Appendix W

Detailed greenhouse gas calculations

WestConnex

Roads and Maritime Services

WestConnex – M4-M5 Link

Detailed greenhouse gas calculations

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Prepared by

AECOM Australia Pty Ltd
Level 21, 420 George Street, Sydney NSW 2000, PO Box Q410, QVB Post Office NSW 1230, Australia
T +61 2 8934 0000 F +61 2 8934 0001 www.aecom.com
ABN 20 093 846 925

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1 Greenhouse gas calculation methodology

The following steps have been taken in estimating the greenhouse gas (GHG) emissions associated with the construction and operation of the M4-M5 Link project (the project), in accordance with the Transport Authorities Greenhouse Group (TAGG) Workbook[1] 2013:

- The GHG emissions relevant to the stages of project construction and operation have been identified
- The GHG inventory boundary of the EIS has been determined, which defined the emissions sources to be considered in the assessment and those to be excluded (refer to Table 22-1 of **Chapter 22** (Greenhouse gas) of this EIS for further details)
- The emissions sources have been quantified (see **Table 2-1** and **Table 4-1**)
- For the different emissions sources, emissions factors have been established and the emissions calculated.

This document provides the methodology used for calculating GHG emissions from fuel use, electricity consumption, vegetation removal, the embodied energy of materials used and the decomposition of waste generated during the project.

1.1 Guiding principles

The assessment has been conducted according to the following GHG accounting and reporting principles:

- Relevance – select and use GHG sources, sinks, data and methodologies appropriate for the project/organisation and intended use of GHG inventory results
- Completeness – include all relevant GHG emissions and information which support methodology and criteria used
- Consistency – use consistent data, calculation/modelling methods, criteria and assumptions to enable valid comparisons
- Transparency – include clear, sufficient and appropriate information to enable others to understand the basis for results and make decisions regarding use of GHG inventory results with reasonable confidence
- Accuracy – reduce bias and uncertainties, as much as practical.

In addition to the accounting and reporting principles presented above, the issue of materiality has also been assessed in the GHG assessment. This is a core accounting and auditing principle which ensures that sources, assumptions, values and procedures included in the GHG assessment are material to the project. As materiality is valued within the context of the project being assessed, this can vary significantly between projects.

The materiality checklist provided in the TAGG Workbook (2013) has been used to identify potential sources of emissions to be included or excluded in the assessment. Based on this guidance the use of inert materials such as imported fill, sand and fly ash are considered to be insignificant to the assessment (represent less than five per cent of total emissions) and are excluded from the assessment boundary.

Vegetation clearance has been included in the GHG assessment boundary in line with the materiality checklist, as more than 0.5 hectares of vegetation would be required to be removed as part of the

[1] The TAGG was formed by Australian state road authorities, including NSW Roads and Maritime Services and the New Zealand Transport Agency as a collaborative effort to share information regarding the estimation, reporting and minimisation of GHG emissions. The TAGG Workbook provides a consistent methodology for estimating the GHG emissions from activities that may contribute significantly to the overall emissions associated with the construction, operation and maintenance of road projects.

project. Cumulative impacts associated with additional clearing required as part of the Rozelle Rail Yards site management works has also been assessed. Specific methodologies for the calculation of emissions from each emissions source (eg fuel use, electricity consumption, vegetation clearance, material use and waste) are provided in the following sections.

1.2 Fuel

The method used to calculate the Scope 1 GHG emissions from the combustion of liquid fuels, for transport energy purposes is given by the formula below, sourced from the National Greenhouse Accounts (NGA) Factors 2016:

Greenhouse gas emissions (t CO_2-e) = ((Q x ECF)/1000) x (EF_{CO2} + EF_{CH4} + EF_{N2O})

Where: Q is the quantity of fuel (in kL)

ECF is the relevant energy content factor (in GJ/kL)

EF_{CO2} is the relevant Carbon dioxide (CO_2) emission factor (in kg CO_2-e/GJ)

EF_{CH4} is the relevant Methane (CH_4) emission factor (in kg CO_2-e/GJ)

EF_{N2O} is the relevant Nitrous oxide (N_2O) emission factor (in kg CO_2-e/GJ)

The method used for calculating the Scope 3 GHG emissions from the combustion of liquid fuels, for transport energy purposes is given by the formula below, as given by the NGA Factors 2016:

Greenhouse gas emissions (t CO_2-e) = (Q x ECF x $EF_{Scope\ 3}$)/1000

Where: Q is the quantity of fuel (in kL)

ECF is the relevant energy content factor (in GJ/kL)

$EF_{Scope\ 3}$ is the relevant emission factor (in kg CO2-e/GJ)

The Scope 1 and Scope 3 emission factors for diesel (post 2004 vehicles) are given in **Table 1-1**.

