TECHNICAL REPORT 8 – GREENHOUSE GAS

Prepared for
Infrastructure Canberra
ABN: 66 676 633 401

Technical Report 8 - Greenhouse gas

May-2025
Light Rail Stage 2B Draft Environmental Impact Statement

aecom.com

Delivering a better world

Technical Report 8 - Greenhouse gas

Client: Infrastructure Canberra

ABN: 66 676 633 401

Prepared by

AECOM Australia Pty Ltd
Ngunnawal Country, Civic Quarter, Lvl 4, 68 Northbourne Avenue, GPO Box 1942, Canberra ACT 2601, Australia
T +61 1800 868 654 www.aecom.com
ABN 20 093 846 925

May-2025

Job No.: 60715876

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 and ISO45001.

Revision History

Revision	Date	Details
1	May 2025	Technical report for draft EIS

Table of Contents

Figures

Tables

Acronyms and abbreviations

Acronyms and abbreviations	Definition
ACT	Australian Capital Territory
CEMP	Construction environment management plan
CERT	The Carbon Estimate and Reporting Tool
DCCEEW	Department of Climate Change, Energy, the Environment and Water
CO_2^e	Carbon dioxide equivalent emissions. A metric measure used to compare the emissions from various greenhouse gases based on their global warming potential by converting amounts of other gases (e.g. NO_x) to the equivalent amount of CO_2 with the same global warming potential.
EIS	Environmental Impact Statement
Embodied energy	Embodied energy in materials refers to the sum of greenhouse gas emissions associated with the upstream stages of a product's lifecycle and can include extraction, production, transport and manufacturing.
EPSDD	Environment, Planning and Sustainable Development Directorate
ERA	Environmental risk assessment
GHG	Greenhouse gas
iCBR	Infrastructure Canberra (formerly known as Major Projects Canberra)
tkm	Tonne-kilometre (tkm) a unit of measure of freight transport which represents the transport of one tonne of goods by a given transport mode over a distance of one kilometre.
km	Kilometre
LRS1	Light Rail Stage 1 – Gungahlin to City
LRS2A	Light Rail Stage 2A – City to Commonwealth Park
LRV	Light rail vehicle
m	Metre
NCA	National Capital Authority
NGA	National Greenhouse Accounts
NGER Act	National Greenhouse and Reporting Act 2007
OESS	Onboard Energy Storage System
Scope 1	Scope 1 emissions are direct GHG emissions that are produced by activities that are controlled by the proponent. Scope 1 are calculated from direct emission factors which give the CO_2^{-e} at the point of release within the boundary of the Project.
Scope 2	Scope 2 indirect GHG emissions are a result of activities associated with the Project from the consumption of electricity, heating, cooling or steam that is produced offsite.
Scope 3	Scope 3 emissions are indirect emissions that have not been accounted for in Scope 2.
Stage 1	Gungahlin to City
Stage 2A	City to Commonwealth Park

Acronyms and abbreviations	Definition
TAGG	Transport Authorities Greenhouse Group
TfNSW	Transport for New South Wales
TPA	Territory Planning Authority
TPS	Traction power substation

Executive summary

Infrastructure Canberra (iCBR) is seeking approval for the construction and operation (including maintenance) of Light Rail Stage 2B (the Project). The Project would deliver a light rail alignment extending from the approved LRS2A Commonwealth Park Stop on Commonwealth Avenue, to a new terminus on Callam Street at Woden Town Centre (the Woden Interchange). An Environmental Impact Statement (EIS) has been prepared to provide an environmental assessment of the Project and to address legislative requirements under the *Planning Act 2023* (ACT) and *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).

Two potential alignments for the Project are currently being considered through the National Triangle and around Parliament House, and have been assessed in the EIS. These alignment options include:

- The State Circle East alignment option: from Commonwealth Avenue along State Circle to Adelaide Avenue
- The National Triangle-Barton alignment option: from Commonwealth Avenue along King George Terrace, Macquarie Street, Bligh Street, National Circuit, and Sydney Avenue, before connecting with State Circle to Adelaide Avenue.

The Project is described in detail in Chapter 5 (Project description) and Chapter 6 (Construction) of the EIS.

This technical report has been prepared to inform the EIS and provides an assessment of the estimated greenhouse gas (GHG) emissions associated with the Project. In doing so, the technical report addresses the assessment requirements issued by the Territory Planning Authority (TPA) within the ACT Environment, Planning and Sustainable Development Directorate (EPSDD) and the Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW).

Scope of technical report

This greenhouse gas technical report provides an assessment of the estimated GHG emissions associated with the construction and operation of the Project, and proposed mitigation measures to address these emissions. The following GHG emissions have been considered from the Project:

- Consideration of construction sources of GHG emissions, including:
  - Combustion of liquid fuels from:
    - Stationary and mobile plant, equipment, and other vehicles
    - International shipping from import of LRVs and steel rails
  - Power consumption from the electrical grid used at construction compounds and laydown areas
  - Embodied energy of:
    - Construction materials
    - Construction and demolition waste
    - LRVs and batteries
  - Land use changes including:
    - Tree removal and grass removal.
    - Replanting of street trees, landscaping, and installation of green track (carbon sink)
- Consideration of operational sources of GHG emissions, including:
  - Fuel combustion from operation of new vehicles and mobile equipment based at the Mitchell Depot and street sweeping
  - Power consumption from the electrical grid from street and station lighting, signalling and from operation of the light rail vehicles (both lithium-ion battery charging and over-head wires)

- Maintenance activities over the asset life including:
  - Combustion of liquid fuels from stationary and mobile plant equipment and other vehicles
  - Replacement of LRVs and LRV lithium batteries.
  - Embodied energy of maintenance materials.

The approach to measuring GHG emissions during construction, operation, and maintenance activities as well as broader emissions from embodied carbon varies throughout the stages of the infrastructure life cycle and depends heavily on the level of information in each stage. The Greenhouse Gas Technical report assesses estimated GHG emissions for the Project as summarised in Section 1. Further details are provided in Chapter 5 (Project description) and Chapter 6 (Construction) of the EIS. Emissions have been quantified based on early asset details and preliminary material quantities for both alignment options. While carbon estimates are generally less accurate at this early stage of the design process, they have the greatest ability to influence carbon emission outcomes and intervention is likely to be more cost effective.

Estimated GHG emissions from Project

The total estimated emissions generated during construction of the Project and for operation and maintenance activities over an estimated 50 year design life for the State Circle East and National Triangle-Barton alignment options are summarised in Table ES-1.

Table ES-1 Summary of estimated GHG emissions for the Project for each alignment option

Phase	GHG Emissions (t CO_2-e)	
	State Circle East alignment option	National Triangle-Barton alignment option
Construction	102,589	98,386
Operation	1,100	1,131
Maintenance	5,931	5,762
Total	**109,620**	**105,278**

Construction GHG emissions

The total estimated GHG emissions from the construction of the Project inclusive of Scope 1, Scope 2 and Scope 3 emissions was found to be:

- 102,589 t CO_2-e for the State Circle East alignment option
- 98,386 t CO_2-e for the National Triangle-Barton alignment option.

Scope 1 emissions material to the Project comprise emissions directly attributed to construction of the Project. Most Scope 1 emissions were attributed to fuel consumption, with diesel fuel mobile equipment and construction vehicles found to be the highest contributor of Scope 1 emissions. The estimated Scope 1 contribution was found to be:

- 20,015 t CO_2-e for the State Circle East alignment option, equating to 20% of the total construction emissions for the Project.
- 23,521 t CO_2-e for the National Triangle-Barton alignment option, equating to 24% of the total construction emissions from the Project.

Scope 2 emissions material to the Project are due to electricity consumption from the grid. These emissions equate to zero for both alignment options due to the ACT Government offsetting 100% of residual electricity emissions through renewable generation and retiring Large Generation Certificates (LGCs).

Scope 3 emissions material to the Project comprise indirect emissions related to the Project in terms of offsite transport or GHG generation during the manufacture of materials and supplies. Scope 3 emissions form the highest emission contribution from the Project and account for:

- 82,574 t CO_2-e for the State Circle East alignment option, equating to 80% of the total construction emissions for the Project
- 74,864 t CO_2-e for the National Triangle-Barton alignment option, equating to 76% of the total construction emissions from the Project.

A single construction year[1] for the Project is expected to represent approximately 0.005% of Australia's total annual emissions for both alignment options. When considered at a territory level, a single construction year equates to 1.5% of ACT's total emissions annually for the State Circle East alignment option and 1.6% of the ACT's total emissions annually for the National Triangle-Barton alignment option. In noting this, construction of either option would aid in meeting key transport strategies listed under the ACT Climate Strategy 2019-2025 including supporting a higher uptake of public transport and trialling new ways roads can better support sustainable transport modes.

Operation and maintenance GHG emissions

Greenhouse gas emissions from operation and maintenance activities were estimated based on both an annual basis and for an assumed design life of 50 years. Similarly major maintenance and reparative works have also been estimated over the design life.

The total estimated GHG emissions generated for operation are provided were:

- 22.0 t CO_2-e annually and 1,100 t CO_2-e over the design life for the State Circle East alignment option
- 22.6 t CO_2-e annually and 1,131 t CO_2-e over the design life for the National Triangle-Barton alignment option.

Scope 1 emissions from fuel combustion are the primary source of GHG emissions. Emission estimates for alignment options are comparatively similar and equate to approximately 0.1% of the ACTs emissions for the 2022-2023 reporting year (ACT Government 2023).

Scope 2 emissions, which are due to electricity consumption from the grid equates to zero emissions for both alignment options due to the ACT Government offsetting 100% of residual electricity emissions through renewable generation and retiring LGCs.

While the effective GHG emissions generated from renewable energy are considered negligible the total estimated electrical consumption from the Project in megawatt hours (MWh) is:

- 2,232 MWh annually and 111,582 MWh over the design life for the State Circle East alignment option
- 2,409 MWh annually and 120,441 MWh over the design life for the National Triangle-Barton alignment option.

Electrical consumption is highest for recharging the LRV batteries on the over-head wire component of the light rail alignment for both alignment options.

Operation of the Project is anticipated to have beneficial GHG impacts associated with increased public transport patronage resulting in a reduction in road vehicle emissions on major roads such as Commonwealth Avenue, State Circle, Adelaide Avenue, Yarra Glen, and the surrounding road network. This modal transport shift also supports the ACT Climate Strategy 2019-2025 longer term priorities by improving public transport to provide an extensive Light Rail network and adaptive use of existing roads to better support more sustainable transport modes.

[1] The Project is assumed to emit approximately one quarter of the above emissions per year, during the construction period. Realistically due to the staging of construction activities this will not be completely accurate, however for the purposes of determining Project life emissions it is not deemed significant.

The total Scope 1 and Scope 3 estimated GHG emissions generated for major maintenance and reparative work over a 50 year design life is as follows:

- 5,931 t CO_2-e for the State Circle East alignment option
- 5,762 t CO_2-e for the National Triangle-Barton alignment option.

Scope 3 emissions from embodied energy in materials was found to be the highest contributor of emissions for both alignments.

Conclusion

This technical report supports the EIS and provides an indicative assessment of potential GHG emissions from both alignment options. Consideration of greenhouse emissions in decision making during options analysis can aid in lowering the potential carbon footprint of the Project. The study also provides recommendations for additional consideration of low carbon alternatives during the design process. A Carbon Management Plan would be developed as a living document to define the Project's approach to carbon management and reduction at procurement, design, construction, and operation stages.

1.0 Introduction

1.1 Background

Light Rail Stage 1 (LRS1) is currently operational from Gungahlin Place, Gungahlin, to Alinga Street, in the city centre. LRS1 includes 12 kilometres (km) of light rail track, 14 stops, 14 light rail vehicles (LRVs) and a maintenance depot in Mitchell. LRS1 provides a sustainable, accessible, and affordable public transport option.

Building on the success of LRS1, the Australian Capital Territory (ACT) Government has committed to continuing to improve connectivity in Canberra by extending the current Light Rail network to Woden Town Centre. The extension of the Light Rail network from the city centre to Woden Town Centre has been separated into two projects. The first stage is Light Rail Stage 2A (LRS2A), and the second is Light Rail Stage 2B (the Project). The raising of London Circuit between Edinburgh Avenue and Constitution Avenue to provide a new at-grade, signalised intersection with Commonwealth Avenue, forms part of the LRS2A project as facilitating works.

LRS2A has been approved and is currently being constructed. LRS2A will connect Alinga Street (the current city centre terminus) to an approved stop at Commonwealth Park. LRS2A will deliver a 1.7 km extension to the existing Light Rail network, and three stops at Edinburgh Avenue, City South and Commonwealth Park.

The Project would include the construction and operation (including maintenance) of a light rail service between the approved Commonwealth Park Stop (part of LRS2A) on Commonwealth Avenue to a new terminus on Callam Street at Woden Town Centre (the Woden Interchange).

LRS1, LRS2A and the Project are shown on Figure 1-1.

The Project is described in detail in Chapter 5 (Project description) and Chapter 6 (Construction) of the Environmental Impact Statement (EIS). Key Project elements relevant to this technical report are summarised in the following sections.

