Melbourne Metro Rail Project

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Greenhouse Gas Impact Assessment

Melbourne Metro Rail Authority

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Glossary and Abbreviations

Acronym	Definition
AASS	Actual Acid Sulfate Soil
AC	Alternating Current
AGEIS	Australian Greenhouse Emissions Information System
AGO	Australian Greenhouse Office
AHU	Air Handling Unit
AIRAH	Australian Institution of Refrigeration, Air-conditioning and Heating (Handbook 2013), energy consumption targets for building types in Melbourne
AJM JV	Aurecon, Jacobs, Mott MacDonald, Joint Venture in association with Grimshaw
ASR	Acid Sulfate Rock
AusLCI	Australian National Lifecycle Inventory Database
BAU	Business As Usual
BPIC	Australian Building Products Innovation Council
BP LCI	Building Products Lifecycle Inventory
CCP	Cities for Climate Protection
CEFC	Clean Energy Finance Corporation
CIBSE	Chartered Institution of Building Services Engineers (UK)
COO	Concept of Operations (PTV)
COP	Conference of the Parties
CPLU	Cranbourne-Pakenham Line Upgrade (a separate PTV project)
DC	Direct Current
EIS	Environment Impact Statement (e.g. in NSW statute)
EMP	Environmental Management Plan
EPA Vic	Environment Protection Authority Victoria
EPRs	Environmental Performance Requirements
ESD	Environmentally Sustainable Design

Acronym	Definition
GFRP	Glass fibre reinforced polymer
GGI	Greenhouse Gas (emissions) Intensity
GHG	Greenhouse Gas
GWP	Global Warming Potential
HCMT	High Capacity Metro Train
HFC	Hydrofluorocarbons
HV	High voltage
HVAC	Heating, Ventilation and Air-Conditioning
IPCC	Intergovernmental Panel on Climate Change
IS	Infrastructure Sustainability (Rating Tool)
ISCA	Infrastructure Sustainability Council of Australia
ISO	International Standards Organization
ITT	Immersed Tube tunnel
LCA	Lifecycle Assessment
LCI	Lifecycle Inventory
LED	Light Emitting Diode, a semiconductor device that converts electricity into light
LGA	Local Government Area
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
MM	Melbourne Metro
MSD	Melbourne Statistical Division
MTM	Metro Trains Melbourne (current operator)
MURL	Melbourne Underground Rail Loop (existing City Loop)
NEPM	National Environment Protection Measure
NCC	National Construction Code (2015), energy consumption for common building spaces
NGER	National Greenhouse Gas and Energy Reporting

Acronym	Definition
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substance
OPC	Ordinary Portland Cement
OPE	Over Platform Extract
p.a.	per annum (year)
PASS	Potential Acid Sulfate Soil
PEM	Protocol for Environmental Management (Greenhouse gas emissions and energy efficiency in industry 2002)
PIW	Prescribed Industrial Waste
PKT	Passenger Kilometres Travelled
PLCs	Programmable Logic Controllers
PT	Post Tensioned (Beams)
PTV	Public Transport Victoria
PV	Photovoltaic (Cells)
QS	Quantity Surveyor
RCA	Recycled Concrete Aggregate
RET	Commonwealth Renewable Energy Target
SCM	Supplementary Cementitious Materials
SEPP (AQM)	State Environment Protection Policy (Air Quality Management)
SFRC	Steel fibre reinforced concrete
SFRS	Steel fibre reinforced shotcrete
SMP	Sustainability Management Plan
TBM	Tunnel Boring Machine
TES	Track Extraction System
TRG	Technical Reference Group
TSA	Temporary Stockpile Area
TVS	Tunnel Ventilation System
tphpd	trains per hour per day

Acronym	Definition
UNFCCC	United Nations Framework Convention on Climate Change
VITM	Victorian Integrated Transport Model
VKT	Vehicle Kilometres Travelled
WASS	Waste Acid Sulfate Soil. Comprises disturbed PASS, AASS and/or ASR classified in accordance with EPA Publication 655.1 Acid Sulfate Soils & Rock 2009

Executive Summary

This report provides an assessment of the greenhouse gas (GHG) emissions associated with the construction and operation of the Melbourne Metro Rail Project (Melbourne Metro). The assessment includes consideration of energy consumed during the construction and operation of the project, including the effects and impacts associated with implementation of best practice GHG abatement initiatives.

The Melbourne Metro would comprise two nine-kilometre-long rail tunnels from Kensington to South Yarra, travelling underneath Swanston Street in the CBD and connecting the Sunbury and Cranbourne/Pakenham railway lines to form the new Sunshine-Dandenong Line. New underground stations would be constructed at Arden, Parkville, CBD North, CBD South and Domain. Other key project infrastructure includes train/tram interchanges at Parkville and Domain stations, and rail tunnel entrances at Kensington (western portal) and South Yarra (eastern portal).