Table 1-1 Scope 1 and Scope 3 emission factors for the use of fuels (post 2004 vehicles) (NGA Factors 2016 Tables 4 and 40)

Fuel	Energy content factor (GJ per kL)	Scope 1 emission factor (kg CO_2-e/GJ)			Scope 3 emission factor (kg CO_2-e/GJ)	Emissions per unit quantity (t CO_2-e per kL)		
		CO_2	CH_4	N_2O		Scope 1	Scope 2	Scope 3
Diesel	38.6	69.9	0.01	0.6	3.6	2.7217	N/A	0.1390

1.3 Electricity

The method used to calculate the Scope 2 and Scope 3 GHG emissions from the consumption of purchased electricity is given by the formula below, as given by the NGA Factors 2016:

Greenhouse gas emissions (t CO_2-e) = Q x ($EF_{for\ scope}$ /1000)

Where: Q is the quantity of purchased electricity (in kWh)

$EF_{for\ scope}$ is the Scope 2 or Scope 3 emissions factor for NSW (in kg CO2-e/kWh).

The emission factors for the consumption of purchased electricity are given in **Table 1-2**.

Table 1-2 Scope 2 and Scope 3 emission factors for the use of purchased electricity for NSW/ACT (NGA Factors 2016 Table 41)

Fuel	Emissions per unit quantity		Units
	Scope 2	Scope 3	
Electricity	0.00084	0.00012	t CO_2-e per kWh

1.4 Vegetation removal

The TAGG Workbook (2013) provides a methodology for estimating the loss of carbon sequestration potential associated with the removal of vegetation that would be required as part of land clearing activities during the project. The methodology provided in Appendix E of the TAGG Workbook was developed by GHD (2012) and is in line with the methodology used by the Australian Government Department of the Environment to estimate Australia's national GHG emissions for reporting under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

The methodology is based on a conservative approach, in line with relevant GHG guiding and reporting principles, and the following assumptions:

- All carbon pools are removed as part of the clearance of vegetation (eg debris and soil)
- All carbon removed is converted to CO_2 and released to the atmosphere
- Sequestration as a result of any revegetation works carried out as part of the project has not been included in the assessment.

The methodology estimates the GHG emissions associated with the loss of carbon sequestration that exists in vegetation at the time of clearing and the potential carbon that could have been sequestered in the future if the vegetation was not cleared. The GHG emissions associated with the loss of CO_2 sequestration potential through the removal of vegetation have been calculated using the following steps:

- The potential maximum biomass class ('Maxbio' class) has been determined for the project location using vegetation maps provided in Appendix E of the TAGG Workbook
- The class of vegetation (Table 1 of the TAGG Workbook Appendix E) and the area in hectares for each vegetation type to be cleared as part of the project has been identified
- The vegetation clearance emissions factors have been identified for each vegetation class for the selected 'Maxbio' class from Table 2 of the TAGG Workbook Appendix E
- The GHG emissions associated with the loss of CO_2 sequestration potential have been estimated by multiplying the area of vegetation to be cleared (in hectares) by the corresponding emissions factor (t CO_2-e per hectare) for each vegetation type
- The total estimate of GHG emissions associated with the loss of CO_2 sequestration potential for the project has been obtained by adding the results for each vegetation type.

Vegetation clearance emissions factors for the project are identified in **Table 1-3**.

Table 1-3 Vegetation clearance emissions factors (TAGG Workbook Appendix E 2013)

Maxbio class	Vegetation type	Vegetation class	Emissions factor (t CO_2-e per hectare)
Class 3 (100 - 150 tonnes of dry matter per hectare)	Local parklands, urban backyards and the Rozelle Rail Yards comprising previously cleared, non-native vegetation dominated by exotic grasses, with some planted native and non-native species.	I (Grassland)	110

Note: the 'Maxbio' class is derived from the Australian Greenhouse Office and estimates the maximum tonnes of dry vegetation matter per hectare for a specific location. Conservative assumptions were used to classify non-native vegetation types.

1.5 Construction materials and waste

Indirect Scope 3 GHG emissions from the embodied energy of materials used in the project and the decomposition of waste generated by the project have been calculated according to the formula below:

Greenhouse gas emissions (t CO_2-e) = Q (t) x EF (tCO_2-e/t)

Where: Q is the quantity of material or waste (in tonnes).

EF is the relevant Emission Factor (in t CO_2-e per tonne of material/waste).

Emission factors have been sourced from the TAGG Workbook (2013) and the NGA Factors 2016, as given in **Table 1-4**.

Table 1-4 Material Emission Factors (TAGG Workbook 2013; NGA Factors 2016)

Material	Emission factor (t CO_2-e/t)	Assumptions
Construction materials		
Concrete (cast insitu)	0.155	TAGG Workbook (2013) Appendix D Concrete 40MPa (1:1.5:3)
Concrete (precast)	0.119	SimaPro: Concrete block, at plant/DE U
Cement (Portland Cement)	0.82	TAGG Workbook (2013) Appendix D
Steel	1.05	(Structural) TAGG Workbook (2013) Appendix D
Aggregate/ road base	0.007	TAGG Workbook (2013) Appendix D
Asphalt	0.058	Hotmix Asphalt TAGG Workbook (2013) Appendix D
Mains water	0.001	SimaPro: Water, drinking, Sydney/AU U
Waste		
Construction and demolition waste	0.2	NGA Factors 2016, Table 44

2 Construction greenhouse gas assessment activity data

This section details the quantification of the GHG emission source data used to estimate emissions associated with construction of the project, including the sources of information used and assumptions made.