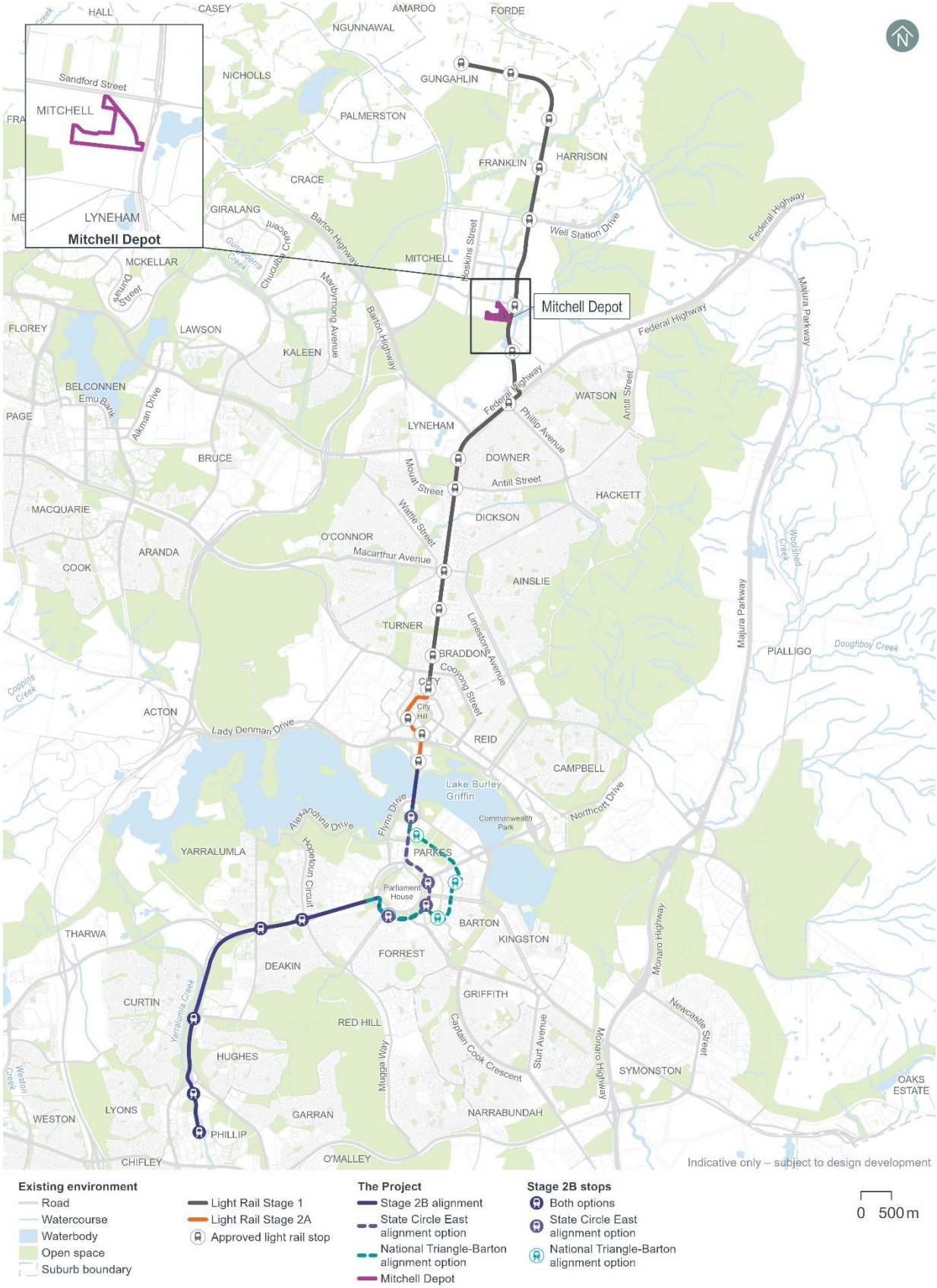


Figure 1-1 Existing and proposed Light Rail network

1.2 The Project

1.2.1 Key features of the Project

A summary of the Project's key features is provided in Table 1-1. Two potential alignments for the Project are being considered through the National Triangle and around Parliament House, and have been assessed in the EIS and this technical report. These alignment options include:

- The State Circle East alignment option: from Commonwealth Avenue along State Circle to Adelaide Avenue
- The National Triangle-Barton alignment option, which extends from Commonwealth Avenue along King George Terrace, Macquarie Street, Bligh Street, National Circuit, and Sydney Avenue, before connecting with State Circle to Adelaide Avenue.

The Project (including both alignment options) is shown on Figure 1-2.

The EIS, including this technical report, has adopted a precinct-based approach to the environmental assessment of the construction and operational impacts of the Project. The environmental assessment approach is discussed further in Section 1.4.1, and the precincts are shown on Figure 1-2.

Table 1-1 Key features of the Project

Project feature	Description	
	State Circle East alignment option	National Triangle-Barton alignment option
Light rail track	A new light rail track around 9.5 kilometres in length, connecting from the approved Commonwealth Park Stop (LRS2A), crossing over Lake Burley Griffin, travelling along the median of Commonwealth Avenue and passing on the eastern side of Parliament House in the median of State Circle.	A new light rail track around 10.5 kilometres in length, connecting from the approved Commonwealth Park Stop (LRS2A), crossing over Lake Burley Griffin, leaving Commonwealth Avenue to travel east along King George Terrace, Macquarie Street, Bligh Street, National Circuit, Sydney Avenue and moving to the inner running on State Circle.
	From State Circle, both alignment options would transition onto Adelaide Avenue via the landscaped annulus between State Circle and Capital Circle before travelling along Adelaide Avenue and Yarra Glen, with a new terminus at Woden Town Centre (Woden Interchange).	
Light rail stops	A total of nine new light rail stops and ancillary infrastructure.	
Bridges	• New light rail bridge structures: - Between the existing Commonwealth Avenue road bridges over Lake Burley Griffin and separately over Flynn Drive - Between the existing Adelaide Avenue northbound and southbound carriageways over State Circle and separately over Hopetoun Circuit - Over Yarralumla Creek at the existing Melrose Drive/Yarra Glen/Yamba Drive interchange • Removal of the existing Melrose Drive road bridge over Yarralumla Creek between Yamba Drive and Melrose Drive • Removal of the existing pedestrian bridge across Yarralumla Creek north of Phillip Oval • Modification (including widening) of the existing Melrose Drive road vehicle bridge over Yarralumla Creek • New pedestrian and cyclist bridge structures over: - Adelaide Avenue at Kent Street - Yarra Glen at Carruthers Street	

Project feature	Description	
	State Circle East alignment option	National Triangle-Barton alignment option
	- Yarralumla Creek, north of the Phillip Oval Stop - Yarralumla Creek main drain, to the east of Irving Street.	
Covered section	A covered section about 125 m long is proposed where the light rail would pass beneath the southbound lanes of Commonwealth Avenue and transition onto the median of State Circle.	There would be no covered sections in the National Triangle-Barton alignment option.
Landscaping and public domain works	Landscaping and public domain features along and around the Project alignment, as presented in the Public Domain Master Plan (refer to Appendix I of the EIS).	
Active travel arrangements	Reconfiguration, modification and/or replacement of existing active travel (walking, cycling and micromobility) infrastructure at various locations, and connection to existing active travel infrastructure within the Project area. New active travel arrangements would include four new pedestrian and cyclist bridges, shared paths to connect with the existing and/or planned active travel network, and bike/scooter parking at stops.	
Road network changes	Road network changes to accommodate the Project, including modifications to existing road carriageways and intersections, new intersection arrangements, changes to line markings and traffic signal phasing.	
	• Realignment of the inner carriageway of State Circle into Capital Hill by up to around 20 m to accommodate the light rail median running arrangement, generally between Commonwealth Avenue and Adelaide Avenue • Realignment into Capital Hill would be greater at intersections along State Circle to accommodate existing turning movements (by up to around 25 m at Canberra Avenue and by up to around 28 m near Melbourne Avenue).	• Introduction of light rail infrastructure into Capital Hill by up to around 22 m to accommodate the inner running arrangement, generally between Sydney Avenue and Adelaide Avenue • This would be greater at intersections along State Circle to accommodate the light rail infrastructure (by up to around 35 m at Sydney Avenue, by up to around 27 m at Canberra Avenue and by up to around 29 m near Melbourne Avenue.
Other facilities and infrastructure	• Modified and additional drainage and stormwater management infrastructure to accommodate the Project • Upgrade of the existing stabling depot and maintenance facility in Mitchell to accommodate additional LRVs, staff and storage • Power supply, including traction power substations (TPSs), inground service routes, track infrastructure, signal/lighting, communications equipment and a combination of wire-free and over-head wiring • Connection of new services (power and water supply) to light rail stops • A variety of utility adjustments, subject to agreement with relevant utility authorities.	
Operation and maintenance	Operation and maintenance of the Project, including operation, storage and maintenance of up to 12 additional LRVs on the Light Rail network.	

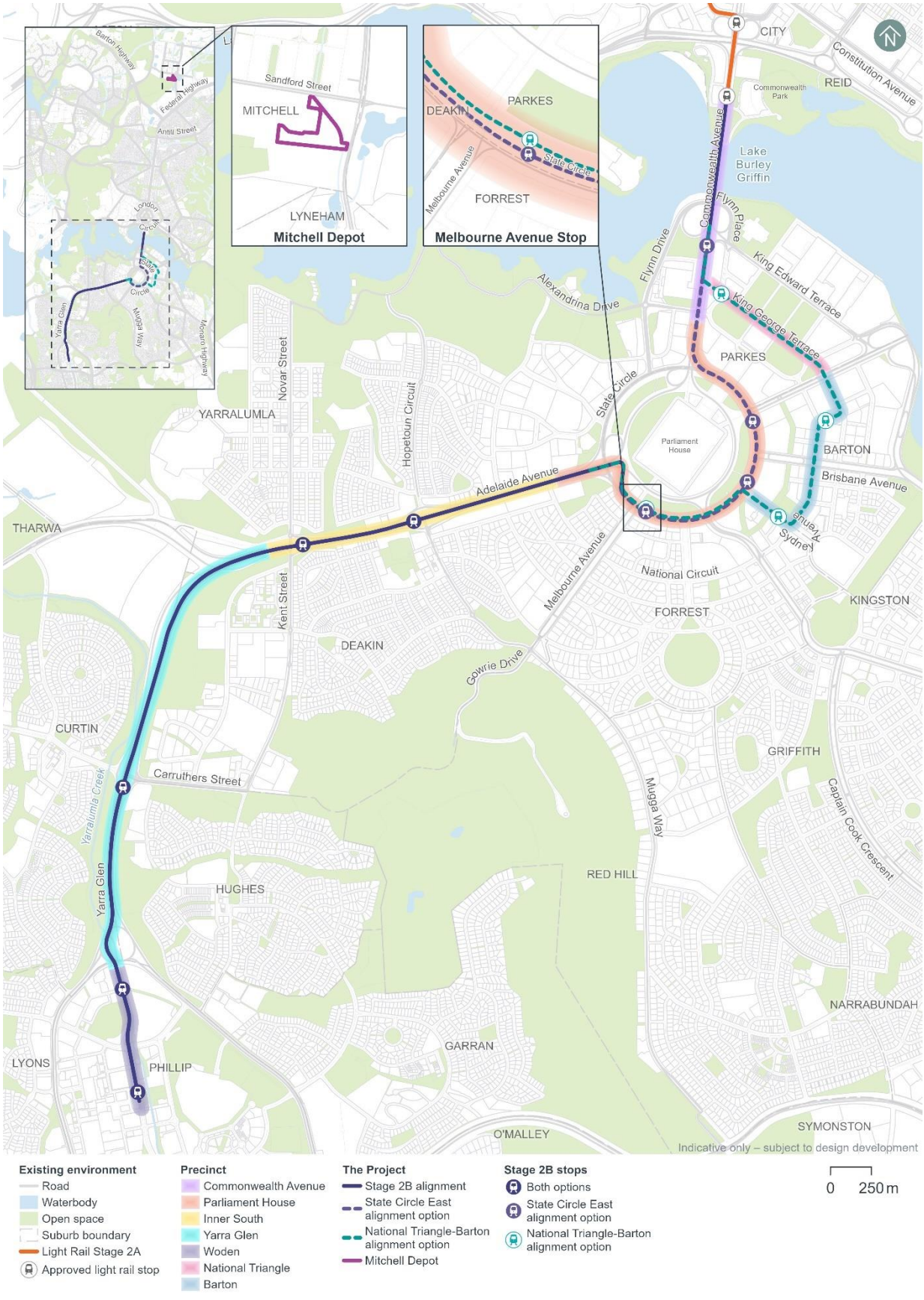


Figure 1-2 Project overview

1.2.2 Project construction

Construction activities and program

Construction of the Project would include:

- Early and enabling works
- Main construction works, including works relating to:
  - Light rail infrastructure
  - Earthworks
  - Road works
  - Bridges
  - The covered section between Commonwealth Avenue and State Circle (for the State Circle East alignment option)
  - Stops
  - Integration with existing active travel links
  - Other infrastructure
- Finishing, testing, and commissioning.

These activities are described in more detail in Chapter 6 (Construction) of the EIS.

Subject to environmental approvals and the Project's procurement strategy, major construction work is anticipated to commence in 2029 and would take about four to five years to complete. The construction duration would depend on further design development, investigations (including geotechnical and utilities), and detailed construction planning, including the construction contractor's final proposed methodology. Early and enabling works may be required prior to 2029, subject to detailed design and construction planning. A decision on how the works are to be packaged would be made as part of ongoing design development.

Construction is anticipated to occur concurrently across each precinct from 2029.

The testing and commissioning phase would begin towards the end of completion of the main construction works and would take around 12 months. The first passenger services are proposed to start in 2034.

The construction of LRS2A is anticipated to be completed in 2027 followed by a period of testing and commissioning, and would begin operation prior to the main construction works of the Project.

Project area

Construction activities associated with the Project would occur within a within a defined construction disturbance footprint referred to as the 'Project area', and shown on Figure 1-3 to Figure 1-6. The Project area would allow sufficient area for both permanent and temporary works required to deliver the Project, however further utility investigations prior to main construction works would confirm this. Temporary occupation of land would be subject to a licence or lease over the land, where required.

Permanent works would include delivery of new and altered infrastructure that supports the operation of the Light Rail extension to Woden, such as the track, stop infrastructure, bridges, landscaping, and TPSs.

Temporary works would include areas for short-term storage of construction plant and equipment, compound areas, traffic management, and temporary alterations required to deliver the permanent Project elements. Land required for temporary works would be used at different times depending on the stage of construction and construction requirements at a particular location. Temporary works would vary over time during the construction period, and would proceed along the Project alignment. Construction planning would aim to minimise and manage potential construction phase environmental impacts through careful selection of locations and scheduling of temporary works across the Project

area. The extent and location of temporary works would depend on which alignment option is selected for the Project.

Indicative construction compound locations are shown on Figure 1-3 to Figure 1-6. All indicative construction compound locations would be required regardless of which alignment option is selected.

Construction compounds would support staff and worker accommodation (such as temporary office buildings, lunch sheds, and amenities) and storage of plant, equipment, and construction materials. Solid hoarding or temporary fencing would be installed around each of the construction compounds. Following construction works, land occupied by the construction compounds would be rehabilitated.

In addition to the construction compounds, smaller short term ‘satellite’ ancillary facilities would also be required. These ancillary facilities would include temporary toilet facilities for workers and small stockpiles of materials and/ or equipment. The ancillary facilities would be short term and would be relocated as the works/crews move to different precincts and construction zones.

