of the Sydney region are likely to experience higher temperatures compared with coastal areas.
- Flood impacts are likely to vary between regions as flood behaviour is highly influenced by local terrain and man-made infrastructure. Flood events in inland areas are influenced by rainfall behaviour, potential evaporation rates and soil moisture. Given the elevated topography of the project area, impacts from flooding are considered to be negligible however, localised flooding impacts may be associated with periods of heavy rainfall.
- The nature of the project, primarily comprising underground tunnel infrastructure, is likely to offer protection from a number climate impacts (eg solar radiation, rainfall, storm events), however the associated surface infrastructure including tunnel interchanges and project buildings are likely to be susceptible to these impacts.

Climate variables identified as potentially generating risks for the project include:

- Mean annual temperature change and extreme temperature events.
- Mean annual rainfall change and extreme rainfall events.
- Increased mean annual potential evaporation.
- Increased solar radiation.
- Extreme events, particularly storms (rainfall, hail, wind, dust, lightning), drought and bushfires.

Projections for these climate variables are presented in **Table 8-35** and summarised in the following section.

## Climate change projections

Based on modelling undertaken by the CSIRO and BOM (2007), the Sydney region, and NSW more broadly, are projected to experience a warming trend, with an increase in the incidence of extreme temperature days over 35ºC. Annual average temperature in Sydney is likely to increase by around 0.9ºC by 2030 and 3.0ºC by 2070. The number of hot days per year in Sydney is projected to increase from 3.5 to 4.5 by 2030, under a moderate emissions scenario, and by up to 9.5 days per year by 2070 under a high emissions scenario.

NSW is likely to experience increased variability in rainfall throughout the year, with an annual average decrease of up to five per cent by 2030. Rainfall is likely to decrease in winter and spring, and increase in summer and autumn across most of NSW. The Sydney region is expected to follow this trend with an overall decrease in annual average rainfall of around three per cent by 2030 and eight per cent by 2070. The likelihood and intensity of extreme rainfall events is projected to increase for the Sydney region, with an increase of around five per cent by 2030 and an additional two per cent by 2070.

CSIRO and BOM (2007) projections show up to 20 per cent more drought months over most of Australia by 2030, with up to 40 per cent more droughts by 2070 across eastern Australia. Regional projections for NSW indicate more severe short term droughts in the northern parts of the state, with less severe medium and long term periods of drought. In the southern-most regions of the state, short, medium and long term periods of drought are all anticipated to increase in severity.

Increases in temperature and wind speed, decreases in mean annual rainfall and periods of prolonged drought are likely to increase the severity, frequency and duration of bushfire events in NSW. Very high to extreme fire danger days are projected to increase by between ten per cent and 50 per cent by 2050 (CSIRO and BOM, 2007).

Detailed projections for the Sydney region for 2030 under the A1B scenario and 2070 under the A1FI scenario, as described in **Section 8.4.3**, are presented in **Table 8-35**.

**Table 8-35 Climate change projections for the Sydney region (CSIRO & BOM, 2007)**

| Climate variable | Baseline data (1990) | 2030 projections (A1B) | 2070 projections (A1FI) |
|---|---|---|---|
| Mean annual temperature | 17 - 26ºC | +0.9ºC<br>(+0.6 to +1.3ºC) | +3.0ºC<br>(+2.1 to +4.3ºC) |
| Extreme temperature events (average days per year above 35ºC) | 3.6 | 4.6<br>(3.9 to 5.3) | 9.5<br>(5.0 to 13.9) |
| Extreme temperature events (average days per year above 40ºC) | 0.3 | 0.7<br>(0.5 to 0.8) | 1.9<br>(0.7 to 3.1) |
| Mean annual rainfall | 1213mm | -3%<br>(-9 to +3%) | -8%<br>(-25 to +10%) |
| Extreme rainfall (change in 40 year 1 day rainfall total) | Not available | +5%<br>(-3 to +12%) | +2%<br>(-7 to +10%) |
| Rainfall intensity (change in 100 year – 2 hour event) | Not available | -10%<br>(-15 to +5%) | +10%<br>(+5 to +15%) |
| Rainfall intensity (change in 5 year – 2 hour event) | Not available | 0%<br>(-5 to +5%) | +10%<br>(+5 to +15%) |
| Average annual potential evaporation | 2.9mm | +3%<br>(+2 to +5%) | +9%<br>(+5 to +15%) |
| Solar radiation (milliJoules per square metre) | 16.9 | +0.3%<br>(-1 to +1.9%) | +0.9%<br>(-3.2 to +6.0%) |

Note: Data in brackets represents the range of uncertainty associated with the magnitude of projections based on CSIRO & BOM (2007) modelled data, with the 10th to 90th percentile range presented in brackets below the median (50th percentile) value.

