15. Greenhouse gases and energy

The following chapter outlines the estimated energy consumption and associated greenhouse gas (GHG) emissions as a result of the project's construction and future operation. Quantitative estimates of direct (for example, as a result of combustion plant and equipment) and indirect (for example, emissions from the generation of electricity at remote power stations) emissions are provided. This chapter discusses the GHG implications of embodied energy in construction materials and waste, and the potential GHG reductions associated with the shift in mode from private transport to the project.

DGRs	Where addressed in the EA
Design, Sustainability and Amenity — including but not limited to:	
▪ stop design and corridor landscaping, relationship to surrounding land uses and built form and the visual impacts of the project from surrounding areas	Chapter 14
▪ safety and security of passengers, GreenWay shared path users and the wider community	Chapter 14
▪ privacy and amenity impacts from stops, the light rail corridor and the GreenWay shared path	Chapter 14
▪ energy demand, efficiency and climate change adaptation measures.	Chapters 8, 15 and 16

15.1 Background

Greenhouse gases are the atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO_2), nitrous oxide (N_{20}), Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and methane (CH_4), sulphur hexafluoride (SF_6).

15.1.1 NSW GHG and Energy Policy

In November 2006, the NSW Government released a policy document, *State Plan — A New Direction for NSW* (NSW Government 2006), which established NSW priorities for the next 10 years. Under the *Environment for Living* chapter, the Government outlined its plans for cleaner air and progress on GHG reductions. The target is to return to year 2000 GHG emissions levels by 2025, with a 60% reduction by 2050 (adopted from a 2005 NSW Government commitment). The most recent State Plan, *Investing in a Better Future*, was released by the NSW Government in 2010 and also affirms this overall target.

Recently, the NSW Government has been developing a new climate change strategy, the *NSW Climate Change Action Plan*, which will complement and replace the work of the 2005 *Greenhouse Action Plan* (NSW Government 2005). The Climate Change Action plan will establish a policy framework for NSW based on emissions reduction, climate change adaptation and low-carbon economy prosperity.

The NSW Greenhouse Gas Inventory (Department of Climate Change 2007a) identified that transport contributes to 13% of NSW GHG emissions and that this figure has grown by 20% between 1990 and 2002. Rail transport contributed 2.6% of Australia's transport emissions in 2005. These are projected to be 3.2% by 2020 (Australasian Railway Association 2010). Nationally, transport emissions are projected to increase 42% from 1990 levels by 2010 and 61% by 2020 (NSW Greenhouse Office 2005). Transport has also been identified as the second fastest growing source of emissions in Australia (Department of Environment, Climate Change and Water NSW 2006).

Rail emissions have been projected to grow at 3.8% a year between 2005 and 2010 on the back of improving infrastructure, high petrol prices and increased traffic congestion (Department of Climate Change 2007b).

This project would be an important component in meeting the target reduction aims of the Department of Environment Climate Change and Water (DECCW) in relation to GHG emissions. The light rail, along with the GreenWay shared path, would provide the potential to reduce private vehicle usage, and a subsequent modal shift towards public transport.

15.2 Assessment approach

The assessment approach used for the project has followed the accounting standards of the *Greenhouse Gas Protocol* (World Business Council for Sustainable Development & World Resources Institute 2004) and has incorporated the following publications:

- National Greenhouse Account (NGA) Factors (Department of Climate Change, 2009; this supersedes the AGO Factors and Methods Workbook, 2006)
- workbooks from the Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006 series (Department of Climate Change)
- emission factors from the IPCC internet database of emissions factors and National Greenhouse Gas Inventories Program publications
- available research, including manufacturer-provided data.

The sources of GHG emissions related to the project can be categorised as part of emissions of three scope types, depending on the sources of these emissions. Table 15.1 describes these categories and the probable sources of emissions.

Table 15.1 Emission scopes and sources

Emission Scope	Type of emission	Probable project source
Scope 1	Direct emissions within the boundary of the project operations, such as fuel combustion and manufacturing processes, or provision of supplementary energy such as generating electricity for onsite usage.	Construction phase: ▪ fuel combustion emissions from construction plant and equipment ▪ clearing site vegetation. Operations phase: ▪ infrastructure maintenance activities.