Twelve construction ancillary facilities are described in this EIS (as listed below). To assist in informing the development of a construction methodology that would manage constructability constraints and the need for construction to occur in a safe and efficient manner, while minimising impacts on local communities, the environment, and users of the surrounding road and other transport networks, two possible combinations of construction ancillary facilities at Haberfield and Ashfield have been assessed in this EIS. The construction ancillary facilities that comprise these options have been grouped together in this EIS and are denoted by the suffix a (for Option A) or b (for Option B).

The construction ancillary facilities required to support construction of the project include:

- Construction ancillary facilities at Haberfield (Option A), comprising:
  - Wattle Street civil and tunnel site (C1a)
  - Haberfield civil and tunnel site (C2a)
  - Northcote Street civil site (C3a); or
- Construction ancillary facilities at Ashfield and Haberfield (Option B), comprising:
  - Parramatta Road West civil and tunnel site (C1b)
  - Haberfield civil site (C2b)
  - Parramatta Road East civil site (C3b); and
- Darley Road civil and tunnel site (C4)
- Rozelle civil and tunnel site (C5)
- The Crescent civil site (C6)
- Victoria Road civil site (C7)
- Iron Cove Link civil site (C8)
- Pyrmont Bridge Road tunnel site (C9)
- Campbell Road civil and tunnel site (C10).

Table 2-1 details the GHG emission source data and emissions factors used in the GHG assessment. The table identifies where input data differs between construction ancillary facilities for Option A and Option B. The seven additional construction ancillary facilities (C4 to C10) are included in the assessment for each option.

The number, location and layout of construction ancillary facilities would be finalised as part of detailed construction planning during detailed design and would meet the environmental performance outcomes stated in the EIS and the Submissions and Preferred Infrastructure Report and satisfy criteria identified in any relevant conditions of approval.

Table 2-1 Construction GHG emission source data and emissions factors

Emissions source category	Emissions source	Assumptions	Quantity	Unit	Emissions factors			
					Scope 1	Scope 2	Scope 3	Units
Fuel use - diesel consumption	Mobile construction plant & equipment	Assumed to include fuel consumption for mobile plant and equipment for all construction works onsite.	12,000	kilolitres (kL)	2.722		0.139	t CO_2-e per kL
	Fuel use (diesel) – transport of materials, spoil and waste to/from site	Assumed to include transport of materials and items transported by heavy vehicles to/from site. Number of transport loads estimated from daily heavy vehicle numbers for each construction ancillary facility as detailed in **Chapter 6** (Construction work) of the EIS. Spoil movements assumed to be via road.	Option A: 33,545 Option B: 30,883	kilolitres (kL)	2.722		0.139	t CO_2-e per kL
Fuel use - petrol consumption (gasoline)	Construction plant, equipment and vehicle use onsite	Assumed to include fuel consumption of light vehicles onsite.	30	kilolitres (kL)	2.313		0.123	t CO_2-e per kL
	Transport of project vehicles - light vehicles	Assumed to include fuel consumption for transport of construction workforce to and from the site.	Option A: 3,706 Option B: 3,617	kilolitres (kL)	2.313		0.123	t CO_2-e per kL

Emissions source category	Emissions source	Assumptions	Quantity	Unit	Emissions factors			
					Scope 1	Scope 2	Scope 3	Units
Electricity purchased from the grid	Electricity consumption to power roadheaders and other associated plant and equipment onsite (eg temporary tunnel ventilation, water treatment and site offices)	Assumed to include electricity consumption of tunnelling machinery, tunnel lighting and ventilation during construction, site offices and other onsite electrical plant and equipment for each construction ancillary facility the duration of the construction period.	Option A: 100,020,000 Option B: 96,250,000	kilowatts per hour (kWh)		0.00084	0.00012	t CO_2-e per kWh
Vegetation clearance	Removal of vegetation from project sites	Local parklands, urban backyards and the Rozelle Rail Yards comprising previously cleared, non-native vegetation dominated by exotic grasses, with some planted native and non-native species.	10.8	Hectares	110			t CO_2-e per hectare
Embodied energy of construction materials	Concrete - cast insitu	2.3 t/m^3 (TAGG Appendix C) Assume 40MPa	920,000	tonnes (t)			0.155	t CO_2-e per tonne
	Concrete - precast	2.3 t/m^3 (TAGG Appendix C) Assume 40MPa	74,175	tonnes (t)			0.155	t CO_2-e per tonne
	Cement (Portland Cement)	Excludes concrete	122,000	tonnes (t)			0.82	t CO_2-e per tonne
	Steel - structural steel	-	450	tonnes (t)			1.05	t CO_2-e per tonne
	Steel – reinforcing steel	-	15,000	tonnes (t)			1.05	t CO_2-e per

Emissions source category	Emissions source	Assumptions	Quantity	Unit	Emissions factors			
					Scope 1	Scope 2	Scope 3	Units
								tonne
	Asphalt	-	70,000	tonnes (t)			0.058	t CO_2-e per tonne
	Aggregate	-	20,000	tonnes (t)			0.007	t CO_2-e per tonne
	Mains water	1 kilolitre per tonne	2,000,000	tonnes (t)			0.001	t CO_2-e per tonne
Waste	Construction and demolition waste	Estimate based on benchmarking of quantity of construction and demolition waste for M4 East and New M5 projects	50,000	tonnes (t)			0.2	tCO2-e per tonne

Note: Estimated quantities have been rounded to the nearest whole number.