### Potential climate change impacts and risks to the project

Road infrastructure is particularly vulnerable to very high temperatures, changes in soil moisture and the ground stability of sloping land forms (Thom et al, 2010). The increased frequency and intensity of extreme weather events, increased rainfall, bushfires and rising temperatures are already causing strain on existing road networks. Recent flood events and bushfire events in NSW have highlighted the susceptibility of the transport sector to extreme events (Thom et al, 2010). More extreme weather events are likely to damage road infrastructure and, by 2030, design criteria for extreme events are very likely to be exceeded more frequently (Thom et al, 2010).

**Table 8-36** presents a high level desktop risk assessment of the projected climate change and associated impacts to key project components. Key risks to project tunnel and surface infrastructure components have been assessed in terms of low (acceptable), medium (tolerable), and high (undesirable) risks, as a result of impacts from projected climate change scenarios. In summary the climate risk assessment (**Table 8-36**) identifies one medium and seven low risks for tunnel infrastructure, and three medium and ten low risks for surface infrastructure.

The climate change risk assessment has been undertaken in line with relevant standards and current guidelines, as described in **Section 8.4.3**.

**Table 8-36 Climate change risks and potential impacts**

| Climate change risk | Possible impacts / consequences | Evaluation of risk level | Risk rating for 2030 | Risk rating for 2070 |
|---|---|---|---|---|
| Tunnel infrastructure | | | | |
| Increased temperatures and increased frequency and severity of extreme temperature days (days over 35 ºC) | Temperatures within the tunnel would be influenced by external surface temperatures as outside air would be drawn into the tunnel through the portals with the in-coming movement of vehicles and through mechanical ventilation fans. Higher temperatures are likely to be experienced within the tunnel as external surface temperatures increase, particularly on extreme temperature days.<br><br>Increased temperatures may cause additional stress on infrastructure through heat expansion and the accelerated degradation of materials, particularly for road pavements. | Although temperatures within the tunnel are likely to be influenced by external surface temperatures, the underground location and drainage of groundwater inflows through the tunnel would provide a cooler environment compared with the surface and potential impacts associated with heat stress are anticipated to be less than those experienced on surface roads.<br><br>In addition, there is sufficient knowledge and experience to demonstrate that bituminous and concrete road surfaces and concrete structures currently perform satisfactorily in Australia's extremely hot climates such as the tropical north and the dry inland where extreme weather conditions are similar to or more severe than predicted as a result of climate change for the Sydney region. | Low (acceptable) | Low (acceptable) |
| | Increased temperatures and extreme temperature days are likely to increase the risk of heat stress conditions for maintenance workers, which may lead to injury or, in a worst case scenario, fatality. | Management measures would be implemented to maintain safety of employees during operation and maintenance in line with current workplace health and safety practices, eg stop work procedures for extreme temperature thresholds. | Low (acceptable) | Medium (tolerable) |
| | Increased temperatures and extreme temperature days are likely to reduce the energy efficiency of electrical equipment including the use of tunnel ventilation fans, water treatment systems and electronic toll and surveillance systems during operation, increasing the consumption of electricity, and the risk of faults, equipment failure and power | The operation of mechanical and electric systems, particularly tunnel ventilation, during operation is anticipated to require significant amounts of electricity. Reductions in the efficiency of electrical equipment and systems as a result of increased temperatures would result in greater consumption of electricity and an increase in operational costs, as well as GHG emissions. However, efficiencies incorporated into the design, such | Low (acceptable) | Low (acceptable) |