Emission Scope	Type of emission	Probable project source
Scope 2	Indirect emissions from consumption of purchased electricity, steam or heat purchased for the project but produced by another organisation.	Construction phase: ▪ electricity used to operate site offices. Operations phase: ▪ operations of light rail infrastructure and systems, such as lighting and signalling.
Scope 3	Indirect emissions from all other emissions that are a consequence of activities of the project but are not from sources owned/controlled by the project.	Construction phase: ▪ embodied energy of construction materials ▪ emissions from transporting such materials to and from site. ▪ emissions from the extraction, production, transmission and distribution of fuel and electricity used onsite. Operations phase: ▪ embodied energy in maintenance materials ▪ rolling stock traffic movements.

15.3 Emissions during construction

GHG emissions may be emitted directly or indirectly. The direct GHG-generating activities associated with construction include mobile vehicular emissions (particularly from using heavy vehicles to move materials like spoil and concrete) and, depending on the extent required, removing vegetation (Scope 1 emissions). Indirect GHG emissions as a result of the project would include emissions associated with the consumption of electricity within site compounds and construction equipment, extraction of diesel and the emissions embodied in the products used on-site, particularly steel and concrete (Scope 2 emissions).

Typically, the operation of on-site machinery during construction works and general site operations account for the majority of construction-related GHG emissions.

Expected GHG sources of construction emissions for the project would include:

- energy consumption from earthworks
- embodied energy from production of materials
- fuel use associated with transporting materials, equipment and staff
- fuel use associated with construction machinery.

The GHG estimate during construction has been based on an assumed 50 week construction period. The estimate is based on selected typical plant and equipment and transport usage during constructing other rail infrastructure projects. The plant and equipment assumptions are presented in Table 15.2.

Table 15.2 Plant and equipment assumptions associated with construction of the project

Plant and equipment metrics	Assumptions
General assumptions	
Assumed average duration of works	50 weeks
Average hours for machinery per week	40 hours
Average hours for machinery per day	8 hours
Diesel consumption for typical equipment:	
Chipper (fuel consumption 36 litres/hour (L/hr))	0.28 kilolitres
30 tonne excavators-bulk excavation (fuel consumption 31 L/hr)	0.5 kilolitres
Dump truck (fuel consumption 20 L/hr)	0.32 kilolitres
Trench rollers — 10 tonne smooth drum vibratory roller (fuel consumption 14 L/hr)	44 kilolitres
Trench rollers — 2–4 tonne smooth drum vibratory roller (fuel consumption 13 L/hr)	40 kilolitres
30 tonne excavators (assumed fuel consumption: 31 L/hr)	27 kilolitres
Assumed total plant and equipment activity	
Total number of hours	3,600 hours
Calculated total diesel consumption	60 kilolitres
Note: Petrol consumption	-

Assumptions for the transport activities associated with the construction of the project are presented in Table 15.3.

Table 15.3 Transport activities associated with the project during construction

Transport metrics	Assumptions
General assumptions	
Assumed average duration of works	50 weeks
Average hours for machinery per day	8 hours
Carrying capacity — truck and trailer (6 axle articulated)	45 tonne
Carrying capacity — bogie tipper	13 tonne
Materials transport	
Supplier distance for materials	25 kilometres
Supplier distance for concrete	200 kilometres
Proportion of truck and trailer usage (fuel consumption 0.35 L/km)	85%
Proportion of fuel tanker usage (0.4 L/km)	15%
Diesel consumption-materials haulage to site	20 kilolitres
Diesel consumption-transporting construction waste	2 kilolitres
Commuting of workers	
Assumed average number of commuters (construction workers)	350
Project duration	50 weeks
Number of commuting trips per worker per day	2 trips
Total number of commuting trips per day	700 trips
Total number of commuting trips per week	3,500 trips

Transport metrics	Assumptions
Total number of commuting trips for project	175,000 trips
Average return trip distance per commuter (construction worker)	15 kilometres
Total distance travelled by commuters (construction workers)	2,625,000 kilometres
Light vehicle fuel consumption	0.112 L/km
Calculated total vehicle consumption	294,000 litres

The calculation of emissions as a result of the project, based on the assumptions outlined in Table 15.2 and 15.3, is presented in Table 5.4, excluding the emissions associated with embodied energy of materials used.