The Environment Effects Statement (EES) Scoping Requirements for Melbourne Metro requires that the EES provides details of all project components including aspects of the operational phase of the project that could give rise to environmental effects. Whilst construction impacts are considered in detail, this GHG assessment also models GHG emissions from the operational phase, which is enabled by construction of Melbourne Metro. Melbourne Metro, ultimately as a construction project, has impacts on operational GHG emissions into the future when compared with the 'no Melbourne Metro' scenario which must therefore be assessed.

Methodology

The methodology for the GHG assessment was prepared in accordance with the requirements of the State Environment Protection Policy (Air Quality Management) (SEPP) Protocol for Environmental Management (PEM): Greenhouse Gas Emissions and Energy Efficiency in Industry, which includes mandatory consideration of energy efficiency and best practice GHG abatement.

Satisfying the objectives of SEPP AQM and the PEM would be met with Melbourne Metro's commitment to implementation of best practice GHG abatement during construction and operation. As such, modelling of GHG emissions has been undertaken considering both a Business-As-Usual (BAU) base case and best practice GHG abatement scenario to demonstrate the reduction in GHG emissions.

The assessment has included the effects of the passenger mode shift as indirect (Scope 3) operational GHG emissions, comparing Melbourne transport GHG emissions of the 'with Melbourne Metro' scenario against the 'no Melbourne Metro' scenario using outputs from the Victorian Integrated transport Model (VITM) provided by PTV.

Sustainability Performance Targets

The following sustainability performance rating schemes and targets are applicable to the project and this GHG assessment:

- ISCA IS rating system (*Infrastructure Sustainability Council of Australia – Infrastructure Sustainability*) for 'Design' and 'As-built' ratings, achieving a minimum overall score of 70 ('Excellent' rating)
- achieve a minimum 5 star rating against Green Star *(Green Building Council of Australia)* 'Design' and 'As-built' certification for stations.

MMRA sustainability performance targets and requirements applicable to the implementation of these rating schemes include:

- Concept Design to achieve reductions in Scope 1 and Scope 2 GHG emissions by a minimum of 20 per cent below a reference footprint (base case), excluding the use of renewable energy, over the infrastructure lifecycle (construction and operation)

- 20 per cent of energy to be sourced from renewable sources for the infrastructure lifecycle (construction and operation phases) through either:
  - Generation of onsite renewable energy; and/or
  - Use of alternative fuels; and/or
  - Purchase of renewable energy from an Australian Government accredited renewable energy supplier
- Reduce materials lifecycle GHG impact by 15 per cent below the base case
- Reduce Portland cement content in concrete by 30 per cent across all concrete used in the project compared to a base case.

The required achievements under these schemes would be a mandatory contract requirement.

Construction Phase Impact Assessment

It is estimated that total GHG emissions from construction of Melbourne Metro adopting BAU GHG abatement would be approximately 642 kt CO_2-e. This includes embodied energy (GHG emissions associated with the extraction, processing and manufacture of construction materials) from construction of Melbourne Metro stations, tunnels (including cross passages and emergency access shafts), Western Turnback, and High Capacity Metro Train (HCMT) rolling stock (includes only the difference in HCMT rolling stock between the 'with Melbourne Metro' and 'no Melbourne Metro' scenarios). Embodied emissions of construction materials represent the highest emissions source at 66.9 per cent of the total construction BAU carbon footprint (with construction of rolling stock representing 3.1 per cent of the total footprint). Fuel consumption from construction plant and equipment, and trucks, also represents a key contribution to the overall construction GHG footprint (15.3 per cent).

In order to meet the project's sustainability requirement and targets defined above, the following examples are best practice GHG abatement initiatives among others that would need to be considered and implemented during detailed design and construction, or have already been captured in the Concept Design:

- Reduce the Portland cement content in concrete (high embodied energy content) by 30 per cent across all concrete used in the project compared to the base case. Significant reductions in CO_2-e emissions could be achieved by partial replacement of cement with fly ash and/or slag. This has been captured in the Concept Design
- Use steel fibres instead of steel reinforcing bar in the segmental lining of tunnels where feasible thus reducing quantities of steel required – 35 kg of steel fibre per m^3 of concrete versus 135 kg of steel reinforcement per m^3 of concrete. This has been captured in the Concept Design
- Use of Post Tensioned (PT) Beams and slabs to ground and concourse levels of stations; significantly reduces the quantity of the conventional steel reinforcement (captured in Concept Design)
- Consideration of the use of biofuels for construction plant and equipment
- High efficacy and energy efficient Light Emitting Diode (LED) construction lighting for night-time works
- Intelligent controls/sensors for lighting
- Purchase of accredited GreenPower to supplement electricity purchased to operate equipment, e.g. tunnel boring machines (TBMs) – this is also a PTV Project Requirement.