| Climate change risk | Possible impacts / consequences | Evaluation of risk level | Risk rating for 2030 | Risk rating for 2070 |
|---|---|---|---|---|
| | outages. | as the consideration of mechanical and electrical systems with high energy efficiencies, would offset or otherwise reduce the impact of energy losses associated with temperature increases.<br><br>The tunnel is also anticipated to maintain a cooler environment compared with surface temperatures and the likelihood of heat stress impacts on underground electrical equipment and systems is considered to be low.<br><br>In addition, the design provides redundancy within the electricity network to minimise the risk of faults disrupting tunnel operation. | | |
| | Increased temperatures and extreme temperature events may affect the efficiency and function of vehicles utilising the tunnel during operation, increasing the risk of vehicles overheating and breaking down. Higher temperatures may also result in an increased rate of fuel consumption due to the increased use of air conditioning and the reduced efficiency of vehicle engines, particularly for older models. | The tunnel is anticipated to maintain a cooler environment compared with surface temperatures and the likelihood of heat stress impacts on vehicles is considered to be low.<br><br>Nonetheless, management measures would be implemented to maintain road safety in the event of breaking down vehicles (refer to **Section 8.2** Hazards and risk). For example, the main tunnel alignments would include provision of a 2.5 metre wide shoulder, which could be used to provide temporary accommodation for broken down vehicles and access for emergency vehicles. In addition, the tunnel would be equipped with automatic incident detection and motorist emergency equipment points would be positioned every 60 metres throughout the tunnel, with a direct telephone link to the motorway control centre. | Low (acceptable) | Low (acceptable) |
| Increased frequency, severity and | In the event of a bushfire or dust storm affecting the surrounding land, there is potential for smoke and embers, and / or dust | Emergency planning and development of incident response plans for the operation of the project would include specific provisions relevant to the management of | Low (acceptable) | Medium (tolerable) |

| Climate change risk | Possible impacts / consequences | Evaluation of risk level | Risk rating for 2030 | Risk rating for 2070 |
|---|---|---|---|---|
| duration of extreme events such as bushfires and storms | to be drawn into the main alignment tunnels and the tunnel ventilation system, reducing visibility, air quality and road safety within the tunnel. | a bushfire with direct or indirect impacts on the project. Management measures would be implemented to maintain road safety in the event of such extreme events, including the implementation of reduced speed limits during periods of reduced visibility, and as a worst case scenario, in the event that conditions within the tunnel are determined to be unsafe for road users, the tunnel would be temporarily closed and traffic diverted to other routes until conditions return to acceptable levels. **Section 8.2** (Hazards and risk), provides further discussion of the risks associated with bushfire events. | | |
| Decreased rainfall and increased frequency, severity and duration of droughts | Decreased rainfall and surface runoff coupled with increased temperature and evaporation are likely to result in a reduction in soil moisture content. These impacts are likely to increase the risk of ground movement, which may result in the accelerated degradation of materials, structures, reinforcement and foundations, increased maintenance requirements and a reduction of the life expectancy of project infrastructure. Further stress caused by extreme climate events may trigger or contribute to structural failure through the cracking of embankments or tunnel walls. | There is sufficient knowledge and experience to demonstrate that bituminous and concrete road surfaces and concrete structures currently perform satisfactorily in Australia's extremely hot dry climates such as the dry inland areas where extreme weather conditions are similar to or more severe than those predicted as a result of climate change for the Sydney region. | Low (acceptable) | Low (acceptable) |
| | Decreased rainfall and surface runoff may lead to an increase in the salinity of soils, increasing the risk of corrosion of materials such as steel and concrete. | Existing road and tunnel infrastructure already cope with a range of soil profiles and standards and specifications are in place to ensure foundations perform to a high standard. | Low (acceptable) | Low (acceptable) |
| Periods of increased rainfall and | Periods of increased rainfall and an increased frequency and intensity of extreme rainfall events under climate change are likely to | The drainage system for the tunnel portals and approaches has been designed to accommodate inflows of a 100-year average recurrence interval (ARI) rainfall | Medium (tolerable) | Medium (tolerable) |