The methodology to estimate the greenhouse gas emissions is taken from the NGA factors approach and converts emissions for gases that are not carbon dioxide into a carbon dioxide equivalent (CO_2-e). The general formula for calculating the various activities is presented as:

tCO_2e= (Q x EC x EF/1,000

Where:

- tCO_2-e *is the tonnes of carbon dioxide equivalent. The global warming impact of all greenhouse gases is measured in terms of equivalency to the impact of carbon dioxide (CO2). For example, one million tonnes of emitted methane, which is more potent than carbon dioxide, is measured as 23 million tonnes of CO_2-e, or 23 $MtCO_2e$.*
- *Q is the quantity of fuel consumed expressed in tonnes or kilolitres.*
- *EC is the energy content factor of the fuel expressed in gigajoules per tonne or kilolitre. If Q is measured as gigajoules then the EC is 1.*
- *EF is the relevant emissions factor for the activity.*

- Diesel consumption — plant and equipment: the formula to estimate the GHG emissions from plant and equipment activity is given as Q multiplied by EC multiplied by EF, where Q is 60 kL, EC is 38.6 gigajoule(GJ)/kilolitre(kL) and the EF (Scope 1) is 69.5 $kgCO_2$/GJ, and the EF (Scope 3) is 5.3 $kgCO_2$/GJ.

- Diesel consumption — transport fuel: the formula to estimate the GHG emissions from transporting materials to site is given as Q multiplied by EC multiplied by EF, where Q is 20 kL, EC is 38.6 GJ/kL and the EF (Scope 1) is 69.9 $kgCO_2$/GJ and the EF (Scope 3) is 5.3 $kgCO_2$/GJ.

- Diesel consumption — construction waste transport fuel: the formula to estimate the GHG emissions from transporting construction waste off site is given as Q multiplied by EC multiplied by EF, where Q is 2 kL, EC is 38.6 GJ/kL and the EF (Scope 1) is 69.9 $kgCO_2$/GJ, and the EF (Scope 3) is 5.3 $kgCO_2$/GJ.

- Petrol consumption — commuter transport fuel: the formula to estimate the GHG emissions from commuting is given as Q multiplied by EC multiplied by EF, where Q is 294 kL, EC is 34.2 GJ/kL and the EF (Scope 1) is 67.1 $kgCO_2$/GJ, and the EF (Scope 3) is 5.3 $kgCO_2$/GJ.

- Emissions from electricity consumption: the formula to estimate the GHG emissions from purchase of electricity is given as Q multiplied by EF, divided by 1,000 (to convert from kg to tonnes), where Q is 93,460 kWh and the EF (Scope 1 for NSW) is 0.89 kgCO_2e/kWh, and the EF (Scope 3) is 0.18 kgCO_2e/kWh.

- Emissions from waste: the formula to estimate the GHG emissions from disposal of waste is given as Q multiplied by EF, where Q quantity of waste by type of either food (default proportion of NGA factors is 0.15) or paper & cardboard (default proportion of NGA factors is 0.4) and the EF by type of either food (0.9 tCO_2e) or paper & cardboard (2.5 tCO_2e).

- Emissions from vegetation loss: the formula to estimate the GHG emissions from vegetation loss is given as Q multiplied by EF, where Q is 1.82 hectares (ha) and the EF (for decomposition) is 7.4 CO2e/ha. We have assumed no trees are being felled and the general classification of the land type is grasslands.

The elements contributing to the CO_2 emissions for constructing the project are identified in Table 15.4 and Table 15.5.