3 Detailed construction greenhouse gas assessment results

Table 3-1 gives the GHG assessment results for the emissions estimated to occur during construction of the project, reported according to Scope 1, Scope 2, Scope 3 and total emissions, where Option A is selected as the preferred construction option at Haberfield. GHG emissions are reported in this assessment as tonnes of carbon dioxide equivalent (tCO_{2}-e).

Table 3-1 Detailed construction GHG emissions results for Option A

Emissions source category	Emissions source	Quantity	Unit	GHG emissions (t CO2-e)				
				Scope 1	**Scope 2**	**Scope 3**	**Total**	**% Total**
Fuel use - diesel consumption	Mobile construction plant & equipment	12,000	kilolitres	32,336		2,455	**34,791**	6.59
	Fuel use (diesel) – transport of materials, spoil and waste to/from site	33,545	kilolitres	90,392		6,863	**97,255**	18.42
Fuel use – petrol consumption (gasoline)	Construction plant, equipment and vehicle use onsite	30	kilolitres	69		5	**74**	0.01
	Transport of project vehicles - light vehicles	3,706	kilolitres	8,483		671	**9,154**	1.73
Electricity purchased from the grid	Electricity consumption during construction	100,020,000	kilowatt hours		86,017	13,003	**99,020**	18.75
Vegetation clearance	Removal of vegetation from project sites	10.8	hectares	1,188			**1,188**	0.23
Construction materials	Concrete - cast in situ	920,000	tonnes			142,600	142,600	27.00
	Concrete - precast	74,175	tonnes			11,497	11,497	2.18
	Cement (Portland Cement)	122,000	tonnes			100,040	100,040	18.95

Emissions source category	Emissions source	Quantity	Unit	GHG emissions (t CO2-e)				
				Scope 1	Scope 2	Scope 3	Total	% Total
	Steel - structural steel	450	tonnes			473	473	0.09
	Steel – reinforcing steel	15,000	tonnes			15,750	15,750	2.98
	Asphalt	70,000	tonnes			4,060	4,060	0.77
	Aggregate	20,000	tonnes			140	140	0.03
	Mains water	2,000,000	tonnes			2,000	2,000	0.38
Waste	Construction and demolition waste	50,000	tonnes			10,000	10,000	1.89
Totals				**132,468**	**86,017**	**309,557**	**528,042**	100%
% Total				25.09	16.29	58.62	**100%**	

Note: Estimated quantities have been rounded to the nearest whole number.

Table 3-2 gives the GHG assessment results for the emissions estimated to occur during construction of the project, reported according to Scope 1, Scope 2, Scope 3 and total emissions, where Option B is selected as the preferred construction option at Haberfield/Ashfield. GHG emissions are reported in this assessment as tonnes of carbon dioxide equivalent (t CO_{2}-e).

Table 3-2 Detailed construction GHG emissions results for Option B

Emissions source category	Emissions source	Quantity	Unit	GHG emissions (t CO2-e)				
				Scope 1	Scope 2	Scope 3	Total	% Total
Fuel use - diesel consumption	Mobile construction plant & equipment	12,000	kilolitres	32,336		2,455	**34,791**	6.74
	Fuel use (diesel) – transport of materials, spoil and waste to/from site	30,883	kilolitres	83,218		6,318	**89,536**	17.34
Fuel use – petrol consumption (gasoline)	Construction plant, equipment and vehicle use onsite	30	kilolitres	69		5	**74**	0.01
	Transport of project vehicles - light vehicles	3,617	kilolitres	8,277		655	**8,932**	1.73
Electricity purchased from the grid	Electricity consumption during construction	96,250,000	kilowatt hours		82,775	12,513	**95,288**	18.45
Vegetation clearance	Removal of vegetation from project sites	10.8	hectares	1,188			**1,188**	0.23
Construction materials	Concrete - cast in situ	920,000	tonnes			142,600	142,600	27.61
	Concrete - precast	74,175	tonnes			11,497	11,497	2.23
	Cement (Portland Cement)	122,000	tonnes			100,040	100,040	19.37

Emissions source category	Emissions source	Quantity	Unit	GHG emissions (t CO2-e)				
				Scope 1	**Scope 2**	**Scope 3**	**Total**	**% Total**
	Steel - structural steel	450	tonnes			473	473	0.09
	Steel – reinforcing steel	15,000	tonnes			15,750	15,750	3.05
	Asphalt	70,000	tonnes			4,060	4,060	0.79
	Aggregate	20,000	tonnes			140	140	0.03
	Mains water	2,000,000	tonnes			2,000	2,000	0.39
Waste	Construction and demolition waste	50,000	tonnes			10,000	10,000	1.94
Totals				**125,088**	**82,775**	**308,506**	**516,369**	100%
% Total				24.23	16.03	59.74	**100%**	

Note: Estimated quantities have been rounded to the nearest whole number.

4 Emissions from road infrastructure operation and maintenance activities

This section estimates the GHG emissions that would be generated from the annual operation and major maintenance activities for the project's road infrastructure.