| Climate change risk | Possible impacts / consequences | Evaluation of risk level | Risk rating for 2030 | Risk rating for 2070 |
|---|---|---|---|---|
| increased intensity and frequency of extreme rainfall events | cause increased volumes of runoff which may result in localised flooding of the tunnel portals and approaches and increase the risk of overloading of the tunnel drainage system.<br><br>Overloading of the tunnel drainage system may impact the asphalt and road foundation quality leading to a loss of strength and bearing capacity as well as accelerating the degradation of the road surface. | event. An additional allowance for the contribution of climate change related rainfall increases would be considered as part of the project's detailed design. Roads are designed to cope with a certain amount of overtopping. However with climate change, there may be changes in floodwater velocity and height which can increase the risk of damage. Inaccessible drainage elements, such as drainage culverts and pits are very difficult to modify once constructed. | | |
| **Surface infrastructure** | | | | |
| Increased temperatures, increased solar radiation, increased evaporation and increased frequency and severity of extreme temperature days (days over 35 ºC) | Increased temperatures, coupled with increased solar radiation and evaporation, are likely to cause additional stress on infrastructure through heat expansion and the accelerated degradation of materials, particularly for road pavements. Deterioration of materials, particularly asphalt and bitumen, would increase the risk of melting, cracking, or rutting of the road surface. | There is sufficient knowledge and experience to demonstrate that bituminous and concrete road surfaces and concrete structures currently perform satisfactorily in Australia's extremely hot climates such as the tropical north and the dry inland where extreme weather conditions are similar to or more severe than predicted as a result of climate change for the Sydney region. | Low (acceptable) | Low (acceptable) |
| | Increased temperatures, solar radiation and evaporation are likely to increase the risk of degradation and damage to structural materials of bridges, through the thermal expansion of bridge joints and paved surfaces. | The forecast increase in mean maximum and minimum temperature arising from climate change is within the range of temperatures presently experienced by bridge infrastructure across the state. Australian design standards allow for significantly hotter (hot inland desert) and cooler (Snowy Mountains) environments than predicted under climate change in the Sydney region. | Low (acceptable) | Low (acceptable) |
| | Increased temperatures and extreme temperature days are likely to increase the risk of heat stress conditions for maintenance workers, which may lead to injury or, in a worst case scenario, fatality. | Management measures would be implemented to maintain safety of employees during operation and maintenance in line with current workplace health and safety practices, eg stop work procedures for extreme temperature thresholds. | Low (acceptable) | Medium (tolerable) |

| Climate change risk | Possible impacts / consequences | Evaluation of risk level | Risk rating for 2030 | Risk rating for 2070 |
|---|---|---|---|---|
| | By 2070, the frequency and duration of heat wave events would increase significantly, with approximately 9.5 days per year above 35 ºC on average (**Table 8-35**), increasing the risk of heat stress related injury or fatality. | | | |
| | Increased temperatures and extreme temperature events may affect the efficiency and function of vehicles, increasing the risk of vehicles overheating and breaking down. Higher temperatures may also result in an increased rate of fuel consumption due to the increased use of air conditioning and the reduced efficiency of vehicle engines, particularly for older models. | Management measures would be implemented to maintain road safety in the event of breaking down vehicles (refer to **Section 8.2** Hazards and risk). The design includes provision of two incident response bays outside of the M1 Pacific Motorway portal and two incident response bays outside of the Hills M2 Motorway portal, which could be used to provide temporary accommodation for broken down vehicles.<br><br>In addition, motorist emergency equipment points along the M1 Pacific Motorway and Hills M2 Motorway would provide a direct telephone link to the motorway control centre. | Low (acceptable) | Low (acceptable) |
| | Increased temperatures and extreme temperature days are likely to reduce the energy efficiency of electrical equipment and systems, increasing the consumption of electricity and the risk of faults, equipment failure and power outages.<br><br>Increased temperatures are also likely to increase electricity consumption through an increased demand for air conditioning. | The project would draw power from the mains supply, through two separate feeders, designed to provide independent and reliable power sources for the project. The design provides redundancy within the reticulation network so that a single fault would not disrupt operations. | Low (acceptable) | Low (acceptable) |
| Increased frequency, severity and | An increased frequency and severity of bushfire events would increase risks to the health and safety of employees and the | Project buildings and infrastructure critical to the ongoing safe operation of the project, such as the Motorway Control Centre, would be located within an urban setting | Low (acceptable) | Medium (tolerable) |