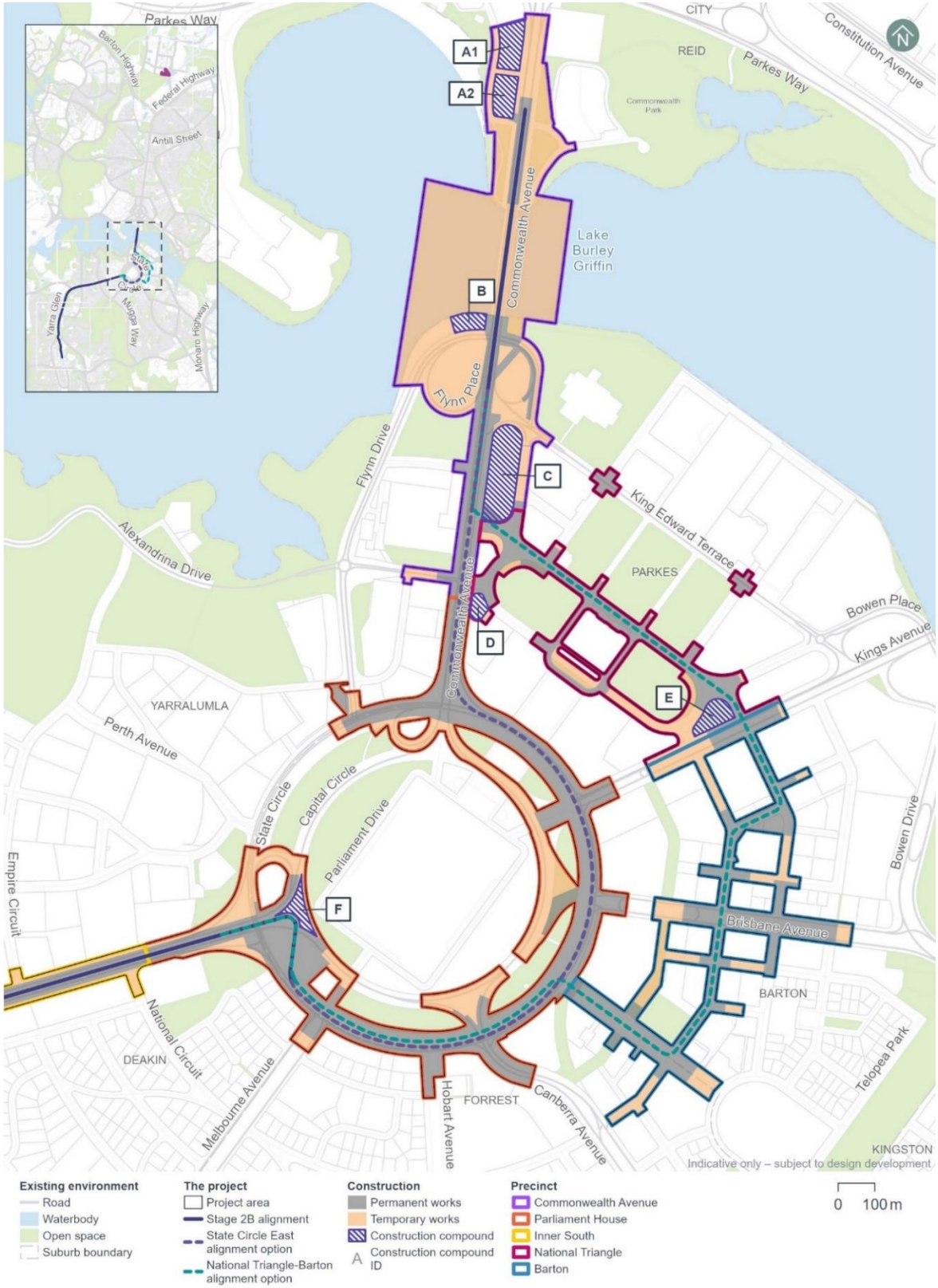


Figure 1-3 Project area (1/4)

Figure 1-4 Project area (2/4)

Figure 1-5 Project area (3/4)

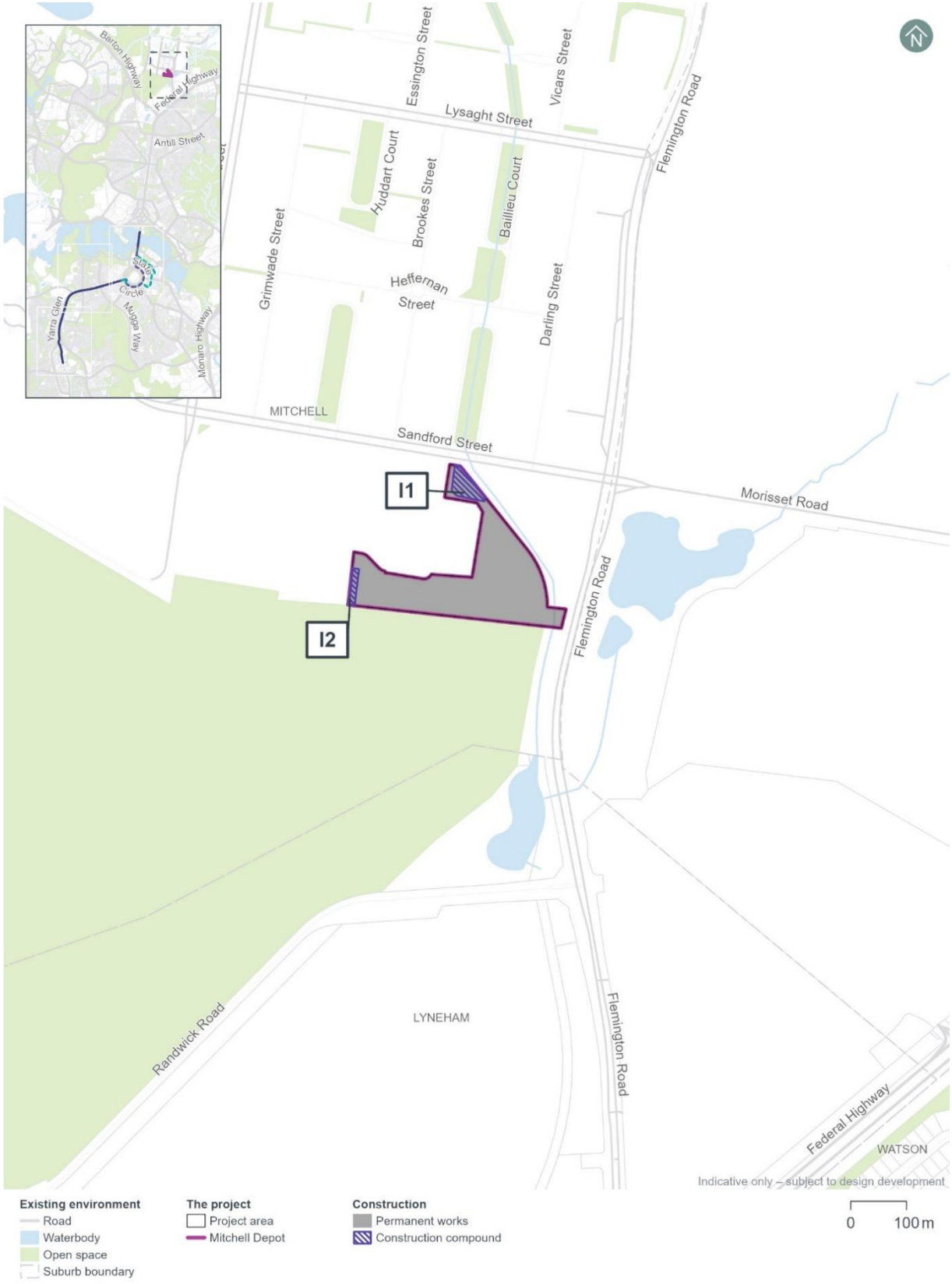


Figure 1-6 Project area (4/4)

1.3 Purpose of this report

An EIS has been prepared to provide an environmental assessment of the Project to comply with various legislative requirements, and to provide the community and other stakeholders with complete and consolidated details of the Project.

This technical report has been prepared to inform the EIS and provides an assessment of the greenhouse gas emissions associated with the construction and operation of the Project, and proposed mitigation measures to address these. In doing so, the technical report addresses the requirements outlined in Section 1.3.1.

1.3.1 Assessment requirements – Scoping Document

Environmental risks and requirements for the EIS are set out in the Scoping Document issued by the Territory Planning Authority (TPA) within the ACT Environment, Planning and Sustainable Development Directorate (EPSDD). The Scoping Document combines the climate change risk and greenhouse gas assessment requirements into one environmental theme. This EIS addresses the greenhouse gas assessment requirements in this technical report, and climate change risks in Technical Report 7 – Climate change risk. The Scoping Document identifies the following risks relating to climate change and greenhouse gas emissions:

- Contribute to climate change effects through the burning of fossil fuels used in the vehicles and other plants and equipment employed in the demolition and construction works
- Climate change related hazards.

Detailed requirements that relate to the greenhouse gas technical report are addressed in this technical report as summarised in Table 1-2.

Table 1-2 Scoping Document detailed requirements - Greenhouse gas

Requirements	Where addressed in this report
Outline the greenhouse gas emissions that will be generated by the proposed development during demolition, construction and operation, including measures to mitigate the impact.	Section 4.0 to Section 6.0
Provide a quantitative estimate of emissions produced during operation.	Section 5.0
Outline how the proposal has assessed and responded to increased natural disaster risk being driven by climate change, particularly the extreme events of heatwaves, droughts, storms with flash flooding, and bushfires.	Refer to Technical Report 7 – Climate change risk of the EIS
Describe the impacts of the proposed development on urban heat and the local microclimate.	Refer to Technical Report 7 – Climate change risk of the EIS

Attachment A of the Scoping Document issued by the TPA includes entity comments that the EIS must address. Of relevance to this technical report are entity comments received from the EPSDD Climate Change and Energy Division. The relevant comments, and where they are addressed, are summarised in Table 1-3.

Table 1-3 Entity comments – Greenhouse Gas Emissions

Entity	Comment	Where addressed in this report
EPSDD Climate Change and Energy Division	This proposal is likely to produce significant greenhouse gas emissions and may impact on the ACT's greenhouse gas emissions targets. It is recommended that the scoping document requires provision of quantitative estimates of the Scope 1 and 2 greenhouse gas emissions that will be generated by the proposed development during construction and operation. Mitigation and/or offsetting measures proposed and the extent to which they reduce emissions must also be quantified. The following emissions are relevant for transport projects: • Changes in transport greenhouse gas emissions resulting from the project, including emissions caused by changes in demand and substitution between modes of transport, as well as emissions reductions due to any decrease in congestion. • Scope 1 and 2 greenhouse gas emissions resulting from the operational energy use of the infrastructure itself. • Estimates must be calculated in a way that is comparable to the greenhouse gas emissions targets in the Climate Change and Greenhouse Gas Reduction Act 2010. Noting our understanding that the light rail project will be using the Infrastructure Sustainability rating (https://www.iscouncil.org/is-ratings/), it would also be useful to include provision of quantitative estimates of the Scope 3 greenhouse gas emissions that will be generated by the proposed development during construction and operation. Mitigation and/or offsetting measures proposed and the extent to which they reduce emissions should, where available, also be quantified. The greenhouse gas protocol guidance for scope 3 emissions may be a useful resource in relation to providing this information: https://ghgprotocol.org/scope-3-calculation-guidance-2.	Emissions are quantified in Section 4.0 to Section 5.0 Mitigation measures are listed in Section 6.1 and would require the development of a Carbon Management Plan as discussed in Section 6.0 Changes in transport greenhouse emissions from proposed transport mode shift are discussed in Section 5.0. Section 4.0 to Section 6.0 The methodology for estimating Scope 3 estimates is provided in Section 3.0.

1.3.2 Assessment requirements – EIS Guideline

Requirements for the EIS are set out in the EIS Guidelines issued by the Commonwealth Minister for the Environment of the Department of Climate Change, Energy, the Environment and Water (DCCEEW).

There are no greenhouse gas assessment requirements within the EIS Guidelines. Assessment requirements relating to climate change risks are addressed in Technical Report 7 – Climate change risk of the EIS.

1.4 Approach to the environmental assessment

1.4.1 Environment risk assessment

An environmental risk assessment (ERA) has been prepared for the Project and is provided in Appendix J (Environmental risk assessment) of the EIS. The ERA identifies the issues that may result from the construction and operation of the Project.

The ERA was used as a tool to identify key environmental issues for the Project to be assessed in detail in this EIS. While all relevant potential environmental impacts have been assessed in the EIS, key environmental issues identified through the ERA (being those issues with a medium or greater risk) have been subject to a greater level of assessment scrutiny with a detailed impact assessment prepared for those matters. This technical report has been prepared to respond to risks and issues identified in the ERA.

Further detail on the approach to the environmental assessment throughout the EIS, and the methodology adopted for the ERA, is provided in Chapter 9 (Approach to the environmental assessment) of the EIS.

2.0 Legislative and strategic context

2.1 Overview

GHG emission reduction goals are periodically set at a global level, and voluntarily adopted by countries around the world. Individual states and territories in Australia further detail their GHG reduction strategies by implementing policies and plans, with reporting of GHG emissions also standardised through an approved reporting scheme. Relevant global and Australian policies and strategies are introduced below.

2.2 International policies and commitments

2.2.1 United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) aims to stabilise GHG concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. It was entered in to force in 1994, and currently has 197 countries (including Australia) that are parties to the convention. The convention also puts the onus on developed (Annex I) countries to lead the way in GHG emissions reduction, requiring them to report regularly on their climate change policies and measures. Annex I countries are also required to submit an annual inventory of their GHG emissions.

2.2.2 Kyoto Protocol

The Kyoto Protocol was adopted in 1997, entered in to force in 2005 and included 192 countries, including Australia, that are parties to the protocol. The aim of the protocol is to implement the objective of the UNFCCC, covering the six GHG: carbon dioxide (CO_2), methane (CH_4), N_2O, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The protocol only binds Annex I countries as they are largely responsible for the current high levels of GHG. Primarily countries must meet emission reduction targets nationally, however there are flexibility mechanisms available including international emissions trading.

The Kyoto Protocol treaty administered two commitment periods to reduce greenhouse gas emissions. The first between 2008 and 2012 and the second period between 2013 and 2020. There is currently no third commitment period for the Kyoto Protocol.