Emissions associated with the operation of road infrastructure have been estimated based on the annual consumption of electricity, purchased from the grid. Annual use of electricity is based on estimates of annual electricity consumption for powering tunnel lighting and ventilation, building services, heating ventilation and air-conditioning (HVAC) systems, surface plants, wastewater treatment, pumps and drainage, communications systems, electronic signage and other associated electrical systems.

Default quantity factors, provided in the TAGG Workbook have been used to quantify activity data associated with the maintenance of the tunnel and road pavements. Emission estimates for the use of fuel and materials for the maintenance of the road pavement are based on one major rehabilitation of asphalt pavement with the top 150 millimetres replaced and five per cent of pavement replaced for patching/repair every 50 years, and five per cent of concrete pavement replaced with only the top layer requiring replacement every 50 years (in accordance with 'typical' maintenance activities given in the TAGG Workbook).

Specific methodologies for the calculation of emissions are provided in **section 1** of this document. **Table 4-1** details the GHG emission source data and emissions factors used in the assessment of GHG emissions generated from the operation and maintenance of road infrastructure.

Table 4-1 Operation and maintenance GHG emission source data and emissions factors

Emissions source category	Emissions source	Assumptions	Quantity	Units	Emissions per unit quantity			
					Scope 1	Scope 2	Scope 3	Units
Electricity consumption	Annual electricity consumption of road infrastructure and associated management systems – Mainline tunnels	The electricity consumption is assumed to include power for tunnel lighting and ventilation, building services, HVAC systems, surface plants, wastewater treatment, pumps and drainage, communications systems, electronic signage and other associated electrical systems.	19,941,946	kilowatt hours (kWh) per year		0.00084	0.00012	tCO_2-e per kWh
	Annual electricity consumption of road infrastructure and associated management systems – Rozelle interchange		30,796,842	kilowatt hours (kWh) per year		0.00084	0.00012	tCO_2-e per kWh
Fuel use - diesel consumption	Mobile maintenance plant and equipment, project vehicles	TAGG workbook Table 7-3 (2013)	1,214	kilolitres	2.7217		0.1390	t CO_2-e per kL
Maintenance materials	Steel	TAGG workbook Table 7-3 (2013)	42	tonnes			1.05	t CO_2-e per t
	Bitumen	TAGG workbook Table 7-3 (2013)	3,969	tonnes			0.63	t CO_2-e per t
	Aggregate	TAGG workbook Table 7-3 (2013)	81,176	tonnes			0.005	t CO_2-e per t
	Cement - Portland Cement	TAGG workbook Table 7-3 (2013)	321	tonnes			0.82	t CO_2-e per t

5 Detailed operation and maintenance emissions results

Table 5-1 gives the GHG assessment results for the emissions estimated to occur during operation of project infrastructure, reported according to Scope 1, Scope 2, Scope 3 and total emissions.

Table 5-2 gives the GHG assessment results for the emissions estimated to occur during maintenance of project infrastructure, reported according to Scope 1, Scope 2, Scope 3 and total emissions.

Table 5-1 Annual operational GHG emissions results

Emissions source category	Emissions source	Quantity	Unit	GHG emissions (t CO_2-e per year)			
				Scope 1	Scope 2	Scope 3	Total
Annual electricity consumption – mainline tunnels	Annual use of electricity for powering tunnel lighting and ventilation, building services, HVAC systems, surface plants, wastewater treatment, pumps and drainage, communications systems, electronic signage and other associated electrical systems.	19,941,946	kilowatt hours (kWh) per year		16,751	2,393	19,144
Annual electricity consumption – Rozelle interchange		30,796,842	kilowatt hours (kWh) per year		25,870	3,695	29,565
Total					**42,621**	**6,088**	**48,709**

Table 5-2 Total maintenance GHG emissions results

Emission source category	Emission source	Quantity	Unit	GHG emissions (t CO_2-e)				
				Scope 1	Scope 2	Scope 3	Total	%
Fuel use - diesel consumption	Mobile maintenance plant and equipment, project vehicles	1,214	kilolitres	3,271		248	3,519	52.3
Maintenance materials	Steel	42	tonnes (t)			44	44	0.7
	Bitumen	81,176	tonnes (t)			406	406	6.0
	Aggregate	3,969	tonnes (t)			2,500	2,500	37.1
	Cement - Portland Cement	321	tonnes (t)			264	264	3.9
Total				**3,271**	**0**	**3,462**	**6,733**	**100%**
Total %				**48.6%**	**0%**	**51.4%**	**100%**	

6 Emissions from operational road use

As improvements to traffic flow and congestion are achieved through increased speeds, reduced travel distances and reduced frequency of stopping, fuel efficiency is improved and subsequently GHG emissions associated with road use are reduced. As such, it is anticipated that the project would result in GHG emissions savings when compared to the base case 'do minimum' scenario (without the project).