Total GHG emissions from construction under this best practice scenario, which assumes the project sustainability requirements and targets would be met through best practice GHG abatement initiatives, would reduce to approximately 543 kt CO_2-e from the BAU scenario footprint of 642 kt CO_2-e. Embodied energy in materials would represent 68 per cent of the best practice GHG footprint (including construction of rolling stock). Under this best practice scenario, construction would represent approximately 11 per cent of total GHG emissions across the infrastructure lifecycle of the project (construction and operation over a 100-year design life).

There are no significant issues with the proposed alignment or infrastructure at each precinct (either Concept Design or alternative design options), with respect to construction GHG emissions. For example, whether the vertical alignment of the tunnels (Precinct 1) is above or below the CityLink tunnels is considered to be immaterial to the overall GHG footprint (for both construction and operation).

Operational Phase Impact Assessment

The significant sources of operational emissions directly associated with operation of the project include traction energy of trains (High Capacity Metro Train (HCMT)) operating within Melbourne Metro tunnels, and energy consumption at stations, tunnels, portals and emergency access shafts.

'Day One' of opening of Melbourne Metro is planned for 2026, and would comprise Standard (7-car) HCMTs in timetable running only. The Standard HCMTs are being introduced across the larger Metro network as part of the State Government's Cranbourne-Pakenham Line Upgrade (CPLU), which is a separate PTV project.

Extended (10-car) HCMTs would commence timetable running on the Melbourne Metro after the first several years of the project as part of PTV's 'Extended Program'. The Melbourne Metro program business case identified a series of subsequent investments with benefits substantially relying on 'future-proofing' elements on the Melbourne Metro operational design. An Extended Program including a range of these investments to enable the operations and passenger catchment of the Sunshine-Dandenong line to be expanded was therefore included in the business case to demonstrate the longer-term benefits of the Melbourne Metro investment.

Annual GHG emissions from operation the project (portal to portal) are estimated to be 47.6 kt CO_2-e per annum in the first year of opening (2026), increasing to 55.7 kt CO_2-e per annum after five years of opening (2031) due to implementation of the Extended Program, and reducing to 37.6 kt CO_2-e per annum after 20 years of opening (2046). This assumes the implementation of best practice GHG abatement initiatives, e.g. 25-27 per cent reduction in energy consumption from regenerative braking on HCMTs compared to a BAU scenario, plus 20 per cent reduction from purchase of accredited GreenPower (Project Performance Requirement). The reduction over time is due to the projected decline in GHG intensity of electricity generation in Victoria as the state reduces its reliance on brown coal and moves to a more renewable electricity market.

GHG emissions from traction energy represent 56 per cent of the overall carbon footprint for the infrastructure lifecycle of the project (i.e. both construction and operation over a 100-year design life), largely due to the relatively high energy requirements to operate the Extended (10-car) HCMTs.

Melbourne Metro would allow for a much larger fleet of Standard and Extended HCMT rolling stock to operate across the Metro, and significantly higher vehicle kilometres travelled (VKTs) of the HCMTs, compared to the 'without Melbourne Metro' scenario. Although the Extended HCMT is heavier than the Standard HCMT (and therefore consumes more power per VKT), it also carries more passengers, which counteracts the additional power consumption. When considering power consumption per passenger kilometre travelled (PKT), there is an estimated reduction in energy consumption (kWh/PKT) of 19.4 per cent and 23.6 per cent for operation of the Standard and Extended HCMT, respectively, compared to the existing 6-car fleet and with implementation of best practice regenerative braking.

When considering the impacts of the operation of the project on the wider transport network, there is a net increase in transport GHG emissions due to the passenger mode shift, compared to the 'without Melbourne Metro' scenario (using 2026, 2031 and 2046 as study years, or operational scenarios).

Although this impact assessment report concludes there is a net increase in transport GHG emissions over time as a result of the project (compared to the 'no Melbourne Metro' baseline scenario) due to the phased implementation of Extended HCMTs, the reality is that GHG emissions are likely to reduce as a result of the 'greening' of the electricity grid in Victoria over the next 30-100 years – noting that GHG intensity projections are not provided beyond 2046 in this assessment. As such, in reality it is expected that the project would contribute positively to Melbourne's future GHG inventory and carbon footprint, over the project's 100-year design life.

The 'functional unit' (GHG indicator) for the operation of the project considers *CO_2-e emissions per PKT.* This has been calculated for all operations portal to portal and uses modelled patronage data provided by PTV. Assuming best practice operational GHG emissions, the functional unit has been determined to be 130 grams CO_2-e per PKT in 2026 and reducing to 55 grams CO_2-e per PKT by 2046. This compares to 150 grams CO_2-e per PKT for cars (projected to 2030) and approximately 90 grams CO_2-e per PKT for the projected national average for passenger rail (projected to 2030) – although it is noted the GHG intensity of electricity generation is considerably lower in all other states and territories.