2.2.3 The Paris Agreement

The Paris Agreement is an international treaty on climate change that was adopted by 196 parties, including Australia, in 2015 and entered in to force in 2016. The aim of the agreement is to limit global warming to below 2°C, and preferably 1.5°C compared to pre-industrial levels. The main driver to limit warming is reducing GHG emissions, and the countries partied to the agreement are required to submit plans on a five-year cycle outlining the actions they will take to reduce emissions. The agreement also puts a focus on best practice technologies for reducing GHG emissions but also adapting to climate change.

Under the Paris Agreement, countries are required to communicate their Nationally Determined Contribution (NDC), which sets out their emissions reduction ambitions. On 16 June 2022, Australia communicated its NDC under Article 4 of the Paris Agreement to the UN. This NDC included confirmation of Australia's commitment to achieve net zero emissions by 2050, and a new, increased, target of 43% below 2005 levels by 2030.

Australia's NDC as part of the Paris Agreement was formally legislated in Australia's domestic law with the introduction of the *Climate Change Act 2022* (Cth) as discussed in Section 2.3.1.

2.3 National legislation and policies

2.3.1 Climate Change Act 2022

The *Climate Change Act 2022* (Cth) administered by the Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW) sets out Australia's greenhouse gas emission reduction targets. Australia's greenhouse gas emission reduction targets are as follows:

a. *Reducing Australia's net greenhouse gas emissions to 43% below 2005 levels by 2023:*
    i. *Implements as a point target; and*
    ii. *Implemented as an emissions budget covering the period 2012 to 2030.*
b. *Reducing Australia's net greenhouse gas emissions to zero by 2050.*

In addition to setting Australia's greenhouse gas emission reduction targets the *Climate Change Act 2022* (Cth) also:

- Requires the Minister for Climate Change to deliver an annual statement, within six months of each financial year
- States the advisory functions of the Climate Change Authority
- Provides for periodic reviews of the operation of the legislation.

2.3.2 Net Zero Plan 2050

The Australian Government is developing a Net Zero Plan to establish a net zero economy by 2050 while also meeting the 2035 emission reduction targets under the *Climate Change Act 2022* (Cth). As part of the decarbonisation strategy six sectorial emission reduction plans are being developed. This includes the Transport and Infrastructure Net Zero Roadmap and Action Plan being developed by the Department of Infrastructure, Transport, Regional Development, Communications, and the Arts (DITRDCA).

Australia's transport sector is the third largest source of Australia's greenhouse gas emissions, amounting to 21% of the national emissions in 2023; and are projected to be the largest contributor of emissions nationally by 2030. In 2023, light vehicles, including passenger and light commercial vehicles made up 59.7% of transport emissions. Heavy vehicles, including on road trucks and buses, made up 23.4%.

A key focus of the Net Zero Plan will be to decarbonise the transport sector through low carbon and renewable energy sources (DITRDCA 2024). The Road Map and Action Plan will examine the potential pathways to reduce GHG to net zero by 2050 across all transport modes (road, rail, aviation and maritime), freight and supply chains, active transport planning and supporting infrastructure.

2.3.3 The Climate Active Carbon Neutral Standards

The Climate Active Carbon Neutral Standards set out the minimum requirements for calculating, reducing, offsetting, auditing, and reporting on emissions based on international standards and tailored to Australia. The Climate Active Carbon Standards include standards for business operations, products and services, events, precincts, and buildings.

2.3.4 Zero Emissions Government Fund

The Zero Emissions Government Fund is the key mechanism for supporting cost effective emission reduction Projects in Government operation. The fund is designed to support emission reduction Projects by providing interest free loans to Government agencies for projects that cut emissions from natural gas and transport. Energy bill savings are used to repay loans, continually replenishing the fund. The Zero Emissions Government fund supports the ACT Government under the Environment, Planning and Sustainable Development Directorate (EPSDD) objective to move towards a zero emissions government by pursuing rapid emission reduction targets of greater than 33% reduction in emissions from government operations by 2025 (from 2020 levels) and zero emissions by 2040. Additional GHG ACT policy information is discussed in Section 2.4.

2.3.5 National Greenhouse and Energy Reporting Act 2007

The *National Greenhouse and Energy Reporting Act 2007* (Cth) (NGER Act) administered by the Commonwealth Department of Climate Change, Energy the Environment and Water (DCCEEW) is the overarching legislation for the dissemination of information relating to GHG emissions in Australia. It is supported by the National Greenhouse and Energy Reporting Scheme (refer to Section 2.3.5.1) for reporting company information relating to GHG emissions, energy production and energy consumption.

The NGER Act is also supported by several legislative instruments that provide additional guidance around GHG reporting requirements including:

- National Greenhouse and Energy Reporting Regulations 2008
- National Greenhouse and Energy Reporting (Measurement) Determination) 2008
- National Greenhouse and Energy Reporting (Audit) Determination 2009
- National Greenhouse and Energy Reporting (Auditor Registration) Instrument 2019
- National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015.

2.3.5.1 National Greenhouse and Energy Reporting Scheme

The National Greenhouse and Energy Reporting Scheme (NGER) is the national framework used for reporting company information about GHG emissions, energy production, and energy consumption. If a facility or corporate groups reach the applicable threshold, they have an obligation under the *National Greenhouse and Energy Reporting Act 2007* (Cth) to report CO_2-e emissions.

section 10 of the *National Greenhouse and Energy Reporting Act* 2007 (as amended 23 April 2024) allows for the provision of the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (amended 7 October 2023) legislative instrument. This determination provides for the measurement of:

a. GHG emissions arising from the operation of facilities

b. The production of energy arising from the operation of facilities

c. The consumption of energy arising from the operation of facilities.

The determination provides four methods and criteria for the measurement of Scope 1 and Scope 2 GHG emissions (refer to acronyms and abbreviations table for a description of Scope 1 and Scope 2 emissions). The four methods used for measurement include:

- **Method 1** (default method) – derived from the National Greenhouse Accounts methods and is based on national average estimates
- **Method 2** – facility specific method using industry practices for sampling and Australian or equivalent standards for analysis
- **Method 3** – same as Method 2 but is based on Australian or equivalent standards for both sampling and analysis
- **Method 4** – facility specific measurement of emissions by continuous or periodic emissions monitoring.

Scope 1 emissions for the construction of the Project have been estimated using Method 1. Emissions estimation methodology for both Scope 1 and Scope 2 emissions from the Project are discussed in more detail in Section 3.3.1.1.

2.4 Territory policy

2.4.1 Climate Change and Greenhouse Gas Reduction Act 2010

The *Climate Change and Greenhouse Gas Reduction Act 2010* (ACT Government) legislates the ACT's targets to reduce greenhouse gas emissions and require monitoring and reporting in relation to set targets.

The primary target of the Act is to achieve net zero emissions by 30 June 2045 (based on 1990 GHG emission levels). In addition to this target the following interim targets have already been achieved:

- A 40% reduction in GHG emissions by 2020
- 100% renewable electricity target.

Further interim targets set by the ACT Government to achieve net zero emissions by 2045 include:

- A 50% to 60% reduction by 2025
- A 65% to 75% reduction by 2030
- A 90% to 95% reduction by 2040.

The Project would support the reduction in GHG emissions targets by encouraging a modal transport shift, increasing the uptake of public transport.

2.4.2 ACT Climate Change Strategy 2019-2025

The ACT Climate Strategy 2019-2025 outlines the actions the ACT Government plan to take to meet its legislated interim reduction target of 50 to 60% by 2025 and establish a pathway for achieving net zero emissions by 2045.

Under the strategy key priorities identified for the transport sector include:

- Immediate priorities towards 2025
    - Support higher uptake of public transport by continuing to improve services to meet community travel needs
    - Trial new ways of using roads more efficiently that most efficiently move people and goods and better support sustainable transport modes
    - Encourage active travel by continuing to improve cycle paths and walkability
    - Encourage the uptake of zero emissions vehicles and explore the need for further incentives
    - Plan for a compact and efficient city to improve access to public transport and active travel options, reduce travel distances and reliance on private car use.
- From 2025 continue to electrify public and private transport and support active travel.

A key element of the ACT Government's plan for the transport sector includes improving public transport to provide an extensive user-friendly Light Rail network that is well integrated with active travel options and supported by an expanded network of park and ride facilities to reduce private car use.

The Project would support the ACT Climate Strategy 2019-2025 objective to provide an extensive user-friendly Light Rail network and aid in achieving GHG emissions targets discussed in Section 2.4.1 by encouraging a modal transport shift; increasing the uptake of public transport.

2.4.3 ACT Sustainable Energy Policy 2011-2020

The *ACT Sustainable Energy Policy 2011-2020* (ACT Government, 2011), establishes an integrated policy framework for managing the social, economic, and environmental challenges faced by the ACT as they relate to energy production and use. The framework consists of four key targeted outcomes:

- Outcome 1: Secure affordable energy
- Outcome 2: Smarter use of energy
- Outcome 3: Cleaner Energy

- Outcome 4: Growth in the clean economy.

Related to each outcome are a series of measures that underpinned the Government's energy policy work program to 2020 including encouragement of uptake in public transport. The *ACT Government Sustainable Energy Policy Discussion Paper* 2020-2025 (ACT Government, 2019) examines a range of potential policy options to achieve a sustainable energy future advancing the original objectives of the policy post 2020. This includes:

- Maintaining the 100% renewable energy targets
- Energy efficient measures including the continuation and expansion of the Energy Improvement Scheme
- Transitioning from natural gas to more sustainable energy sources
- Promotion of Zero Emission Vehicles
- Energy storage solutions including batteries to support a renewable energy grid
- Measures to support low income and vulnerable households to benefit from energy efficient programs and renewable energy
- Opportunities for innovation and investment in renewable energy.

3.0 Assessment methodology

3.1 Relevant guidelines and policies

Relevant polices have been discussed above in Section 2.0. Several guidance documents have been used to estimate potential GHG emissions from the Project, including:

- *National Greenhouse and Energy Reporting (Measurement) Determination* 2008 and the National Greenhouse Accounts Factors 2023
- *Transport for NSW Embodied Carbon measure for Infrastructure*, Technical Guidance (TfNSW, 2024)
- *Transport for NSW Carbon Estimate and Reporting Tool Manual* (CERT) (TfNSW, 2018)
- Transport Authorities Greenhouse Group (TAGG) (2013); Greenhouse Gas Assessment Workbook for Road Projects.

Guidance documents used in the estimation of GHG emissions are further discussed in Section 3.3.1.1.

The Entity comments provided by the EPSDD Climate Change and Energy Division (refer to Table 1-3) also recommend the consideration of the *Greenhouse Gas Protocol: Technical Guidance for Calculating Scope 3 Emissions* (WRI and WBCSD, 2013). The Greenhouse Gas Protocol provides guidance relating to data collection from secondary data sources to calculate Scope 3 emissions. Guidance regarding data collection provided under the Protocol is to prioritise emission factors of geographic relevance and from sources such as transport departments, government ministries, or agencies, national statistics publications and/or industry associations.

The use of Scope 3 emission factors adopted in this technical report as detailed in Section 3.3.2.3 are largely published by Australian government agencies including transport departments and from national statistical publications. Furthermore, the technical report has adopted the emission factor hierarchy in line with the *Transport for NSW Embodied Carbon measure for Infrastructure*, Technical Guidance document (TfNSW, 2024) which provided further recommendations on preference selection for secondary data.

3.2 Key assumptions

Key assumptions relating to the scope of the GHG emissions inventory are defined in Section 3.3.1 and have been based on information provided in Chapter 5 (Project Description) and Chapter 6 (Construction) of the EIS and preliminary design information, prior to selection of the final alignment option.

3.3 Methodology

The approach to estimating GHG emissions varies throughout the different stages of the infrastructure life cycle and depends heavily on the level of detail of information available at each stage of the project. The Greenhouse Gas Technical Report assesses GHG emissions for the Project as summarised in Section 1. Further details are provided in Chapter 5 (Project Description) and Chapter 6 (Construction) of the EIS. Emissions have been estimated based on early asset details and preliminary material quantities. The assessment methodology includes the following steps:

- ***Establishment of the extent of the assessment***. This is achieved by identifying the infrastructure design life, sources of emissions and removals (e.g. new carbon sinks), and considering changes to GHG emissions from the surrounding transport network. This is undertaken in Section 3.3.1
- ***Quantification of the GHG emissions***. This stage involves the quantification and reporting of potential GHG emissions and removals during construction and operation of the Project based on Chapter 5 (Project description) and Chapter 6 (Construction) of the EIS and supporting information, initial quantity estimates, and draft operational considerations. These data are used to provide an assessment of State Circle East and National Triangle-Barton alignment options in Section 4.0 for

construction and in Section 5.0 for operation. An assessment of the changes to GHG emissions from the surrounding transport network is also provided

- ***Definition of mitigation measures***. This stage involves identification of measures to manage and reduce GHG emissions and provide a positive influence on GHG emission outcomes associated with the Project. Management measures are provided in Section 6.0.

3.3.1 Establishment of the extent of the assessment

Emission sources from construction and operational activities were identified based on Chapter 5 (Project Description) and Chapter 6 (Construction) and preliminary design information. Acknowledging that there are limitations in data availability at the initial stage of infrastructure projects and that there are two alignment options currently being considered, the extent of the assessment is limited to early initial quantity estimates and sub asset details.

The Project is likely to have both direct and indirect emissions. Direct emissions are produced from activities controlled by the proponent, such as construction activity. Indirect emissions are generated in the wider economy as a consequence of the Project, such as goods and services required to facilitate the Project, with electricity the most significant category of indirect emissions.

Sources of GHG emissions considered for construction and operation of the Project; including maintenance activities over an estimated design life of 50 years are provided in Table 3-1 and Table 3-2 respectively. For the purposes of the greenhouse gas assessment a design life of 50 years has been assumed, although some components of the Project (such as bridges) would have a longer design life, as described in Section 6.1 of Chapter 6 (Construction) of the EIS.

Table 3-1 Construction sources GHG emission inventory

Source	Sub parameter	Comment
Fuel Combustion	Stationary plant equipment	Scope 1 emissions from diesel fuel combustion within Project area from operation of diesel generators, air compressors, and LED lighting towers within the Project area.
	Mobile plant material	Scope 1 emissions from operation of mobile equipment within the Project area. Mobile plant equipment has been based on draft construction program estimates.
	Workforce vehicles	Scope 1 and Scope 3 emissions from fuel combustion from light vehicles traveling within and to and from the Project area based on monthly day and night-time averages. Fleet mix was assumed to include light commercial vehicles, diesel, petrol and hybrid cars.
	Construction vehicles	Scope 1 emissions for diesel emissions associated with onsite construction vehicle movements within the Project area.
	Traffic control	Scope 1 emissions for diesel emissions associated with onsite construction vehicle within the Project area.
	Domestic deliveries	Scope 1 and Scope 3 emissions from fuel combustion associated with domestic deliveries both travelling within and to and from the Project area. Deliveries were based on estimated: • Construction material volumes for ready mix concrete, culverts and drainage, steel, copper, aluminium, aggregate, timber, glass, granite pavement, cobble, soil, and asphalt. • Deliveries for precast concrete transported by Jinker trucks • Deliveries required for crane and associated other construction equipment.
	International deliveries	Scope 3 emissions associated with international shipping and road transport activities from port transfers associated with import of LRVs from Spain and import of rail steel from Austria.