6.1 Methodology

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

- At opening (2023): it is proposed that the project would be constructed and fully operational in 2023. The following scenarios have been assessed in the project year of opening:
  - Operation 'do minimum' or 'without project' (2023): assumes that NorthConnex, M4 Widening, M4 East, King Georges Road Interchange Upgrade and New M5 are completed and open to traffic, but that the M4-M5 Link has not been built. It is called 'do minimum' rather than 'do nothing' as it assumes ongoing improvements will be made to the broader transport network over time including some new infrastructure and intersection improvements to improve capacity and cater for traffic growth
  - Operation 'with project' (2023): with the 'do minimum' projects completed and the M4-M5 Link completed and open to traffic
  - Operation 'cumulative' (2023): with 'do minimum' projects and M4-M5 Link completed and open to traffic, and in addition, the proposed future Sydney Gateway and Western Harbour Tunnel projects are completed and open to traffic
- Future 10 years after opening (2033): assessment of the future operation of the project and transport network elements 10 years after opening. The following scenarios have been assessed in the future 10 years after project opening:
  - Operation 'do minimum' or 'without project' (2033): with the same 2023 'do minimum' projects complete and some upgrades to the broader transport network over time to improve capacity and cater for traffic growth but does not include the M4-M5 Link
  - Operation 'with project' (2033): with the 'do minimum' projects completed and the M4-M5 Link completed and open to traffic
  - Operation 'cumulative' (2033): with the 'do minimum' projects and M4-M5 Link completed and open to traffic, and in addition, the proposed future Sydney Gateway, Western Harbour Tunnel, Beaches Link and the F6 Extension projects completed and open to traffic.

These scenarios are summarised in Table 22-5 of **Chapter 22** (Greenhouse gas) of the EIS. The proposed construction program has the mainline tunnels planned for completion in 2022 and the Rozelle interchange, including the Iron Cove Link, planned for completion in 2023.

Traffic volumes were modelled for 2023 and 2033 in line with **Appendix H** (Technical working paper: Traffic and transport) of the EIS. These future years were chosen as they provide an indication of road network performance at project opening (2023), and 10 years after opening (2033).

The analysis is based on the vehicle kilometres travelled (VKT) and the average speed of vehicles travelling on key routes within the GHG assessment study area, as generated by WestConnex Road Traffic Model version 2.3 (WRTM v2.3), ie the strategic traffic model developed and operated by

Roads and Maritime. The GHG assessment for operational road use involved calculation of the following inputs:

- Average speed for each road link[2]
- VKT for both light and heavy vehicles
- Rate of fuel consumption
- Total fuel quantity
- Fuel quantity by fuel type
- Calculation of GHG emissions.

It is acknowledged that the assessment uses the methodology described in the guideline document, Austroads Guide to Project Evaluation Part 4: Project Evaluation Data, Part 6 (2008), which has since been removed from Austroads publications due to uncertainties in the accuracy of the fuel consumption coefficients provided therein (see **section 6.2.4**). However, as the project uses outputs of the WRTM, which provides strategic-level demand forecasts for the Sydney Metropolitan area in place of other analytical intersection assessment tools (eg SIDRA, which includes a carbon accounting function), no alternative methodology was available to assess operational road use emissions for the project. As a result, Scope 3 road use emissions estimated in this assessment are considered to be subject to the limitations of the fuel consumption coefficients used and the assumptions used to generate traffic forecasts as part of the WRTM.

6.2 Calculation of operational road use emissions

6.2.1 GHG study area boundary

The GHG assessment study area contains major transport corridors and infrastructure, covering parts of the main travel demand corridors in Sydney: Parramatta to the Sydney central business district (CBD) via Strathfield, Parramatta to the Sydney CBD via Ryde, Sydney Airport to the Sydney CBD, and Victoria Road to St Peters. These corridors are some of the most highly congested road corridors in Sydney, with demand on some sections already exceeding capacity during peak periods. This congestion increases travel time and variability. The study area also allows for a cumulative assessment of proposed future transport corridors, such as Sydney Gateway, Western Harbour Tunnel, Beaches Link and the F6 Extension.

The GHG study area boundary was chosen to assess emissions associated with changes in daily traffic volumes and performance on the road network (both increases and decreases) as a result of the project. As the project does not replace a single existing route within the road network, the GHG study area boundary was selected to include key routes that currently serve as alternate routes to the project as well as other roads within the vicinity that were considered to be influenced by the project.

These key routes for the GHG study area boundary were identified in accordance with **Appendix H** (Technical working paper: Traffic and transport) of the EIS, using:

- Difference plots from WRTM v2.3 – the difference plots showed the percentage change in traffic flows between different road network scenarios and confirmed the study area would cover the material changes in traffic volumes as a result of the project.
- Screenline analyses – used to examine how traffic patterns may change between the alternative parallel corridors through the study area. Four screenlines were selected to analyse directional and two-way traffic volume outputs from the different modelling scenarios for each common future year.

[2] As classified within WRTM v2.3 and include Motorway, Highway, Regional Arterial, Arterial, Sub-arterial, Collector and Minor.

Key routes within the GHG study area boundary include:

- Parramatta Road between Five Dock and Broadway
- City West Link and Anzac Bridge/Western Distributor
- Victoria Road between Lyons Road and Anzac Bridge
- The Sydney Harbour Bridge and Sydney Harbour Tunnel
- Cahill Expressway, Eastern Distributor and Southern Cross Drive
- The eastern extent of the M4 East Motorway, between Five Dock and the Wattle Street interchange
- The existing M5 Motorway and New M5 Motorway, between the Princes Highway and General Holmes Drive
- Princes Highway, King Street and City Road, between Rockdale and Ultimo
- Roads surrounding the Wattle Street interchange, the Rozelle interchange, and the St Peters interchange.