Considering CO_2-e emissions per PKT across all transport modes is a better indicator to assess the carbon efficiency of the project, due to the knock-on effects (benefits) of the project on other transport modes, i.e. rail (electric and V/Line), cars, trucks, buses and trams. Under this type of operational assessment, a net GHG indicator across the entire Melbourne transport network can be determined, for the operational scenarios of 2026, 2031 and 2046 'with' and 'without' Melbourne Metro. This is calculated by summing the annual estimated (modelled) GHG emissions (kt CO_2-e) across all transport modes, and dividing by the total passenger kilometres travelled (PKT) across all transport modes (as provided in the VITM outputs). When considering the movement of people across all transport modes, the project would provide a net reduction of 1.2 grams CO_2-e per PKT compared to the 'without Melbourne Metro' scenario after 20 years of operation (2046); this means there would be approximately a 1 per cent reduction in GHG emissions per PKT across the entire Melbourne transport network, compared to the 'no Melbourne Metro' scenario.

This demonstrates that the project allows for a greater carbon efficiency of transport operation (considering both public and private transport modes) across Melbourne as the project moves toward operating as a fully Extended Program i.e. making full use of the Extended HCMTs in timetable running. This is not surprising given the benefits of the project allowing for significant improvements in capacity for public transport and moving more people out of cars and onto passenger rail.

In order to meet the project's sustainability requirements and targets, the following examples are best practice GHG abatement initiatives (among others) that have been captured in the Concept Design:

- Traction energy: advanced regenerative braking on rolling stock to provide energy back into the electricity supply (25-27 per cent reduction from a BAU regenerative braking scenario)
- Geothermal piling at stations: incorporates pipework for a geothermal heat exchange system (to be further investigated in the Detailed Design)
- Variable speed drive escalators that enable a 'slow mode' when not in use
- Regenerative power on vertical transportation: elevators and escalators
- Optimise ventilation between stations and tunnels e.g. Air Handling Units (AHUs) to include bypass for reduced pressure drop opportunity, expanded temperature bands within transient spaces; platform screen doors
- Solar photovoltaics (PV) at Domain, Parkville and Arden stations, and transparent PV film for entry canopies at CBD North and CBD South
- Zone areas of the Heating, Ventilation and Air-Conditioning (HVAC) system to deal with separate areas that are known to have different occupancy periods and requirements.

Environmental Performance Requirements

The following Environmental Performance Requirements are recommended.

Environmental Performance Requirements
Develop and implement a Sustainability Management Plan to meet, as a minimum, the Melbourne Metro sustainability targets, including achieving the specified ratings under the Infrastructure Sustainability Council of Australia's *Infrastructure Sustainability Rating Tool* and the *Green Star Design and As Built Melbourne Metro Rail Tool*.
Monitor and report on how each of the best practice GHG abatement measures and sustainability initiatives identified in the Concept Design is implemented in the detailed design of the project and whether any additional measures not included in the Concept Design are feasible.

With the adoption of the final Environmental Performance Requirements outlined above, the residual rating for all risk issues identified during construction and operation is considered to be Low. As such, the impact of the project's GHG emissions is considered acceptable given the significant benefits and improvement the project makes to Melbourne's road and rail transport network. With consideration of the greening of the electricity grid over the next few decades in line with international, Commonwealth and Victorian Government climate change policy, it is expected that the project would also contribute positively to Melbourne's future GHG inventory and carbon footprint.

1 Introduction

This report provides an assessment of the greenhouse gas (GHG) impacts associated with construction and operation of the Melbourne Metro project. Related issues – traffic and transport – are addressed in Technical Appendix D *Transport*.

1.1 Project Description

The Melbourne Metro would comprise two nine-kilometre-long rail tunnels from Kensington to South Yarra, travelling underneath Swanston Street in the Central Business District (CBD), as part of a new Sunbury to Cranbourne/Pakenham line to form the new Sunshine-Dandenong Line.

The infrastructure proposed to be constructed as part of Melbourne Metro broadly comprises:

- Twin nine-kilometre rail tunnels from Kensington to South Yarra connecting the Sunbury and Cranbourne/ Pakenham railway lines (with the tunnels to be used by electric trains)
- Rail tunnel portals (entrances) at South Kensington and South Yarra
- New underground stations at Arden, Parkville, CBD North, CBD South and Domain with longer platforms to accommodate longer High Capacity Metro Trains (HCMTs). The stations at CBD North and CBD South will feature direct interchange with the existing Melbourne Central and Flinders Street Stations respectively
- Train/tram interchange at Domain station.