Source	Sub parameter	Comment
	Waste transport	Scope 1 and Scope 3 emissions associated with waste transport activities both travelling within and to and from the Project area including transport of: • Construction waste estimated volumes including from earthworks, and construction and demolition waste. • Waste generated at compound sites and within individual precincts • Vacuum trucks used for utility service and civil works.
Land use changes	Vegetation clearing	Scope 1 emissions from loss of carbon sink associated with tree removal and clearing of grassed areas from the Project area has been quantified.
	Replanting vegetation	Scope 1 carbon sink emissions quantified for replanting of street trees and installation of green track
Power consumption	Electrical consumption	Scope 2 emissions from electricity quantified from all construction compounds sites including from compound buildings, flood and security lighting and CCTV operation.
Waste	Construction and demolition waste	Scope 3 emissions estimated from earthworks spoil volumes and total estimates of construction and demolition waste including inert construction material, timber and other green waste, and solid general waste.
Embodied energy	Construction materials	Scope 3 emissions from construction materials have been estimated for fundamental building components for the Project such as trackform, rails and over-head wires, stops, bridges, retaining walls, road pavement and kerbing, drainage, substations and construction compounds. Key construction materials included concrete, culverts and drainage, steel, copper, aluminium, aggregate, timber, glass, granite pavement, cobble, and asphalt.
	LRVs and batteries	Scope 3 emissions have been estimated for new LRVs. Embodied energy GHG estimates have included steel quantities required for each vehicle and lithium ferro-phosphate batteries required

Table 3-2 Operational sources GHG emission inventory

Source	Sub parameter	Comment
Fuel Combustion	Street sweeping	Scope 1 emissions from diesel fuel combustion associated with street sweeping for maintenance of track.
	Mitchell Depot operations	Scope 1 emissions from diesel fuel combustion from operation of additional vehicles required for the Project at the Mitchell Depot. This includes additional utility vehicles and a mower.
	Major maintenance replacement works	Scope 1 emissions from diesel fuel combustion from construction activities associated with major preventative and reparative works including full and/or partial replacement of asphalt at substations, culverts and drainage, pavement and partial concrete replacement of retailing walls, stop platforms, track slabs, over-head wire foundations and bridge and deck approaches.
	Domestic deliveries	Scope 3 emissions from diesel fuel combustion associated with delivery of construction materials required for major maintenance reparative works including for asphalt, stone pavements, concrete replacement and associated steel reinforcement and reinforced concrete pipes.
	International deliveries	Scope 3 emissions associated with international shipping and port transfers associated with import of LRVs from Spain. A single replacement of the entire new LRV fleet has been assumed.

Source	Sub parameter	Comment
Power consumption	Signalling	Scope 2 emissions from signalling has been estimated for traffic, pedestrian and light rail lanterns.
	Station lighting	Scope 2 emissions for lighting at stops for both side and island platforms including statutory and accent lighting.
	Street lighting	Scope 2 emissions for street lighting for both alignment options using a combination of 150W and 100W LED lighting.
	LRVs	Scope 2 emissions from energy use from charging LRV batteries, based on energy reduction rates from the onboard energy storage system (OESS) both north and southbound between Commonwealth Avenue and Hopetoun Circuit for both alignments. Energy usage from LRVs using over-head wire (OHW) has also been estimated.
Embodied Energy	Major maintenance replacement works	Scope 3 emissions have been estimated for embodied energy in construction materials used for construction materials required for major maintenance reparative works including for asphalt, stone pavements, concrete replacement and associated steel reinforcement and reinforced concrete pipes.
	LRV vehicle and battery replacement	Scope 3 emissions have been estimated based on the quantity of steel required to replace the entire new fleet of LRVs once over the design life of the project and replacement of lithium ferro phosphate batteries within the new fleet every seven years equating to seven replacements over the asset life.

In addition to the operational GHG emissions sources quantified for the Project as listed in Table 3-2 user carbon emissions associated with a potential modal shift from more carbon intensive road transport to public transport using light rail is discussed in Section 3.3.1.1.

3.3.1.1 User GHG emissions

Analysis of GHG emissions associated with patronage of LRVs is important to determine the whole life carbon implications of the Project. Energy use for LRVs has been quantified as described in Section 3.3.2.2. In addition to this, user GHG emissions avoided because of transport modal shift due to increased uptake of public transport is assessed in Section 5.0.

Avoided user GHG emissions have been assessed using available information at this early stage of the Project. It is difficult to quantify emissions with a high level of accuracy at this stage of the project cycle and as such, it is challenging to estimate the extent of emissions reduction. Similarly for operation of LRS1, complete data is not available to assess the degree of mode shifting from private vehicles or other forms of transportation to light rail in Canberra, making extrapolation of data for the Project difficult.

The initial estimate of the avoided user GHG emissions has been provided based on the data used to inform Technical Report 1 – Traffic and Transport) of the EIS and information provided by the ACT Government based on the following documentation:

- *Light Rail Five Years On: Benefits Realisation Report 2024* (ACT Government, 2024)
- *Carbon Dioxide Emissions Intensity for New Australian Light Vehicles* 2022 (NTC, 2023)
- *ACT & Queanbeyan Household Travel Survey 2022* (Sift Research, 2023).

3.3.2 Quantification of GHG emissions

This section provides an overview of emission factors sources used to estimate greenhouse gas emissions for the Project.

3.3.2.1 Scope 1 emissions

Scope 1 emissions as described in 3.3.1 include emissions from the combustion of liquid fuels from vehicles and mobile and stationary plant equipment and carbon sink and losses due to removal and planting of vegetation.

Fuel quantity estimation method

The calculation methodology utilised to estimate the GHG contribution from combustion of fuels from the Project is as outlined in the *National Greenhouse and Energy Reporting Act 2007* and the accompanying National Greenhouse and Energy Reporting (Measurement) Determination 2008 (amended 7 October 2023).

Scope 1 emissions have generally been estimated using the default method (Method 1) using GHG emission factors listed in The National Greenhouse Accounts Factors, Australian National Greenhouse Accounts (Commonwealth of Australia, 2023) (NGA) to assess the GHG contribution of the Project. This includes combustion of fuels from mobile and stationary plant equipment, as well as some vehicle movements.

Tonnes kilometres estimation method

Scope 1 transport emissions associated with delivery of materials and waste transport have also been estimated using default emission factors based on the mass of material (in tonnes) and the distance travelled (in kilometres) (tkm) from the *Embodied Carbon Measurement for Infrastructure Technical Guidance* (TfNSW, 2024). These emission factors have been derived from the Australia National Life Cycle Inventory Database (AusLCI) Carbon Emission factors.

Land use change estimation method

Emission factors for the removal and planting of trees and landscape features have been adopted in accordance with the emission factor hierarchy described in Table 3-3 using generic emission factors referenced in the following documentation:

- *Transport Authorities Greenhouse Group; Greenhouse Gas Assessment Workbook for Road Projects* (TAGG, 2013)
- *Carbon Estimate and Reporting Tool Manual,* Transport for NSW (TfNSW, 2018).

3.3.2.2 Scope 2 Emissions

Calculation of Scope 2 emissions has adopted an ACT specific emission factor for electricity consumption as published within ACT Greenhouse Gas Inventory for 2022-23 (ACT Government, 2023). Since 1 January 2020 the ACT Government has offset 100% of residual electricity emissions through renewable generation and retiring Large Generation Certificates (LGCs) in accordance with its ongoing Sustainable Energy Policy (ACT Government, 2011) (refer to Section 2.4.3). The NGA emission factor (Commonwealth of Australia, 2023) for the ACT and NSW region is 0.68 kg CO_2^{-e}/kWh is considered overly conservative for ACT given NSW's high dependence on fossil fuels. The ACT Greenhouse Gas Inventory for 2022-23 (Point Advisory, 2023) reported for the 2022-23 financial year zero electricity related emissions.

A zero emission factor (0 kg CO_2^{-e}/kWh) was adopted for the Project for electricity consumption, this value is considered more representative of actual GHG emissions which are used to estimate potential construction and operational impacts from the Project.

For transparency Scope 2 electricity emissions have also been reported using the ACT/NSW NGA 2023 indirect (Scope 2) emission factors.

3.3.2.3 Scope 3 Emissions

Scope 3 emissions for fuel consumption and waste have largely been estimated using NGA 2023 emission factors. However, the National Greenhouse and Energy Reporting (Measurement) Determination 2008 only addresses Scope 1 and Scope 2 emissions. Currently in Australia there is no centralised database of emission factors to estimate embodied energy from infrastructure projects. As such the following hierarchy of emission factors has been adopted based on the *Transport for NSW Embodied Carbon measurement for Infrastructure*, Technical Guidance (TfNSW 2024) as detailed in Table 3-3.

Emission calculations are most accurate when based on measured/estimated material quantities, however this data is not always available, particularly when project data is limited and reliance on more generic emission factors may need to be applied to estimate emissions from the project.

Emission factors used in this technical report are defined below in accordance with the hierarchy of emission factors shown in Table 3-3.

Table 3-3 Emission factor hierarchy for estimating embodied carbon

Priority	Classification	Supported data sources	Used in this assessment
1	Product specific emission factor	• Environment Product Declaration (EDP) for specific products and suppliers (third party verified) • Climate active carbon footprint area	No
2	Industry average emission factor	• Australian National Greenhouse Account Factors • Industry average EDP for a product type • NABERS Embodied Emissions Tool factors (when available) • Infrastructure Australia's Supporting Appendices: Embodied Carbon Projections for Australian Infrastructure and Buildings - industry average emission factors	Yes
3	Generic emission factor from database[1]	• TfNSW Carbon Tool factors (when available) • AusLCI Carbon Emission Factors	Yes
4	Generic emission factor from global literature scan	• Generic emission factors from global literature where above emission factor sources do not provide coverage	Yes
5	Sub-asset or element level carbon intensity Benchmark	• There are currently no suitable published data sources available in Australia for Priority 5 emission factors	No
6	Asset Level Carbon intensity benchmark.	• Asset level carbon intensity benchmarks listed in Appendix 6 of the Transport for NSW Embodied Carbon measure for Infrastructure, Technical Guidance (TfNSW, 2024)	No

1. The TfNSW Carbon Tool factors has currently not been publicised. Generic emission factors have been derived from CERT 2018 and the TAGG Workbook 2013 cited in Appendix A of the TfNSW 2024 Technical Guidance document.

Table 3-3 also provides a brief overview of the types of emission factors used in this assessment based on the level of data available based on Chapter 5 (project description) and Chapter 6 (Construction) of the EIS, supporting information, an initial quantity estimates and draft operational considerations. Emission factors used for individual Project activities include:

- Industry average emission factors including:
  - The National Greenhouse Accounts Factors, Australian National Greenhouse Accounts (Commonwealth of Australia 2023)
  - Embodied Carbon measurements for Infrastructure, Technical Guidance (Transport for NSW 2024).

- Generic emission factors from databases:
  - AusLCI Carbon Emission Factors
  - Transport for NSW Carbon Estimate and Reporting Tool (CERT) 2018
  - Transport Authorities Greenhouse Group (TAGG) (2013); Greenhouse Gas Assessment Workbook for Road Projects.
- Generic emission factors from global literature scan including:
  - GHG Emissions from the Production of Lithium-Ion Batteries for Electric Vehicles in China. Sustainability 2017 9(4) 504 (Han Hao *et al* 2017).
  - Inventory of Carbon and Energy (ICE). Version 1.6a, University of Bath, (Hammond and Jones 2008)

3.3.3 Definition of mitigation measures

Management measures are provided in Section 6.0. Greenhouse gas management includes the assessment, reduction, and removal of carbon emissions during early planning, option selection, concept and detailed design, construction, and operation.

During the early stages of the Project the ability to influence carbon emission outcomes is the greatest and intervention is likely to be more cost effective, even though carbon estimates are less accurate. Mitigation measures are proposed in Section 6.1 and have a strong focus on identifying opportunities to reduce carbon emissions through option selection and detailed design. Implementation of a carbon management plan for continual improvement of the accuracy of measurement in carbon emissions as the Project progresses is also discussed in Section 6.0.

3.4 Limitations

Estimates of upfront and broader embodied carbon is an important consideration throughout the different stages of the Project. This GHG Technical report has been prepared based on Chapter 5 (Project description) and Chapter 6 (Construction) of the EIS, initial quantity estimates and draft operational considerations.

Carbon estimates are linked to level of detail available as the design progresses, the accuracy of GHG estimates are also expected to improve. It is assumed that material quantities used for GHG estimation are not as accurate now as they would be at the time of construction, due to expected variations in the Project during design development and during the construction period. Fuel estimates are based off early high-level plant take off information for mobile and stationary equipment; deliveries are also estimated from initial material quantities; both of which are expected to be refined as the design progress progresses. If any quantities are changed significantly, especially concrete and steel estimates or significant variations in the construction program and plant take off information used to estimate fuel emissions, then this assessment should be revisited and verified for accuracy.

In addition, electrical consumption for both construction and operation has been based on early estimates. Expected electrical consumption for construction has been based on high level assumptions as construction compound sizes; and function for individual identified sites still to be determined. Estimates have been based on the construction program length and peak labour force estimates documented in Chapter 6 (Construction) of the EIS. Electrical consumption for compound buildings has been derived from the *Commercial Building Baseline Study 2022 Final Report* (DCCEEW 2022). Electrical consumption for operation relates to traction power and charging of the onboard energy storage system (OESS), charging of the OESS has been estimated using the emissions estimation methodology consistent LRS2A.

Similarly, user GHG emissions associated with modal transport shift have been semi-quantitatively estimated due to the early stage of the project; and can be expected to be refined both following operation of the Project and further collation of patronage data from LRS1 and LRS2A once operational.