| Climate change risk | Possible impacts / consequences | Evaluation of risk level | Risk rating for 2030 | Risk rating for 2070 |
|---|---|---|---|---|
| duration of extreme events such as bushfires | general public at the M1 Pacific Motorway tie-in and the Hills M2 Motorway integration works and within project operated buildings. Bushfires also increase the risk of damage to infrastructure through additional heat stress.<br><br>Project areas mapped as on or in proximity to bushfire prone land include:<br><br>Vegetated areas in proximity to the M1 Pacific Motorway tie-in works which mark the start of the vegetation contiguous with Ku-ring-gai Chase National Park.<br>Vegetated areas including Darling Mills State Forest and the Cumberland State Forest located in proximity to the Hills M2 Motorway integration works. | and are not mapped within bushfire prone areas.<br><br>The design of areas mapped within bushfire prone land, such as the M1 Pacific Motorway tie-in and the Hills M2 Motorway integration works, would take into account the establishment of appropriate asset protection zones (APZ), emergency access and egress, and the use of fire resistant materials.<br><br>Most of the project's operational infrastructure would be relatively invulnerable to bush fire attack due to its incombustible nature (eg road surface materials, retaining walls, road barriers).<br><br>Emergency planning and development of incident response plans for the operation of the project would include specific provisions relevant to the management of a bushfire with direct or indirect impacts on the project. | | |
| Decreased rainfall and increased frequency, severity and duration of droughts | Decreased rainfall and surface runoff coupled with increased temperature and evaporation are likely to result in a reduction in soil moisture content. These impacts are likely to increase the risk of ground movement, which may result in the accelerated degradation of materials, structures, reinforcement and foundations, increased maintenance requirements and a reduction of the life expectancy of project infrastructure. Further stress caused by extreme climate events may trigger or contribute to structural failure eg through the cracking of embankment walls. | There is sufficient knowledge and experience to demonstrate that bituminous and concrete road surfaces and concrete structures currently perform satisfactorily in Australia's extremely hot dry climates such as the dry inland areas where extreme weather conditions are similar to or more severe than those predicted as a result of climate change for the Sydney region. | Low (acceptable) | Low (acceptable) |

| Climate change risk | Possible impacts / consequences | Evaluation of risk level | Risk rating for 2030 | Risk rating for 2070 |
|---|---|---|---|---|
| | Decreased rainfall and surface runoff may lead to an increase in the salinity of soils, increasing the risk of corrosion of steel reinforcement for concrete structures such as bridges. | Existing road and bridge infrastructure already cope with a range of soil profiles and standards and specifications are in place to ensure foundations perform to a high standard. | Low (acceptable) | Low (acceptable) |
| Periods of increased rainfall and increased intensity and frequency of extreme rainfall events | Periods of increased rainfall and an increased frequency and intensity of extreme rainfall events under climate change are likely to cause increased volumes of runoff which may result in temporary periods of localised flooding or overtopping of the road surface.<br><br>Overloading of the drainage system and the subsequent overtopping of the road surface is likely to impact the asphalt and road foundation quality leading to a loss of strength and bearing capacity as well as accelerating the degradation of the road surface.<br><br>Increased temperatures, solar radiation and evaporation cause the road surface to crack and become more brittle, which further reduces surface waterproofing. These impacts would be exacerbated by periods of extreme rainfall and localised flooding which have the potential to cause significant damage to roads eg through extensive potholing. | The drainage system has been designed to accommodate inflows of a 100-year ARI rainfall event. An additional allowance for the contribution of climate change related rainfall increases would be considered as part of the project's detailed design. Roads are designed to cope with a certain amount of overtopping. However with climate change, there may be changes in floodwater velocity and height which can increase the risk of damage. Inaccessible drainage elements, such as drainage culverts and pits are very difficult to modify once constructed. | Medium (tolerable) | High (undesirable) |
| | Periods of increased rainfall and an increased frequency and intensity of extreme rainfall events under climate change are likely to cause increased volumes of runoff which may result in temporary periods of localised | Flooding loads are well understood and are currently considered during bridge structural design which allows for the passage of a 100-year ARI rainfall event. An additional allowance for the contribution of climate change related rainfall increases would be considered as part of | Medium (tolerable) | Medium (tolerable) |