Table 15.4 Emissions calculations for plant transport, electricity and waste during constructing the project

GHG metrics	Assumptions	GHG metrics	Assumptions
Plant and equipment — diesel		**Transport — diesel for construction waste**	
Volume of fuel	60 kilolitres	Construction waste proportion of materials	10%
Energy Content Factor	38.6 GJ/kilolitre	Volume of fuel	2 kL
Energy	2,316 GJ	Energy Content Factor	38.6 GJ/kL
Emission Factor – Scope 1	69.5 kg CO_2/GJ	Energy	77 GJ
Emission Factor – Scope 3	5.3 kg CO_2/GJ	Emission Factor – Scope 1	69.9 kg CO_2/GJ
CO_2e – Scope 1	161 t CO_2e	Emission Factor – Scope 3	5.3 kg CO_2/GJ
CO_2e – Scope 3	12 t CO_2e	CO_2e – Scope 1	5 t CO_2e
CO_2e – TOTAL	**173 t CO_2e**	CO_2e – Scope 3	0.4 t CO_2e
		CO_2e – TOTAL	**5.4 t CO_2e**
Transport — diesel		**Waste**	
Volume of fuel	20 kL	Assumed waste generated per worker	290 kgs per year
Energy Content Factor	38.6 GJ/kL	Degradable Organic Carbon proportion – Food	0.15
Energy	772 GJ	Degradable Organic Carbon proportion – Paper and cardboard	0.4
Emission Factor – Scope 1	69.9 kg CO_2/GJ	Emission Factor – Food	0.9 t CO_2e
Emission Factor – Scope 3	5.3 kg CO_2/GJ	Emission Factor – Paper and cardboard	2.5 t CO_2e
CO_2e – Scope 1	54 t CO_2e	Emission Factor – Concrete, metals, glasses, plastic	0 t CO_2e
CO_2e – Scope 3	4 t CO_2e	CO_2e – Scope 3 – Food (project duration)	46 t CO_2e
CO_2e – TOTAL	**58 t CO_2e**	CO_2e – Scope 3 – Paper and cardboard (project duration)	342 t CO_2e
		CO_2e – Scope 3 – TOTAL (construction phase)	**388 t CO_2e**
GHG metrics	**Assumptions**	**GHG metrics**	**Assumptions**
Electricity		**Transport — petrol for commuting**	
Electricity purchased – project duration	93,460 kwh	Volume of fuel	294 kL
Emission Factor – Scope 2	0.89 kg CO_2e/kwh	Energy Content Factor	34.2 GJ/kL
Emission Factor – Scope 3	0.18 kg CO_2e/kwh	Energy	226,968 GJ
CO_2e – Scope 2	83 t CO_2e	Emission Factor – Scope 1	67.1 kg CO_2/GJ
CO_2e – Scope 3	17 t CO_2e	Emission Factor – Scope 3	5.3 kg CO_2/GJ
CO_2e – TOTAL	**100 t CO_2e**	CO_2e – Scope 1	675 t CO_2e
		CO_2e – Scope 3	53 t CO_2e
		CO_2e – TOTAL	**728 t CO_2e**

Table 15.5 Emissions calculations during construction of the project for plant transport, electricity and waste

GHG metrics	Assumptions
Vegetation loss	
Assumed type of vegetation area for clearing	Grasslands
Area	1.82 ha
Emission factor-breakdown of biomass on-site (decomposition)	7.4 t CO_2e/ha
Carbon sequestration potential — single tree	0.268 t CO_2e
Scope 1 emissions-site decomposition	13.47 t CO_2e
Scope 1 emissions- tress felled	0 t CO_2e
CO_2e – TOTAL	**13.47 t CO_2e**

The combined total tonne CO_2 emissions for project during construction as identified in the elements presented in Table 15.4 and Table 15.5 would equate to 1,466 tonne CO_2e.

15.4 Operation emissions

GHG emissions during the project's operation would be associated mainly with operating the light rail facilities once they are completed. These would be considered indirect emissions (Scope 2 emissions) because they would not be emissions from the light rail facilities but from off-site generation of electricity to power the facilities.

Electricity consumption associated with the project's operation relates to:

- light rail vehicles using the rail line (assessed against a base case, refer to Section 15.4.1)
- energy associated with operating light rail infrastructure, such as at stops, signalling, underpass or tunnel lighting.