Project data availability increases during the various project stages including detailed design, procurement, and construction. This provides an opportunity for improvement of the accuracy of measurement in carbon emissions. During the early stages of the Project the ability to influence carbon

emission outcomes is the greatest and intervention is likely to be more cost effective, even though carbon estimates are less accurate (TfNSW, 2024). At this stage the major sources of emissions based on available data have been included to provide an initial estimate of emissions for each alignment option. Major sources of emissions for construction and operation have been identified in Table 5-2 and Table 5-3. Measurement of estimated carbon emissions should be viewed as an important step in the early decision making process where influence on carbon emissions is greatest.

4.0 Assessment of construction impacts

This section details the estimated quantities of GHG generating materials and activities for the Project for construction, and associated GHG emissions. GHG estimates for the Project have been calculated using emission factors documented in Section 3.3.1.1.

The total estimated GHG emissions from construction of the Project inclusive of Scope 1, Scope 2 and Scope 3 emissions was found to be:

- 102,589 t CO_2-e for the State Circle East alignment option
- 98,386 t CO_2-e for the National Triangle-Barton alignment option.

Table 4-1 provides a summary of the estimated GHG emissions and reduction from construction of each alignment option, categorised by scope, source group and activity type. GHG emissions in Table 4-1 are shown as positive values. GHG reductions from carbon sinks such as from planting additional trees, installation of green track and embodied energy from structural timber used in construction are shown as negative values. A summary of the total estimated GHG contributions broken down by scope type for both alignment options is also illustrated on Figure 4-1.

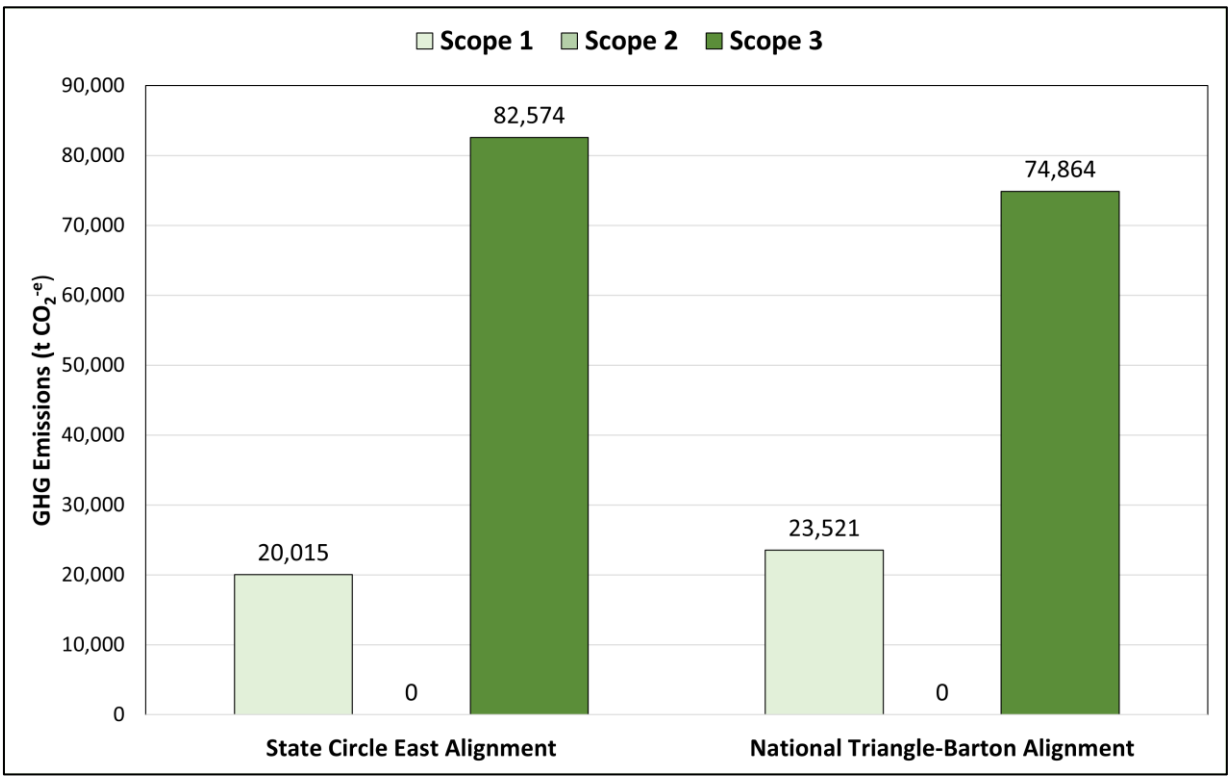


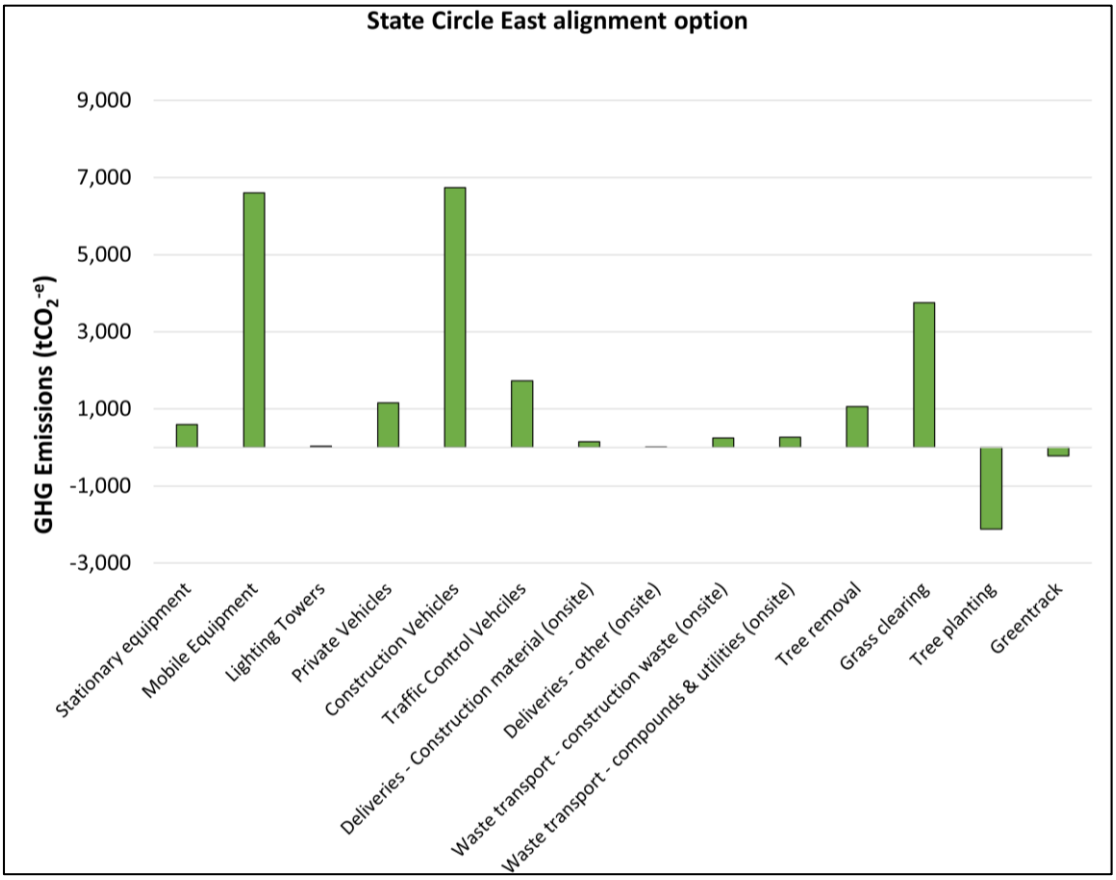
Figure 4-1 Comparison of estimated Scope 1, Scope 2, and Scope 3 emissions for alignment options

Scope 1 emissions

Scope 1 emissions are directly attributed to construction of the Project and include all fuel consumption activities within the Project area as detailed in Table 3-1 as well as loss of carbon sinks through tree removal and clearing of grassed areas and the addition of new carbon sinks through tree planting and installation of green track. As shown on Figure 4-1 the total Scope 1 emissions from the project was found to be:

- 20,015 t CO_2-e for the State Circle East alignment option, equating to 20% of the total construction emissions for the Project
- 23,521 t CO_2-e for the National Triangle-Barton alignment option, equating to 24% of the total construction emissions from the Project.

A breakdown of Scope 1 emissions is provided in Table 4-1. Figure 4-2 also shows that the highest contributor of Scope 1 emissions from construction is from fuel combustion, with emissions from mobile equipment and construction vehicles as the highest contributors. Both tree planting and installation of green track act as carbon sinks reducing the overall Scope 1 emissions from the Project for both alignment options.



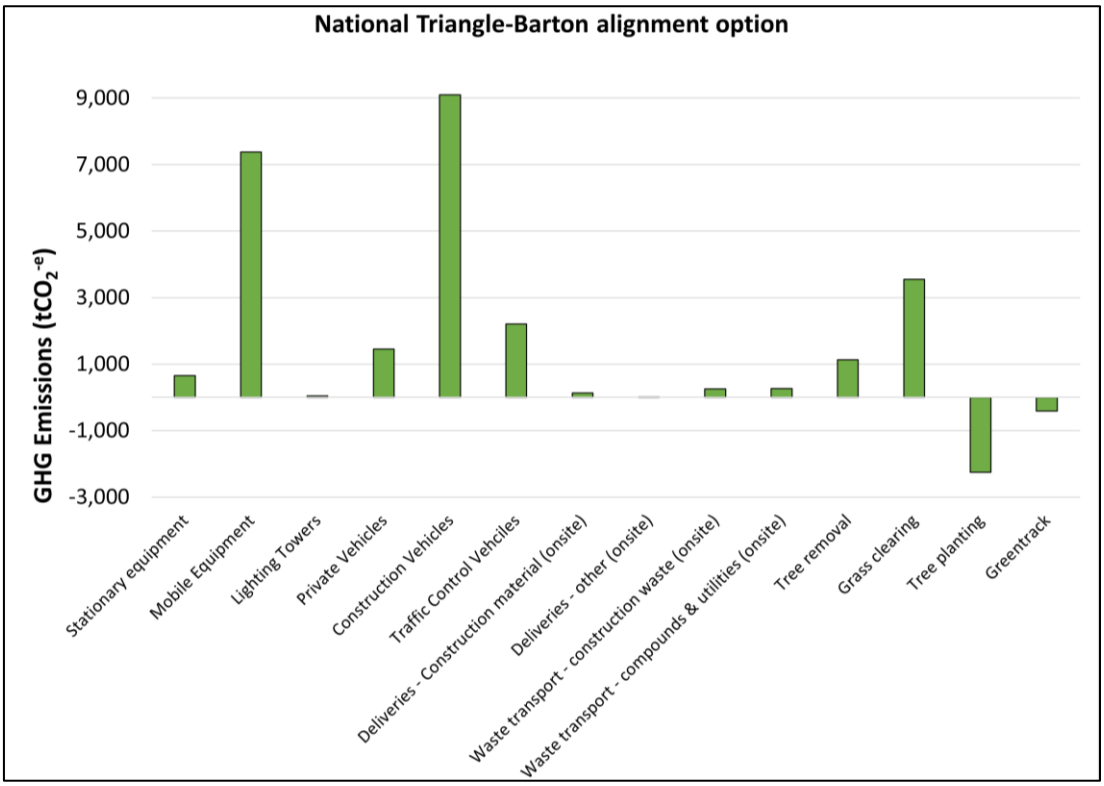


Figure 4-2 Estimated Scope 1 emissions for State Circle East and National Triangle-Barton alignment options

Scope 2 emissions

Scope 2 emissions equate to zero emissions for both alignment options due to the ACT Government offsetting 100% of residual electricity emissions through renewable generation and retiring LGCs in accordance with its ongoing Sustainable Energy Policy. Electrical consumption for construction compounds was estimated to be:

- 1,637,316 kWh for the State Circle East alignment option
- 1,739,816 kWh for the National Triangle-Barton alignment option.

For transparency Scope 2 emissions have also been estimated for construction using more conservative emission factor from NGA 2023 for NSW and ACT for Scope 2 emissions of 0.68 kg CO_2-e/kWh; which accounts for electricity generated by fossil fuels was assumed this would equate to:

- For the State Circle East alignment option a total of 1,113.4 tCO_2-e
- For the National Triangle-Barton alignment option a total of 1,183.1 tCO_2-e.

Scope 3 emissions

Scope 3 emissions are indirectly attributed to construction of the Project and include fuel consumption activities from transport of waste and materials, and embodied energy during the manufacture of materials and supplies. Scope 3 emissions form the highest emission contribution from the Project and were estimated to be:

- 82,574 t CO_2-e for the State Circle East alignment option, equating to 80% of the total construction emissions for the Project
- 74,864 t CO_2-e for the National Triangle-Barton alignment option, equating to 76% of the total construction emissions from the Project.

A breakdown of estimated Scope 3 emissions is provided in Table 4-1. Figure 4-3 also shows that the highest contributors to Scope 3 emissions from construction are fuel combustion from the workforce traveling to and from the site and embodied energy from concrete and steel and waste.