Further information regarding the difference plot and screenline analyses, and the project's operational study area, is provided in **Appendix H** (Technical working paper: Traffic and transport) of the EIS.

6.2.2 Average speed by road type

For each scenario, the average weekday speeds on links within the study area were sourced from the WRTM v2.3, for each direction of traffic in the AM peak, inter-peak, PM peak and evening periods. Average speed is influenced by the level of congestion experienced for each link, as well as factors such as the number of traffic lights, road or tunnel gradient and ramp curvature.

6.2.3 Vehicle kilometres travelled

For each scenario, VKT for light and heavy vehicles on each link within the study area was sourced from the WRTM v2.3, for each direction of traffic in the AM peak, inter-peak, PM peak and evening periods. The average VKT for each daily time period was multiplied to give the average volume of traffic for each time period over 365 days per year. The VKT assessed is based on model outputs of average weekday traffic (AWT) projections. This provides a conservative assessment for annual VKT based on higher weekday traffic volumes, rather than average daily traffic (ADT), as generally ADT volumes are lower than AWT on most roads and similar on a few roads.

6.2.4 Rate of fuel consumption

The rate of fuel consumption was calculated for each vehicle type within the traffic impact footprint, using the basic fuel-speed formula given below (Equation 1 in Austroads Guide to Project Evaluation Part 4: Project Evaluation Data, Part 6 (2008)):

Fuel Consumption (L/100km) = A+ (B/V) + (CxV) + (DxV²)

Where: A, B, C, D are the fuel consumption parameter values given in **Table 6-1**.

V is the all day average link speed in km/h

Table 6-1 Fuel consumption parameter values on freeways − litres/100 km (Austroads Guide to Project Evaluation Part 4: Project Evaluation Data Table 6.3)

Vehicle type	A	B	C	D
Cars	-18.433	1306.02	0.15477	0.0003203
Light commercial vehicle (LCV)	-27.456	2060.5	0.1911	0.000851
Rigid trucks	-65.056	4156.75	0.49681	0.0006798
Articulated vehicles	-80	6342.8	0.48496	0.0020895

Buses	-80	5131.63	0.60539	0.0015775

As the GHG emissions from road use were assessed for two vehicle categories (light vehicles and heavy vehicles), weighted average fuel consumption parameters were applied according to the likely proportional makeup of vehicle types within each category, based on the most recent Australian Bureau of Statistics (ABS) NSW Registration vehicle type data for the census date 31 January 2016 (released July 2016), as given in **Table 6-2**. **Table 6-3** details the likely proportional makeup of cars and light commercial vehicles (LCVs) within the category of 'light vehicles' and of rigid trucks, articulated vehicles and buses within the category 'heavy vehicles'. The weighted average fuel consumption parameters applied are given in **Table 6-4**.

Table 6-2 ABS NSW Registration vehicle type data for calculating weighted average fuel consumption parameters for light and heavy vehicles (ABS 9309.0 Motor Vehicle Census at the Census date 31 January 2016)

Category	2016 NSW registrations	Proportion of total vehicles	Heavy/ Light vehicle	Sub-classification according to fuel consumption parameters	Proportion heavy/light
Articulated trucks	21,450	0.40%	H	Articulated vehicles	0.11
Buses	25,939	0.48%	H	Buses	0.14
Heavy rigid trucks	91,242	1.70%	H	Rigid trucks	0.48
Non-freight carrying trucks	2,908	0.05%	H	Rigid trucks	0.02
Light rigid trucks	48,788	0.91%	H	Rigid trucks	0.25
Total	**190,327**	**3.54%**	**-**	**-**	**1.00**
Light commercial vehicles	804,665	14.97%	L	LCV	0.16
Motor cycles	229,296	4.27%	L	Cars	0.04
Passenger vehicles	4,134,786	76.93%	L	Cars	0.80
Campervans	15,345	0.29%	L	Cars	0.00
Total	**5,184,092**	**96.46%**	**-**	**-**	**1.00**

Table 6-3 Estimated proportional makeup of light and heavy vehicles according to vehicle type

Category	Cars	LCV	Rigid Trucks	Articulated vehicles	Buses
Light vehicles	0.84	0.16	0	0	0
Heavy vehicles	0	0	0.75	0.11	0.14

Table 6-4 Fuel consumption parameter values on freeways for light and heavy vehicles − litres/100 km (adapted from Austroads Guide to Project Evaluation Part 4: Project Evaluation Data Table 6.3)

Vehicle category	A	B	C	D
Light	-19.87668000	1426.73680000	0.16058280	0.00040521
Heavy	-68.79200000	4533.69870000	0.51070770	0.00096055

Rates of fuel consumption calculated according to the parameters in **Table 6-1** are applicable for 2008 (year of publication of Austroads Guide to Project Evaluation). Annual rates of fuel efficiency improvement were applied to calculate rates of fuel consumption, for light and heavy vehicles, in 2023 and 2033, according to road transport fuel intensity projections by vehicle type, given by SKM (2011) in Australian Transport Emissions Projections to 2050 (see **Table 6-5**), as follows:

- Rates of fuel consumption for 2023 were calculated by applying the annual percentage change in fuel intensity from 2020 to 2030, given in **Table 6-5**, to the rate of fuel consumption in the year 2020
- Rates of fuel consumption for 2033 were calculated by applying the annual percentage change in fuel intensity from 2030 to 2050, given in **Table 6-5**, to the rate of fuel consumption in the year 2030.