| Climate change risk | Possible impacts / consequences | Evaluation of risk level | Risk rating for 2030 | Risk rating for 2070 |
|---|---|---|---|---|
| | flooding or overtopping of bridges.<br><br>Storm related damage and localised flood events as a result of extreme rainfall have the potential to cause significant damage to bridge infrastructure, such as the failure of abutments on bridges (foundations and supports are likely to be able to withstand storm events and localised flooding), resulting in significant costs associated with rebuilding and repair. An increase in the frequency and intensity of extreme rainfall events would increase the vulnerability of bridge infrastructure. | the project's detailed design. With climate change, there may be changes in floodwater velocity and height which can increase the risk of damage to bridge infrastructure. Bridges are difficult to modify once constructed. | | |
| | Periods of increased rainfall and extreme rainfall events are considered to be the dominant factor in the occurrence of land slides, which can have implications on the maintenance and repair of roads as well as disruptions to road users through impaired access.<br><br>Increased rainfall would also exacerbate dry soil conditions and increase the risk of land slip or rock fall hazards which may occur in areas of instability such as cuttings around the dive structures at the southern and northern interchanges. | Road foundations and embankments are designed to cope with a certain amount of runoff and potential overtopping. However with climate change, there may be changes in floodwater velocity and height which can increase the risk of damage.<br><br>The drainage system has been designed to accommodate inflows of a 100-year ARI rainfall event. An additional allowance for the contribution of climate change related rainfall increases would be considered as part of the project's detailed design. | Medium (tolerable) | Medium (tolerable) |

| Climate change risk | Possible impacts / consequences | Evaluation of risk level | Risk rating for 2030 | Risk rating for 2070 |
|---|---|---|---|---|
| | The increased frequency and severity of extreme rainfall events may result in an increased malfunctioning of power supplies, communications systems and radio signal propagation. | Emergency management plans and procedures would be implemented as part of the project, so that in the event of an emergency, traffic controllers, working with the Police, Ambulance, Fire and other emergency services would respond to unplanned incidents on the road network. | Low (acceptable) | Low (acceptable) |
| | An increased frequency and severity of extreme rainfall events would increase risks to road user safety, particularly as the incidence of collisions increases in wet weather conditions (Austroads, 2004). | Management measures would be implemented to maintain road safety in the event of such extreme events, including the implementation of reduced speed limits during periods of extreme rainfall. | Low (acceptable) | Low (acceptable) |

The risks to infrastructure described above may also generate knock-on effects or additional risks, such as (Maddocks et al, 2010):

- Risks to road user health and safety.
- Interruption or delays to commuter travel.
- Interruption or delays to commercial activities that depend on road transport, such as the movement of freight.
- Increased maintenance and replacement costs.
- Increased liability resulting from damage to road infrastructure.
- Higher insurance costs for road authorities.

For example, for a temperature increase of 2ºC to 3ºC Austroads (2004) predicts an average 17 per cent increase in road maintenance costs over most of Australia, based on predicted rates of pavement deterioration and assumptions around forecast traffic growth. By 2100, NSW is predicted to experience a 23 per cent increase in routine and periodic maintenance costs, including pothole patching, kerb and channel clearing, surface correction and resealing activities, and a 26 per cent increase in major rehabilitation or long term maintenance costs. Major maintenance or rehabilitation of the project road surface is anticipated to be required within 50 years of construction, occurring around 2070. **Table 8-35** indicates that a temperature increase of 3ºC is projected for 2070 under a high emissions scenario (CSIRO and BOM, 2007). As a result, project maintenance and rehabilitation costs are likely to be significantly greater than those expected under current climate scenarios and pavement deterioration rates.

Given the interconnected nature of climate variables, the risks identified are likely to occur in combination, resulting in amplified impacts on project infrastructure. Mitigation measures identified in **Section 8.4.5** are identified to minimise the risk of climate change impacts on the project.

### 8.4.5 Environmental management measures

Over the long term, the project has been shown to provide a net reduction in greenhouse gas emissions due to the provision of a free-flowing motorway standard alternative to Pennant Hills Road with improved travel times even accounting for the emissions during the construction period.