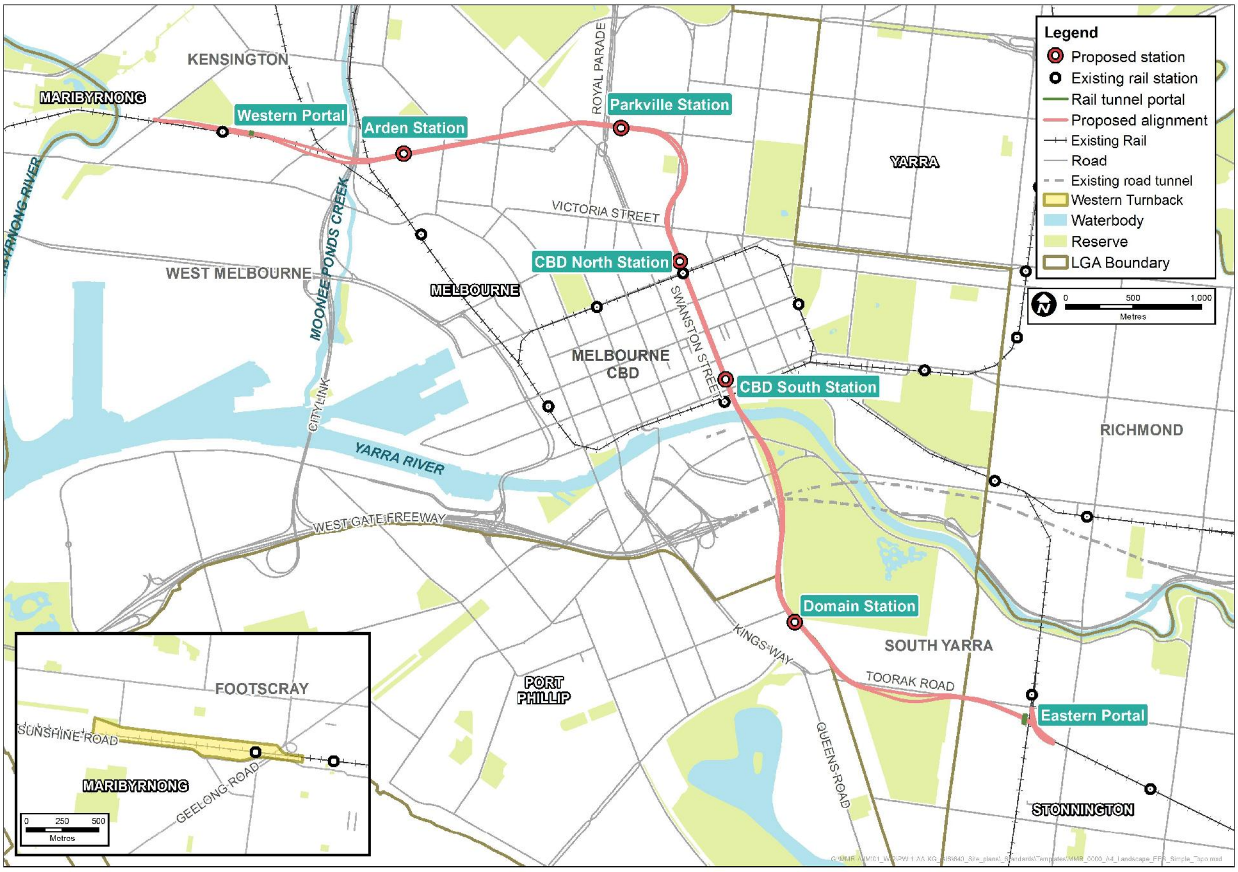

Figure 1-1 Map of the Melbourne Metro and five underground stations

Proposed construction methods would involve bored and mined tunnels, cut-and-cover construction of station boxes at Arden, Parkville and Domain and portals, and cavern construction at CBD North and CBD South. The project would require planning, environmental and land tenure-related approvals to proceed.

Operation of Melbourne Metro would involve the operation of new HCMTs. The trains are planned to be able to carry 1,100 passengers at rated performance (7-car), with the ability to be lengthened to 10-cars carrying 1,570 passengers at rated performance. It is expected by 2031 that Extended HCMT operation[1] would have been at least partially implemented on the Sunbury and Cranbourne/Pakenham corridor (with a mix of Standard HCMT and Extended HCMT operating on all lines), for the 'with Melbourne Metro' scenario (PTV, 2016).

1.2 Project Precincts

For assessment purposes within the EES the project area has been divided into precincts as outlined below. The precincts have been defined based on the location of project components and required construction works, the potential impacts on local areas and the character of surrounding communities.