Other aspects of the project resulting in emissions include:

- energy to maintain project infrastructure (plant and equipment)
- embodied energy from materials used to maintain light rail infrastructure.

15.4.1 Light rail vehicles (rolling stock)

Light rail vehicles operating on the project would be electric multiple unit vehicles operating from an overhead power reticulation system. As such, emissions would relate to the generation of electricity elsewhere, and there would be no significant point source emissions from the light rail vehicles.

The operation of additional light rail services on the extended rail line would result in increased GHG direct emissions through increased electricity use. However, this increase is expected to be small on a per capita basis (i.e. the amount of electricity consumed relative to the number of passengers using the light rail services), and is likely to be offset by minimising increases in GHG emissions from private motor vehicles — on the basis that the project is expected to generate a modal shift from private cars to public transport (i.e. existing motorists use the train service instead of private vehicles).

Furthermore, the proposed construction of an integrated movement corridor is expected to reduce private vehicle use through increased active transport around the project area, such as walking and cycling.

15.4.2 Light rail infrastructure

The daily operation of light rail stops would generate GHG emissions. The main sources of indirect emissions would come from lighting, CCTV cameras and electronic indicators. The operation of light rail stops is not expected to contribute significantly to the overall GHG emissions from the project. Preliminary data suggests the existing system consumes energy as shown in Table 15.6.

Table 15.6 Energy consumption for the existing light rail system

	Energy use	GHG emissions (tCO_2-e)	
	Electricity (kWh)	**Monthly**	**Annual**
Substations	135,000 kWh	144.45	1733.4
Stops	2,000 kWh	2.14	25.68
Main depot/offices	25,000 kWh	26.75	321
TOTAL	25,000 kWh	173	2080

The single largest component is derived from the substations, which account for the traction power demand, which delivers power to the light rail vehicles and other infrastructure.

15.4.3 Maintenance

The project would also generate indirect GHG emissions during the maintenance of stops, track work and associated infrastructure, from using maintenance plant and equipment and embodied energy of maintenance waste and associated transport. These activities are not expected to generate a significant increase in GHG emissions.

15.4.4 Embodied energy of replacement infrastructure

The project would also generate indirect GHG emissions where various plant and equipment would require replacement parts, although this is expected to form a small portion of operations emissions.

15.5 Mitigation measures

According to the Commonwealth Department of Climate Change's National Greenhouse Inventory (Department of Climate Change 2009a), in 2007 transport in Australia was responsible for 78.8 Mt CO_2-e, which represented 14.6% of Australia's national emissions; NSW emitted 21.1 Mt CO_2-e during the same period (Department of Climate Change 2009b). Emissions directly attributable to the construction of the light rail infrastructure would therefore represent less than 1% of the NSW transport profile.

Nonetheless, there are a number of mitigation measures that can be applied to further reduce the contribution of the project's emissions. These carbon reduction measures are categorised under energy demand and energy efficiency improvements.

The major opportunities for mitigation can be derived from:

- selection of low embodied energy materials and construction approaches: the amount of energy embodied within structures can significantly change through using materials with a lower content of embodied energy, such as concrete and steel production, where, for example, recycled steel reduces carbon life cycle emissions by approximately 75%
- fuel efficiency: using fuel-efficient construction machinery and vehicles, as well as behavioural aspects associated with using this equipment, can significantly reduce emissions from these sources.

Table 15.7 details what carbon mitigation measures, or energy usage and GHG emission reduction measures could be taken to reduce the emissions associated with both constructing and operating the project's infrastructure.

As detailed in Chapter 8, a sustainability management plan (SMP) would be implemented as part of the detailed design of the project. The SMP would include a series of initiatives aimed at reducing energy usage and GHG emissions that would be applied throughout the project's construction and operation. A list of the potential initiatives that would be considered for inclusion in the SMP is presented in Table 15.7.