The design of the project has been optimised such that measures to reduce energy and resource requirements, and therefore GHG emissions, are inherent in the preferred tender design. The project design has been optimised to:

- Reduce the cross sectional area required to be excavated, which results in a reduction in spoil volumes and road header electricity consumption.
- Pass through a higher proportion of sandstone rock, as opposed to shale, reducing the number of rock bolts required and providing increased opportunities for the reuse of sandstone spoil at other developments.
- Reduce power consumption associated with tunnel ventilation by locating the ventilation facilities close to the main alignment tunnel portals thereby optimising the piston generated vehicle effect.
- Provide enhanced reflectivity and luminance so as to reduce the required level of lighting and associated power requirements within the tunnel.

- Provide large radius curves within the tunnel in order to allow consistent vehicle speeds to be maintained and reduce the need for vehicles to slow down on the approach to corners.
- Provide for long term performance and durability of the main tunnel alignments, the M1 Pacific Motorway, the Hills M2 Motorway and Pennant Hills Road and the associated local road network, increasing asset design lives and reducing the frequency of maintenance activities.

Environmental management measures relating to GHG mitigation and climate change adaptation for the construction and operation of the project are provided in **Table 8-37**.

Additional mitigation measures which would contribute to the reduction of GHG emissions or reduce the vulnerability of the project to climate change are provided in other sections of this environmental impact statement, including vegetation clearance (**Section 7.6** Biodiversity), waste reduction and recycling (**Section 8.3** Resource management and waste minimisation) and bushfire risk management (**Section 8.2** Hazards and risk).

**Table 8-37 Environmental management measures – GHG and climate change**

| Impact | No. | Environmental management measure | Timing |
|---|---|---|---|
| **Construction** | | | |
| GHG emissions | GHG1 | Emissions intensity of construction materials would be considered during procurement. | Procurement |
| | GHG2 | Where feasible, recycled content road construction and maintenance materials such as recycled aggregates in road pavement and surfacing would be used. | Procurement |
| | GHG3 | The fuel efficiency of the construction plant and equipment would be considered during selection. | Procurement / pre-construction |
| | GHG4 | Project planning would be aim to minimise double handling of materials, long haulage distances and additional fuel use. | Prior to construction |
| | GHG5 | Locally produced goods and services would be procured where feasible and cost effective to reduce transport fuel emissions. | Procurement / pre-construction |
| Climate change impacts | CC1 | The risks of future climate change would be further considered during detailed design. | Detailed design |
| | CC2 | Where high or medium risks to project infrastructure have been identified, the construction contractor would review existing design policies, specifications or practices to consider the impacts of climate change. | Detailed design |
| **Operation** | | | |
| GHG emissions | OpGHG1 | The tunnel would be designed to minimise fuel use associated with motorist use of the road through the optimisation of design, for example the provision of a vertical alignment that allows consistent vehicle speeds to be maintained. | Detailed design |

| Impact | No. | Environmental management measure | Timing |
|---|---|---|---|
| | OpGHG2 | Low carbon energy generation options would be investigated as part of the design process in order to reduce the demand on mains electricity where feasible. | Detailed design |
| | OpGHG3 | A life cycle assessment would be undertaken as part of the detailed design in order to select mechanical and electrical systems with increased energy efficiencies, such as the tunnel ventilation system, water treatment systems and electronic toll and surveillance systems. | Detailed design |
| Climate change impacts | OpCC1 | A stop work threshold (eg for extreme heat, storm events) for operation and maintenance activities would be implemented in line with current workplace health and safety practices. | Operation |
| | OpCC2 | Emergency planning and management controls would be implemented during operation to reduce the risk of adverse climate impacts, maintain public safety and minimise congestion. For example, bushfire management would include measures to ensure safety such as reduced speed limits and temporary tunnel closures where required (refer to **Section 8.2** Hazards and risk). | Operation |
| | OpCC3 | Maintenance regimes for road surface and other ancillary infrastructure would be developed to accommodate accelerated rates of asset degradation. | Operation |
| | OpCC4 | The motorway operator would develop emergency response management plans in consultation with emergency management services, local governments and other relevant agencies to ensure better disaster management during extreme climate events. | Operation |
| | OpCC5 | The motorway operator would monitor and review the performance of structures and materials in response to climate change related events. Where possible, the most cost-effective response would be to include adaptive measures in the regular maintenance of the project. | Operation |

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