The precincts are:

- Precinct 1: Tunnels (outside other precincts)
- Precinct 2: Western Portal (Kensington)
- Precinct 3: Arden station (including substations)
- Precinct 4: Parkville station
- Precinct 5: CBD North station
- Precinct 6: CBD South station
- Precinct 7: Domain station
- Precinct 8: Eastern Portal (South Yarra)
- Precinct 9: Western Turnback (West Footscray).

The nine precincts are shown in Figure 1-2.

As this GHG impact assessment considers GHG emissions associated with the project across all precincts as a whole, the assessment is not broken down by precinct as per other specialists' assessments. Section 1.3 further defines the study area of the GHG impact assessment.

[1] Extended HCMT refers to an extended HCMT design developed as part of the HCMT procurement. These trains are expected to cater for over 42% more passengers than the Melbourne Metro 'Day One' HCMT design through addition of intermediate carriages – resulting in a longer train (PTV, 2016).

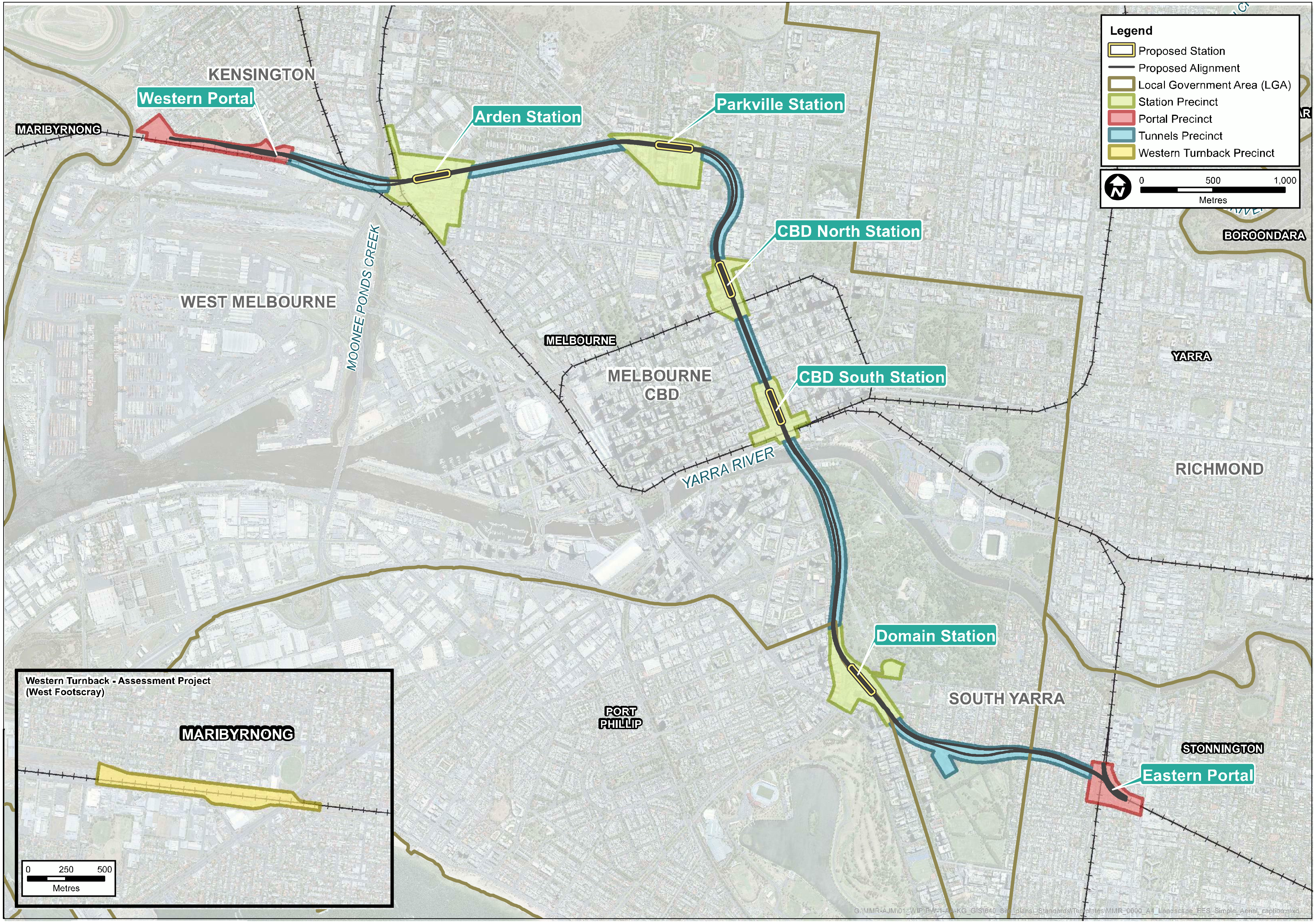

Figure 1-2 Melbourne Metro precincts

1.3 Study Area

The GHG impact assessment includes both construction and operational phases of the project. The study area is different for each, and is discussed below.