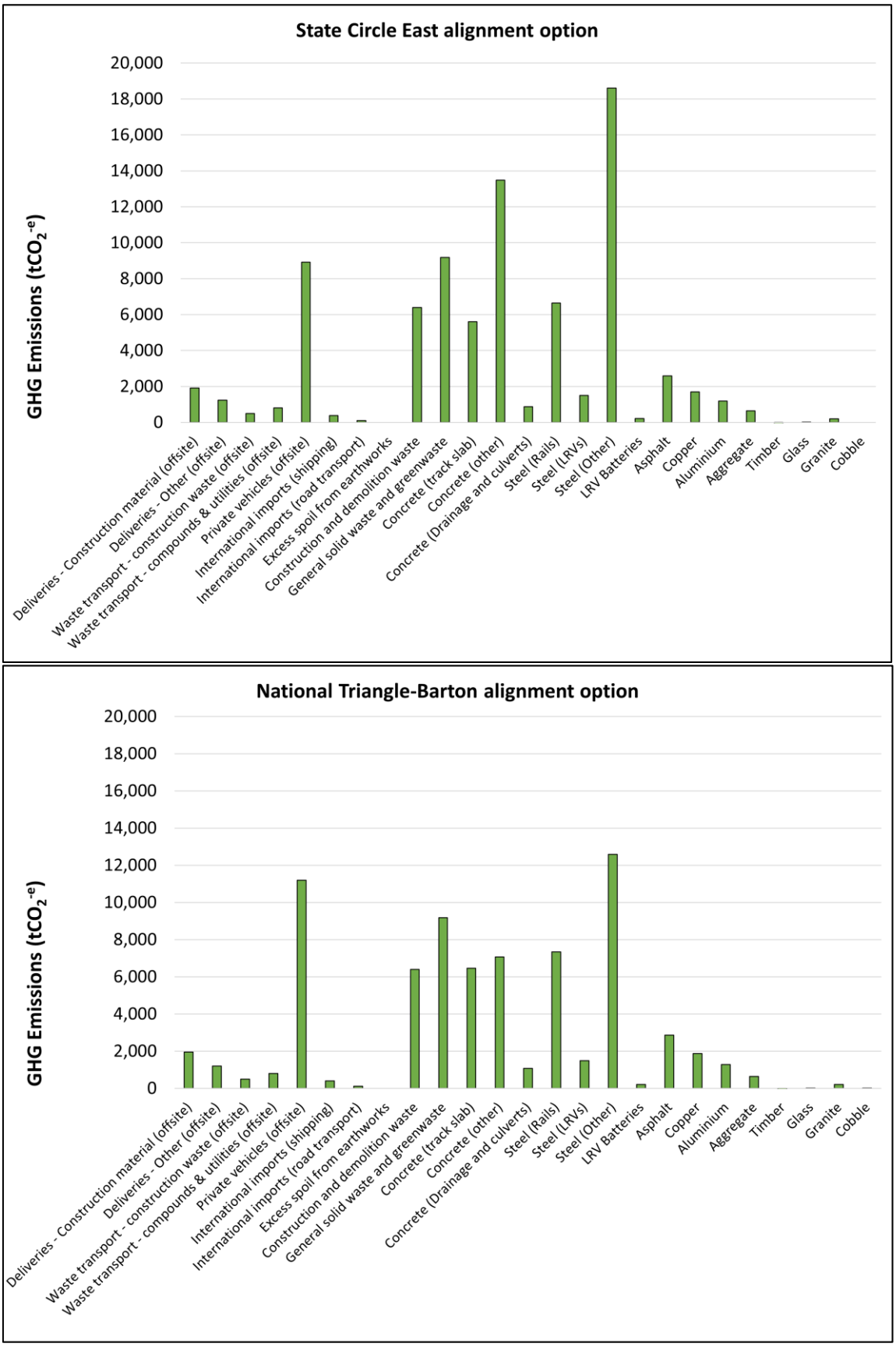


Figure 4-3 Estimated Scope 3 emissions for State Circle East and National Triangle-Barton alignment options

Comparison to ACT and National Emissions and Policy Alignment

Construction of the Project is assumed to occur over a four-to-five-year period. At this early stage of the Project annual emissions for individual years during construction program cannot definitively be estimated based on available data. As such an annual average over a four year construction period has been used to provide additional context when compared to ACT and national emissions.

In 2023 Australia's total GHG emissions were 467 mega tonnes (Mt) CO_2-e (Climate change Authority, 2023) with ACT contributing 1.622 Mt CO_2-e (ACT Government, 2023). In comparison, a single construction year for the Project is expected to represent approximately 0.005% of Australia's total annual emissions for both alignment options. When compared to ACT's contribution this equates to 1.6% of ACT's total emissions annually for the State Circle East alignment option and 1.5% of the ACT's total emissions annually for the National Triangle-Barton alignment option.

Noting that the construction of either option would aid in meeting key transport strategies listed under the ACT Climate Strategy 2019-2025 as described in Section 2.4.2 including supporting a higher uptake of public transport and trialling new ways roads can better support sustainable transport modes. Due to the early stage of design for the Project there is also increased opportunity for carbon emission reductions as discussed in Section 6.0.

Table 4-1 Summary of Scope 1, Scope 2, and Scope 3 Construction GHG emissions for the Project Construction Period as CO_2 equivalent

Scope	Parameter	Sub-Parameter	State Circle East alignment option					National Triangle-Barton alignment option				
			Qty	Unit	Emissions (t CO_2-e)	Total (t CO_2-e)	Contribution (%)	Qty	Unit	Emissions (t CO_2-e)	Total (t CO_2-e)	Contribution (%)
Scope 1	Fuel consumption	Generators	218	kL	592	**17,539**	**17.1**	239	kL	647	**21,504**	**21.9**
		Mobile equipment	2,432	kL	6,608			2,716	kL	7,378		
		Lighting towers	14	kL	37			18	kL	47		
		Private vehicles	464	kL	1,162			580	kL	1,456		
		Construction vehicles	2,479	kL	6,736			3,347	kL	9,096		
		Traffic control vehicles	635	kL	1,726			813	kL	2,210		
		Deliveries - Construction material (onsite)	1,597,881	tkm	150			1,457,644	tkm	131		
		Deliveries - other (onsite)	4	kL	11			4	kL	11		
		Waste transport - construction waste (onsite)	3,460,810	tkm	249			3,589,610	tkm	258		
		Waste transport - compounds & utilities (onsite)	98	kL	268			99	kL	268		
	Land use changes	Tree removal	683	No. Trees	1,059	**4,810**	**4.7**	726	No. Trees	1,125	**4,678**	**4.8**
		Grass clearing	34.1	ha	3,751			32.3	ha	3,553		
		Tree planting	1,366	No. Trees	-1,683	**-2,334**	**-2.3**	1,457	No. Trees	-2,251	**-2,661**	**-2.7**
		Green track	2.0	ha	-216			3.7	ha	-410		
Scope 2	Electricity	Construction compounds	1,637,316	Total kWh	0	**0**	**0.0**	1,739,816	Total kWh	0	**0**	**0.0**
Scope 3	Fuel consumption	Deliveries, construction material (offsite)	25,332,347	tkm	1,913	**13,846**	**13.5**	26,227,976	tkm	1,962	**16,201**	**16.5**
		Deliveries, other (offsite)	455	kL	1,237			441	kL	1,198		
		Waste transport, construction (offsite)	6,828,178	tkm	491			7,082,301	tkm	509		
		Waste transport, compounds & utilities (offsite)	296	kL	804			296	kL	805		
		Private vehicles (offsite)	3,554	Kl	8,916			4,464	kL	11,200		
		International imports (shipping)	38,031,180	tkm	380			41,195,057	tkm	412		
		International imports (road transport)	1,461,453	tkm	105			1,601,672	tkm	115		
	Waste	Excess spoil from earthworks	263,200	tonnes	0	**15,584**	**15.2**	274,400	tonnes	0	**15,584**	**15.8**
		Construction and demolition waste	32,000	tonnes	6,400			32,000	tonnes	6,400		
		General solid waste and green waste	5,740	tonnes	9,184			5,740	tonnes	9,184		

Scope	Parameter	Sub-Parameter	State Circle East alignment option					National Triangle-Barton alignment option				
			Qty	Unit	Emissions (t CO_2-e)	Total (t CO_2-e)	Contribution (%)	Qty	Unit	Emissions (t CO_2-e)	Total (t CO_2-e)	Contribution (%)
	Embodied energy	Concrete (track slab)	11,624	m^3	5,598	**53,144**	**51.8**	13,638	m^3	6,465	**43,080**	**43.8**
		Concrete (other)	29,633	m^3	13,478			16,164	m^3	7,067		
		Concrete (Drainage and culverts)	3,137	tonnes	878			3,834	tonnes	1,074		
		Steel (Rails)	1,953	tonnes	6,641			2,159	tonnes	7,340		
		Steel (LRVs)	500	tonnes	1,499			500	tonnes	1,499		
		Steel (Other)	8,630	tonnes	18,608			5,507	tonnes	12,596		
		LRV Batteries	1,633	kWh	222			1,633	kWh	222		
		Asphalt	36,544	tonnes	2,582			40,582	tonnes	2,867		
		Copper	830	tonnes	1,696			920	tonnes	1,880		
		Aluminium	99	tonnes	1,184			107	tonnes	1,279		
		Aggregate	116,331	tonnes	641			117,928	tonnes	650		
		Timber	274	m^3	-75			283	m^3	-75		
		Glass	1	tonnes	1			1	tonnes	1		
		Granite	2,066	tonnes	192			2,296	tonnes	214		
		Cobble	0	tonnes	0			315	tonnes	1		
					Total	**102,589**	**100**				**98,386**	**100**

5.0 Assessment of operational impacts

This section details the estimated quantities of GHG generating materials and activities, and associated emissions from operation and regular maintenance activities of the Project and have been reported both an annual basis and for an assumed design life of 50 years. Similarly major maintenance and reparative works have also been estimated over the design life. GHG estimates for the Project have been calculated using emission factors documented in Section 3.3.1.1.

Estimated total emissions over the design life of the Project are provided in Table 5-1 for each alignment option. Additional information is also provided in Table 5-1 for operation and Table 5-2 for maintenance.

Table 5-1 Summary of total GHG emissions from Operation and Maintenance over Design Life

Phase	Total GHG Emissions (tCO_2^{e-})	
	State Circle East alignment option	National Triangle-Barton alignment option
Operation	1,100	1,131
Maintenance	5,931	5,762

Operational emissions

Table 5-2 provides a summary of the estimated GHG emissions from operation for each alignment option, categorised by scope, source group, and activity type and includes Scope 1 and Scope 2 emissions. A breakdown of operational sources quantified in the emission inventory has been provided earlier in Table 3-2.

Inclusive of Scopes 1 and 2 the total emissions generated from the Project are estimated to be:

- 22.0 t CO_2^{-e} annually and 1,100 t CO_2^{-e} over the design life for the State Circle East alignment option
- 22.6 t CO_2^{-e} annually and 1,131 t CO_2^{-e} over the design life for the National Triangle-Barton alignment option.

Scope 1 emissions from fuel combustion form the primary source of GHG emissions. Emission estimates for the alignment options are comparatively similar and equate to approximately 0.1% of the ACT's emissions for the 2022-2023 reporting year (ACT Government, 2023).

Scope 2 emissions equate to zero emissions for both alignment options due to the ACT Government offsetting 100% of residual electricity emissions through renewable generation and retiring LGCs in accordance with its ongoing Sustainable Energy Policy. The total estimated electrical consumption from the Project in megawatt hours (MWh) is:

- 2,232 MWh annually and 111,582 MWh over the design life for the State Circle East alignment option
- 2,409 MWh annually and 120,441 MWh over the design life for the National Triangle-Barton alignment option.

Additionally, if the more conservative emission factors from NGA 2023 for NSW and ACT for Scope 2 emissions of 0.68 kg CO_2^{-e}/kWh; which accounts for electricity generated by fossil fuels was assumed this would equate to:

- For the State Circle East alignment option, 1,517 t CO_2^{-e} emissions annually or 75,876 t CO_2^{-e} emissions over the asset life
- For the National Triangle-Barton alignment option, 1,638 t CO_2^{-e} emissions annually or 81,900 t CO_2^{-e} emissions over the asset life.

Recharging of LRV batteries (on over-head wire sections) due to energy losses on the wire-free component of the light rail for both alignment options requires more electricity than LRV's directly drawing power from over-head wires to operate.

As discussed above, Scope 2 user GHG emissions for LRVs have been quantified in Table 5-2. It is difficult to quantity avoided user GHG emissions with a high level of confidence for the Project. Based on data used to inform the Technical Report 1 – Traffic and Transport of the EIS, and using assumptions based on the Household Travel Survey (ACT Government, 2023) and the Carbon Dioxide Emissions Intensity for New Australia Light Vehicles Report (National Transport Commission, 2023) indicative estimates of the avoided user GHG emissions as a result of mode shift have been undertaken. These estimates indicated that between approximately 2,900 and 5,300 tonnes of CO_2^e annually would be avoided as a result of the Project. Specifically, this refers to the anticipated modal shift from more carbon intensive road vehicle emissions to a higher uptake in zero emission public transport as a direct result of the Project for both alignment options. To date, no complete data is available on the mode shift as a result of LRS1 (ACT Government, 2024), as such it is difficult to estimate the extent of the emissions reduction. The estimate above is provided at a point in time and is based on early indicative data to be reviewed and reassessed as the Project progresses, and as the emission intensity of private vehicles change over time. Regardless, any modal transport shift supports the ACT Climate Strategy 2019-2025 longer term priorities by improving public transport to provide an extensive Light Rail network and adaptive use of existing roads to better support more sustainable transport modes.

Maintenance emissions

A preliminary GHG emission estimate for major maintenance and major reparative works have been estimated for embodied energy (Scope 3) associated with replacement of materials and fuel estimates associated with mobile equipment emissions and from domestic and international deliveries (Scope 1 and Scope 3). Electrical consumption has not been quantified for major maintenance activities as electrical demand and need for construction compound areas is currently unknown but given the ACT's renewable energy policies Scope 2 emissions are expected to be zero.

Table 5-3 provides an estimate of Scope 1 and Scope 3 fuel use as well as Scope 3 emissions from embodied energy from major preventive maintenance activities and reparative works estimated over the 50 year design life. Major preventative maintenance activities have been limited to key materials identified for construction works based on preliminary design estimates including for concrete and asphalt as well as replacement as well as replacement of LRVs and LRV lithium ferro phosphate batteries.

For maintenance over a 50 year design life the Scope 1 and 3 emissions generated from the Project are estimated to be:

- 5,931 t CO_2^{-e} for the State Circle East alignment option
- 5,762 t CO_2^{-e} for the National Triangle-Barton alignment option.

Scope 3 emissions from embodied energy in materials was found to be the highest contributor of emissions for both alignment options. Scope 3 contributions made up an estimated 89% and 92% of the total emissions from maintenance activities from State Circle East and National Triangle-Barton alignment options respectively.

Table 5-2 Summary of Scope 1 and Scope 2 operational GHG emissions for the Project Design Life as CO_2 equivalent.

Scope	Parameter	Sub-Parameter	State Circle East alignment option				National Triangle-Barton alignment option			
			Annual Qty	Unit	GHG emissions ($t CO_2^{-e}$)		Annual Qty	Unit	GHG emissions ($t CO_2^{-e}$)	
					Annual	Design life			Annual	Design life
Scope 1	Fuel consumption	Operational vehicles and mobile equipment	8.3	kL	22.0	1,100	8.6	kL	22.6	1,131
Scope 2	Electrical consumption	Lighting and Traffic Signals	651,960	kWh	0	**0**	547,214	kWh	0	**0**
		LRVs (Recharging batteries)	1,196,217	kWh	0		1,478,132	kWh	0	
		LRVs (OHW)	383,471	kWh	0		383,471	kWh	0	
				Total	**22.0**	**1,100**			**22.6**	**1,131**

Table 5-3 Summary of Scope 1 and Scope 3 major maintenance and replacement work GHG emissions for the Project Design Life as CO_2 equivalent.