Table 15.7 Potential energy usage and GHG emission reduction measures

Phase	Reduce energy/GHG intensity	Materials	Fuel management and sustainable transport	Equipment, labour and management	Waste	Design
Site establishment	Use energy efficient electrical appliances.	Consider suppliers who have some kind of low carbon policy.	Hire local staff as much as possible to reduce emissions associated with commuting.	Source equipment and materials locally to reduce emissions associated with their transportation.	Vegetation clearing — consider re-use of cleared materials and avoid onsite burning.	Use renewable energy sources (e.g. passive solar heating) wherever feasible.
	Install occupancy-sensor lighting and timer switches on lighting to make the best use of building spaces.	Consider suppliers that have an accredited environmental management system. Identify concrete suppliers who use sustainable procurement approaches	Promote public transport modes for commuting workers, sub-contractors.	Give preference to providers of environmentally friendly maintenance and recycling services (e.g. non-toxic cleaners).	Consider the efficiency of mode of transport, e.g. bogey tippers vs. trucks, when disposing of materials.	Minimise need for additional heating, ventilation and lighting through landscape design that is sensitive to micro-climatic conditions.
	Purchase green power to minimise GHG emissions associated with electricity use.	Follow *Waste Avoidance and Resource Recovery Act 2001* waste hierarchy.	Give preference to providers that use cleaner fuels.		Establish recycling programs for items like packaging.	In purchasing concrete, plan quantities in advance to avoid bottle-necks of over/under supply.
	Install energy metering and switching for energy management purposes.	Minimise vegetation clearing.			Document waste streams in a waste management plan.	
Construction and operation	Assess energy efficiency when selecting equipment (e.g. energy ratings).	Use recycled materials (e.g. recycled steel content, recycled aggregate) as much as reasonably possible to minimise the lifespan impact ('Scope 3') of GHG in production.	Consider use of biofuels (e.g. Biodiesel or ethanol) to reduce GHG emissions associated with construction.	Maintain equipment regularly to ensure optimum operations and fuel efficiency.	Consider items that are easy to recycle such as steel, concrete, pallets and paper and packaging.	Specify waste reduction and recycling in the contracts for the designer and the construction contractor(s).
	Where possible, shift more efficient vehicles and machinery into higher duty cycles and less-efficient ones to lower duty jobs.		Fill fuel tanks to 95% of capacity to allow for expansion and reduce spillage.	Log fuel use by vehicle and machinery to help identify fuel leaks and poorly performing vehicles.	Minimise onsite concrete dust, air and water pollution.	Plan delivery schedules so that there are fewer and shorter trips.

Phase	Reduce energy/GHG intensity	Materials	Fuel management and sustainable transport	Equipment, labour and management	Waste	Design
Construction and operation	Avoid prolonged idling: develop a policy about idling times and monitor it.	Use recycled concrete and aggregate as often as possible to minimise embodied energy profile.		Where appropriate, combine the loads of small vehicles into one larger vehicle.	Store materials properly to avoid waste.	
	Throttle down and switch off construction equipment when not in use.	Use materials of low GHG intensity where feasible (e.g. pre-fabricated inputs).		Switch off truck engines when they await loading and unloading.	Emphasise to building designers that waste reduction is a priority.	Design facilities to comprise prefabricated components
	Install energy-saving devices like power factor regulators and drive controls on energy-intensive equipment.	Salvage re-usable materials from site, e.g. wood beams and railings.		Optimise local transport routing for construction equipment.	Use prefabricated components to reduce waste	
	Consider closer sources of concrete suppliers.	Source building materials locally as much as possible.	Train staff to increase energy efficiency awareness, e.g. improved maintenance	Where control technologies can do so, seek to improve energy consumption of light rail vehicles		Conduct training of staff to increase energy efficiency awareness.
	Purchase green power to minimise GHG emissions associated with electricity use.					
Decommissioning	Use equipment that is rated as more fuel efficient		Give preference to providers that use cleaner fuels	Source equipment and materials locally to reduce emissions associated with their transportation	Consider the efficiency of mode of transport e.g. bogey tippers vs. trucks when disposing of materials.	Where possible, design for eventual demobilisation.
				Give preference to providers of environmentally friendly maintenance and recycling services		