1.3.1 Construction

The study area for the GHG inventory for the construction phase includes areas directly related to the following construction activity and infrastructure:

- Stations
- Tunnels, including portals, cross passages and emergency access shafts
- Western Turnback.

Early works and wider network projects are not included within the study area and have been excluded from the GHG assessment boundary. Further commentary is provided in Section 4.6.2.

1.3.2 Operation

The scope of the GHG inventory for the operational phase 'with Melbourne Metro' includes all direct and indirect GHG emissions associated with operation of Melbourne Metro using the Concept Design as the benchmark. This includes all operational infrastructure portal to portal (including stations, tunnels and traction energy) and the Western Turnback.

The assessment and management of GHG emissions associated with operation of the project must also be considered over the larger Melbourne metropolitan area given the complexity of the project's influences on the regional transport network. This requires an assessment of the effects of trains operating across the Metro (i.e. beyond the Melbourne Metro tunnels) – and the knock-on effects to other transport modes – as a result of the operation of Melbourne Metro.

For consistency, the study area (or system boundary) for the GHG emissions estimation associated with transport and traffic predictions aligns with the regional operational boundary as defined in the Victorian Integrated Transport Model (VITM), given that the operational GHG footprint includes assessment of potential GHG reductions in some transport modes from change in mode share to public transport from the 'no Melbourne Metro' scenario. The same study area applies for both the 'no Melbourne Metro' and 'with Melbourne Metro' operational scenarios, to enable a direct comparison.

The geographical area covered in the first regional VITM was based on the Melbourne Statistical Division (MSD), which is the name given by the Australian Bureau of Statistics to the census division covering metropolitan Melbourne. The VITM has since expanded its coverage to include the growth areas in the western, northern and south-eastern suburbs. An indicative map of the VITM extents, and therefore the geographical extent of the transport network that has informed the operational GHG inventory, is provided in Figure 1-3.

The VITM includes both road and public transport modes. The key transport groups that are included in the VITM, and therefore included in the operational GHG inventory, are:

- Road-based vehicle types: cars, trucks (rigid, articulated, B-double, HPFV[2]) and buses
- Trains: Metro and V/Line
- Trams.

[2] High Productivity Freight Vehicles (HPFVs): not captured in VITM model until 2046. Access for HPFVs would include high quality, duplicated freeways and, within metropolitan Melbourne, access would be permitted on the major existing freeways and ring/link roads (VicRoads, 2015).

Figure 1-3 Victorian integrated transport model (VITM) network.

Source: GIS output from VITM (AJM JV); contains Vicmap Information © State of Victoria 2015

The scope of the GHG inventory for both the construction and operational phases of the 'with Melbourne Metro' scenarios includes the direct and indirect GHG emissions associated with the project, as outlined in Table 4-7 and Table 4-11. Indirect emissions may therefore be associated with sources which are outside of this geographical study area (e.g. generation of electricity which could be associated with a power plant geographically located outside of the VITM system boundary).

2 Scoping Requirements

2.1 EES Objectives

The following draft EES evaluation objective (Table 2-1) is relevant to the GHG impact assessment and identifies the desired outcomes in the context of potential project effects. It provides a framework to guide an integrated assessment of the environmental effects of the project, in accordance with the *Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978*.

Table 2-1 Transport connectivity draft evaluation objective

Draft EES evaluation objective	Key legislation
Transport connectivity: To enable a significant increase in the capacity of the metropolitan rail network and provide multimodal connections, while adequately managing effects of the works on the broader transport network, both during and after the construction of the project.	*Transport Integration Act 2010*
Project description and context: Describe aspects of the operational phase of the project that could give rise to environmental effects, including with regard to greenhouse gas emissions.	*Climate Change Act 2010* *Environment Protection Act 1970*

2.2 EES Scoping Requirements

The EES Scoping Requirements for Melbourne Metro require that the EES provide details of all the project components including aspects of the operational phase of the project that could give rise to environmental effects, including GHG emissions.

In addition, the following extracts from the Scoping Requirements, issued by the Minister for Planning, are relevant to the GHG emissions evaluation objective (Table 2-2).

Table 2-2 Transport connectivity scoping requirements

Aspect	Response
Design and mitigation measures	• Identify potential options and actions that could further mitigate adverse effects or optimise the transport system benefits of the project.

3 Legislation, Policy and Guidelines

Table 3-1 below summarises the relevant primary legislation that applies to the project and the implications, required approvals and interdependencies, and information requirements associated with obtaining approvals. Descriptions of all relevant legislation are contained in Appendix A of this report.