Scope	Parameter	Sub-Parameter	State Circle East alignment option				National Triangle-Barton alignment option			
			Design life Qty	Unit	GHG emissions ($t CO_2^{-e}$)		Design life Qty	Unit	GHG emissions ($t CO_2^{-e}$)	
					Design life	Total			Design life	Total
Scope 1	Fuel combustion	Major maintenance and replacement work	195	kL	529	529	133	kL	361	361
Scope 3	Fuel combustion	International deliveries (shipping & port transfers)	8,103,715	tkm	89	133	8,103,715	tkm	89	134
		Domestic deliveries	390,177	tkm	44		400,036	tkm	45	

Scope	Parameter	Sub-Parameter	State Circle East alignment option				National Triangle-Barton alignment option			
			Design life Qty	Unit	GHG emissions ($t CO_2$-e)		Design life Qty	Unit	GHG emissions ($t CO_2$-e)	
					Design life	Total			Design life	Total
	Embodied energy	LRV Battery Replacement	11,431	kWh	1,551	5,268	11,431	kWh	1,551	5,268
		LRV Replacement (Steel)	500	tonnes	1,499		500	tonnes	1,499	
		Culverts & drainage	157	tonnes	44		192	tonnes	54	
		Asphalt	90	tonnes	6.4		90	tonnes	6.4	
		Stone pavement	2,066	tonnes	192		2,296	tonnes	214	
		Concrete	5,018	m^3	1,897		4,061	m^3	1,137	
		Steel reinforcement	51	tonnes	97		34	tonnes	66	
					Total ($t CO_2$-e)	**5,931**				**5,762**

6.0 Management of impacts

Greenhouse gas management includes the assessment, reduction, and removal of carbon emissions during the early planning, option selection, concept and detailed design, construction, and operation to achieve carbon management outcomes for the Project. As discussed above, during the early stages of the Project the ability to influence carbon emission outcomes is the greatest and intervention is likely to be more cost effective, even though carbon estimates are less accurate. As such mitigation measures in Section 6.1 have a strong focus on identifying opportunities to reduce carbon emissions through option selection and detailed design.

As the project progresses, the influence over carbon emissions declines; but is not insignificant. As such a carbon management plan as described in Table 6-1 should be implemented for the life of the project and allows for continual improvement of the accuracy of measurement in carbon emissions as the Project progresses.

6.1 Mitigation measures

Design, construction, and operation management and mitigation measures to manage potential greenhouse gas impacts of the Project are outlined in Table 6-1.

Table 6-1 Mitigation measures – GHG generation

ID	Objective	Mitigation measure	Timing	Applicable location(s)
GG1	Minimising greenhouse gas emissions through design, construction and operation	A **Carbon Management Plan** will be developed as part of the CEMP for the Project in accordance with the requirements specified in Section 2.12 of Appendix L (Environmental Management Plan outline). This will include a strategy to minimise, and a process for reporting on, direct (Scope 1) and indirect (Scope 2 and Scope 3) greenhouse gas emissions associated with the Project. A **Carbon and Energy Management Plan** will be developed as part of the OEMP for the Project in accordance with the requirements specified in Section 3.7 of Appendix L (Environmental Management Plan outline).	Design, construction and prior to operation	All

ID	Objective	Mitigation measure	Timing	Applicable location(s)
GG2	Minimising the embodied energy of the Project	Through the application of the circular economy hierarchy (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle), the Project will be designed and constructed to maximise the use of materials with lower embodied energy values where they are a reasonable substitute. For high embodied energy materials (such as concrete, steel and asphalt), effective opportunities to reduce or substitute quantities used will be prioritised where in line with the decarbonisation objectives of Infrastructure Australia's Embodied Carbon Projections for Australian Infrastructure and Buildings report.	Design, construction	All
GG3	Maintaining and replacing vegetative carbon sinks	The Project will be designed to minimise vegetation clearance and will replace trees impacted at a minimum replacement ratio of 2:1.	Design	All

7.0 Conclusion

AECOM were commissioned to prepare a GHG technical report to inform the EIS and provide an assessment of the estimated greenhouse gas emissions associated with the construction and operation of the Project for both alignment options and propose mitigation measures to address these.

The approach to estimating GHG emissions for construction and operation as well as boarder emissions from embodied carbon varies throughout the stages of the infrastructure life cycle and depends heavily on the level of detail of information in each stage. The Greenhouse Gas Technical Report for the Project has been based on Chapter 5 (Project description) and Chapter 6 (Construction) of the EIS, initial quantity estimates and draft operational considerations. While carbon estimates are generally less accurate at this early stage of the design process, they have the greatest ability to influence carbon emission outcomes and intervention is likely to be more cost effective.

Estimated GHG Emissions from the Project

The total estimated emissions that would be generated during construction of the Project and for operation activities over an estimated 50 year design life for the State Circle East alignment option and National Triangle-Barton alignment option and is summarised in Table 7-1.

Table 7-1 Summary of estimated GHG emissions for the Project for each alignment option

Phase	GHG Emissions (t CO_2-e)	
	State Circle East alignment option	National Triangle-Barton alignment option
Construction	102,589	98,386
Operation	1,100	1,131
Maintenance	5,931	5,762
Total	**109,620**	**105,278**

Construction GHG Emissions

The total estimated GHG emissions from construction of the Project inclusive of Scope 1, Scope 2 and Scope 3 emissions was found to be:

- 102,589 t CO_2-e for the State Circle East alignment option
- 98,386 t CO_2-e for the National Triangle-Barton alignment option.

Scope 1 emissions material to the Project comprise emissions directly attributed to construction of the Project. Most Scope 1 emissions were attributed to fuel consumption, with diesel fuel mobile equipment found and construction vehicles to be the highest contributor of Scope 1 emissions. The estimated Scope 1 contribution was found to be:

- 20,015 t CO_2-e for the State Circle East alignment option, equating to 20% of the total construction emissions for the Project.
- 23,521 t CO_2-e for the National Triangle-Barton alignment option, equating to 24% of the total construction emissions from the Project.

Scope 2 emissions, which are due to electricity consumption from the grid equates to zero emissions during construction for both alignment options due to the ACT Government offsetting 100% of residual electricity emissions through renewable generation and retiring LGCs.

Scope 3 emissions material to the Project comprise indirect emissions related to the Project in terms of transport or GHG generation during the manufacture of materials and supplies. Scope 3 emissions form the highest emission contribution from the Project and account for:

- 82,574 t CO_2-e for the State Circle East alignment option, equating to 80% of the total construction emissions for the Project

- 74,864 t CO_2-e for the National Triangle-Barton alignment option, equating to 76% of the total construction emissions from the Project.

A single construction year[2] for the Project is expected to represent approximately 0.005% of Australia's total annal emissions for both alignment options. When considered at a territory level a single construction year equates to 1.6% of ACT's total emissions annually for the State Circle East alignment option and 1.5% of the ACTs total emissions annually for the National Triangle-Barton alignment option. In noting this, the construction of either alignment option would aid in meeting key transport strategies listed under the ACT Climate Strategy 2019-2025 including supporting a higher uptake of public transport and trialling new ways roads can better support sustainable transport modes.

Operation GHG Emissions

Greenhouse gas emissions from operation and maintenance activities were estimated based on both an annual basis and for an assumed design life of 50 years. Similarly major maintenance and reparative works have also been estimated over the design life.

The total estimated GHG emissions generated for operation and routine maintenance are:

- 22.0 t CO_2-e annually and 1,100 t CO_2-e over the design life for the State Circle East alignment option
- 22.6 t CO_2-e annually and 1,131 t CO_2-e over the design life for the National Triangle-Barton alignment option.

Scope 1 emissions from fuel combustion are the primary source of GHG emissions. Emission estimates for alignment options are comparatively similar and equate to approximately 0.1% of the ACTs emissions for the 2022-2023 reporting year (ACT Government 2023).

Scope 2 emissions, which are due to electricity consumption from the grid equates to zero emissions during operation for both alignment options due to the ACT Government offsetting 100% of residual electricity emissions through renewable generation and retiring LGCs.

Operation of the Project is anticipated to have beneficial impacts associated with increased public transport patronage resulting in a reduction in road vehicle emissions on major roads such as Commonwealth Avenue, State Circle, Adelaide Avenue, and Yarra Glen, and the surrounding road network. This modal transport shift also supports the ACT Climate Strategy 2019-2025 longer term priorities by improving public transport to provide an extensive Light Rail network and adaptive use of existing roads to better support more sustainable transport modes.

A preliminary GHG emission estimate for major maintenance and major reparative works have been estimated for embodied energy (Scope 3) associated with replacement of materials and fuel estimates associated with mobile equipment emissions and from domestic and international deliveries (Scope 1 and Scope 3). Electrical consumption (Scope 2) has not been quantified for major maintenance activities but given ACT's renewable energy policies Scope 2 emissions are expected to be zero.

The total Scope 1 and Scope 3 estimated GHG emissions generated for major maintenance and reparative work over a 50 year design life is as follows:

- 5,931 t CO_2-e for the State Circle East alignment option
- 5,762 t CO_2-e for the National Triangle-Barton alignment option.

Scope 3 emissions from embodied energy in materials was found to be the highest contributor of emissions for both alignments.

[2] The Project is assumed to emit approximately one quarter of the above emissions per year, during the construction period. Realistically due to the staging of construction activities this will not be completely accurate, however for the purposes of determining Project life emissions it is not deemed significant.

Conclusion

This technical report supports the EIS and provides an indicative assessment of potential GHG emissions from both alignment options. Consideration of greenhouse emissions in decision making during options analysis can aid in lowering the potential carbon footprint of the Project. A Carbon Management Plan would also be developed to define the Project's approach to carbon management and reduction at procurement, design and construction and operation stages.

8.0 References

AECOM (2024) Draft Project Design Proposition, Canberra Light Rail Stage 2, Document No. s220-acm-mem-man-na-0001. April 2024.

ACT Government (2011) *Sustainable Energy Policy, Energy for a Sustainable City 2011-2020,* Australian Capital Territory Government, Environment and Sustainable Development Directorate, Climate Change, ACT, Canberra

ACT Government (2017) *Past and Projected future components of electricity supply to the ACT, and resultant emissions intensity*. Australian Capital Territory Government, Environment and Planning Directorate, Climate Change, ACT, Canberra

ACT Government (2019) *Sustainable Energy Policy Discussion Paper* 2020-2025, Australian Capital Territory Government, Environment and Sustainable Development Directorate, Climate Change, ACT, Canberra

ARUP (2021) *Major Projects Canberra, Canberra Light Rail Stage 2, Traction Power Model*, Revision A, August 2021, Arup Pty Ltd, Sydney, NSW, Australia

ACT Government (2023) *ACT Greenhouse Gas Inventory for 2022-23*, Prepared by Point Advisory for the Environment, Planning and Sustainable Development Directorate, ACT Government, 30 September 2023.

ACT Government (2024) *Light Rail Five Years On: Benefits Realisation Report 2024*, Transport Canberra and City Services Directorate, ACT Government, ACT, Canberra: Light Rail Five Years On: Benefit Realisation Report 2024 (act.gov.au)

ALCUS (2023) AusLCI Carbon Emission Factors, Version 1.42, ALCUS Australian Life Cycle Assessment Society.

Commonwealth of Australia (2023) National Greenhouse Accounts Factors, Australian National Greenhouse Accounts (August 2023), Australian Government, Department of Climate Change Energy, the Environment and Water, Commonwealth of Australia.

Climate Change Authority (2023) *2023 Annual Progress Report, October 2023*, Climate Change Authority, Commonwealth of Australia, Canberra, Australian Capital Territory

DITRDCA (2024) Transport and Infrastructure Net Zero Roadmap and Action Plan, Accessed 19 March 2024: https://www.infrastructure.gov.au/infrastructure-transport-vehicles/transport-and-infrastructure-net-zero-roadmap-and-action-plan

DITRDCA (2024) Green Vehicle Guide, Department of Infrastructure, Transport, Regional Development, Communities and the Arts, Accessed 13 August 2024: Green Vehicle Guide Home

Infrastructure Australia (2024) Guide to assessing greenhouse gas emissions, information requirements for submissions to Infrastructure Australia, March 2024, Infrastructure Australia.

Han Hao *et al* (2017) *GHG Emissions from the Production of Lithium-Ion Batteries for Electric Vehicles in China*. Sustainability 2017 9(4) 504

NTC (2023) *Carbon Dioxide Emissions Intensity for New Australian Light Vehicles* 2022, Information Paper, December 2023, National Transport Commission, Melbourne, Victoria, Australia.

Point Advisory (2023) *ACT Greenhouse Gas Inventory for 2022-23*, Prepared by Point Advisory, ERM Group for Environment, Planning and Sustainable Development Directorate, ACT Government, 30 September 2023.

Sift Research (2023) *ACT & Queanbeyan Household Travel Survey 2022*, Travel Overview, Sift Research July 2023: ACT-QPRC-Travel-Overview-2022-FINAL.pdfTransport Authorities Greenhouse Group (TAGG) (2013); Greenhouse Gas Assessment Workbook for Road Projects

TCCS. (2022). *Transport Canberra Quarterly Data Report: Issue 14 (Q2-1 October to 31 December 2022).* Canberra City, ACT.

TfNSW (2018) *Carbon Estimate and Reporting Tool Manual,* Transport for NSW, NSW Government

TfNSW (2017a) *Civil Infrastructure Design Standards,* Version 1.0, 25 May 2017, T LR CI 12500 ST, Transport for New South Wales, NSW Government, Sydney.

TfNSW (2017b) *Durability Requirements for Civil Infrastructure,* Version 1.0, 5 October 2017, T HR CI 12002 ST, Transport for New South Wales, NSW Government, Sydney.

TfNSW (2024) Embodied Carbon measurement for Infrastructure, Technical Guidance, April 2024, Transport for New South Wales, NSW Government, Sydney.

ACT Government (2024) *Canberra Light Rail Operations Considerations LRS2B* Draft, April 2024

WRI and WBCSD (2013) *Greenhouse Gas Protocol: Technical Guidance for Calculating Scope 3 Emissions* (Version 1.0), World Resources Institute and World Business Council for Sustainable Development.