Table 6-5 Estimated fuel intensity projections by Road Type (SKM (2011) Australian Transport Emissions Projections to 2050)

Vehicle Type	Annual % fuel intensity change (2020-2030)	Annual % fuel intensity change (2030-2050)	Heavy/Light vehicle classification	Annual % fuel intensity change (2020-2030) (based on vehicle proportions)	Annual % fuel intensity change (2030-2050) (based on vehicle proportions)
Passenger	-1.4	-1.8	Light	-1.37	-1.80
Motorcycles	-0.8	-0.8			
LCV	-1.2	-1.8			
Buses	0.3	1.1	Heavy	-0.53	-0.64
Rigid	-0.6	-0.9			
Articulated	-1.1	-1.1			

6.2.5 Total fuel quantity combusted

For each scenario, VKT was factored by the rate of fuel consumption for each road type to determine the total quantity of fuel consumed in each scenario.

6.2.6 Fuel quantity combusted by fuel type

The analysis considered three fuel types: petrol, diesel and LPG. The total quantity of fuel combusted in each scenario, for 2023 and 2033, was apportioned according to fuel type, based on Australian Bureau of Statistics Survey of Motor Vehicle Census at the Census date 31 January 2016. Estimates of the proportional makeup of light and heavy vehicles by fuel type are given in **Table 6-6**.

Table 6-6 Fuel type proportions for light and heavy vehicles (calculated from data in ABS 9309.0 Motor Vehicle Census for the Census date 31 January 2016)

Vehicle Category	Fuel Type	Estimated Proportion
Light vehicles	Petrol	0.795
	Diesel	0.181
	LPG/CNG/dual fuel/hybrid (assume LPG)	0.024
Heavy vehicles	Petrol	0.061
	Diesel	0.928
	LPG/CNG/dual fuel/hybrid (assume LPG)	0.011

6.3 Detailed operational road use emission results

6.3.1 The GHG emissions calculation

The Scope 3 GHG emissions associated with the use of petrol, diesel and LPG in each scenario for 2023 and 2033 were calculated according to the formula below, as given by the NGA Factors 2016:

Greenhouse gas emissions $(t\ CO_2\text{-}e) = (Q \times EF_{full\ fuel\ cycle})/1000$

Where: Q is the quantity of fuel (in kL).

$EF_{full\ fuel\ cycle}$ is the relevant emission factor (in kg CO_2-e/kL).

The emission factor applied represents the full fuel cycle, which is the sum of Scope 1 and Scope 3 emissions. The emission factors for petrol, diesel and LPG, for general transport as a conservative assumption, are given in **Table 6-7**.

Table 6-7 Scope 1, Scope 3 and full fuel cycle emission factors for general transport (Source: NGA Factors 2016 Tables 4 and 40)

Fuel	Energy content factor (GJ per kL)	Scope 1 emission factor (kg CO_2-e/GJ)			Scope 3 emission factor (kg CO_2-e/GJ)	Emissions per unit quantity (t CO_2-e per kL)			Full fuel cycle (t CO_2-e per kL)
		CO_2	CH_4	N_2O		Scope 1	Scope 2	Scope 3	
Petrol (gasoline)	34.2	67.4	0.5	1.8	3.6	2.38374	N/A	0.12312	2.50686
Diesel oil	38.6	69.9	0.1	0.5	3.6	2.7213	N/A	0.13896	2.86026
Liquid petroleum gas (LPG)	26.2	60.2	0.6	0.7	3.6	1.6113	N/A	0.09432	1.70562

The estimated GHG emissions per annum from the use of fuel in each scenario for 2023 and 2033 are given in **Table 6-8** below.

Table 6-8 Scope 3 GHG emissions results for operational road use

Route	GHG emissions (t CO_2-e)						Difference between scenarios (t CO_2-e)			
	'Do minimum' (without project)		'With project'		'Cumulative'		'With project' – 'Do minimum'		'Cumulative' – 'Do minimum'	
	2023	2033	2023	2033	2023	2033	2023	2033	2023	2033
Existing road network (within the study area)	9,891,755	11,687,799	9,491,704	11,140,131	9,242,368	10,811,985	-400,052	-547,668	-649,387	-875,814
M4-M5 Link	N/A	N/A	38,471	42,917	46,886	54,686	38,471	42,917	46,886	54,686
Totals	**9,891,755**	**11,687,799**	**9,530,175**	**11,183,048**	**9,289,254**	**10,866,671**	**-361,581**	**-504,751**	**-602,501**	**-821,128**

Note: negative values indicate a savings in GHG emissions for the 'with project' and 'cumulative' scenarios compared with the 'do minimum' (without project) scenario. N/A = not applicable (the 'do minimum' scenario does not include the project).