Table 3-1 Primary legislation and associated information

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies
International				
Kyoto Protocol	Refer to Appendix A of this report	Driver for setting of Commonwealth and State GHG legislation/policy and targets.	NA	NA
Greenhouse Gas Protocol by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI)[3]	Refer to Appendix A of this report	Methodology for GHG impact assessment.	NA	NA
ISO 14064-1:2006 Greenhouse gases – Part 1: Specification with guidance at the organisation level for quantification and reporting of greenhouse gas emissions and removals	Refer to Appendix A of this report	Includes requirements for the design, development, management, reporting and verification of the project's GHG inventory. Used as the standard for calculating lifecycle environmental impacts from materials (IS Materials Calculator); refer Section.	NA	Verification of the project's GHG inventory (modelled) would be undertaken as part of the ISCA IS rating scheme, which would be applied on the project. Actual annual GHG inventories would be prepared and reported by the constructor and operator.

[3] The first edition of The Greenhouse Gas Protocol: *A Corporate Accounting and Reporting Standard* (Corporate Standard) was published in 2001. Since then the GHG Protocol has built upon the Corporate Standard by developing a suite of calculation tools to assist companies in calculating their GHG emissions.

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies
Commonwealth				
National Greenhouse and Energy Reporting Act 2007 (NGER Act) ***National Greenhouse and Energy Reporting (Measurement) Determination 2008***	Refer to Appendix A of this report	Methodology and GHG emissions factors for impact assessment. The entity responsible for the operation of Melbourne Metro is likely to be required to report its Scope 1 and Scope 2 GHG emissions and energy consumption/production under *NGER Act* as the trigger thresholds are likely to be exceeded.[4] The construction contractor may also trigger reporting thresholds for annual Scope 1 and Scope 2 emissions during the construction phase.	NA	End of each financial year during construction. End of each financial year during operation.
Renewable Energy (Electricity) Act 2000 **Renewable Energy (Electricity) Regulations 2001**	Renewable Energy Target (RET)	Would inform the MMRA Sustainability Performance Targets, e.g. source a minimum 20 per cent of energy from renewable sources for the infrastructure lifecycle (construction and operation phases).	NA	Would inform decisions made with respect to energy consumption (construction and operation).
Clean Energy Legislation (Carbon Tax Repeal) Act 2014	Emissions Reduction Fund (ERF), as part of the Direct Action Plan	Emission reduction technologies implemented on Melbourne Metro could be eligible for offsets credited through the ERF[5].	Nil approvals, however the project would need to be registered in the scheme to participate. A contract would then need to be secured with the Australian Government by participating in an auction.	NA

[4] The current facility threshold is 25 kt or more of Scope 1 and Scope 2 greenhouse gas emissions expressed as carbon dioxide equivalents (CO_2-e) per annum, production of 100 TJ or more of energy per annum, or consumption of 100 TJ or more of energy per annum.
[5] There are a number of ERF methodologies that could be applicable to the Melbourne Metro. It is worth noting that to be eligible for the large-scale project methodology however, GHG abatement needs to average 250 kt CO_2-e per annum (which would not be the case for the Melbourne Metro). The land and sea transport methodology involves activities such as replacing or modifying existing vehicles, changing or modifying fuel sources or improving operational practices; it does not include solar or wind technologies.

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies
			A minimum of three scheduled audits across the seven-plus year crediting period is typically required. All scheduled audits need to establish reasonable assurance that the GHG abatement achieved and reported by the project is accurate.	
State				
Climate Change Act 2010	Victoria's Renewable Energy Roadmap (August 2015). Victorian Climate Change Adaptation Plan (March 2013).	Requirement to demonstrate how the Melbourne Metro would align with the Victorian Government strategies of responding to climate change (as presented in the Plan), under the EES process. Melbourne Metro contributing to state policy by purchase of 20 per cent accredited renewable energy.	NA	GHG abatement initiatives of the Melbourne Metro (construction and operation) to be captured in the Concept Design.
***Environment Protection Act 1970* (*EP Act*)**	State Environment Protection Policy (Air Quality Management) 2001 (SEPP AQM). Protocol for Environmental Management (PEM): Greenhouse gas emissions and energy efficiency in industry (2002).	Management of GHG emissions during construction and operation (ongoing monitoring, assessment, data collection and reporting). Utilisation of renewable energy sources during construction and operation. Ongoing best practice6 and continuous improvement.	No direct triggers for EPA Vic works approval for GHG as the project, as a whole construction project, is not a scheduled premises under the *Environment Protection Act 1970*. GHG assessment would be required as part of an EPA Vic works approval, if triggered by other	Satisfying the objectives of SEPP AQM and the PEM would be met with Melbourne Metro's commitment to implementation of best practice GHG abatement during construction and operation.

[6] Best practice is defined in the PEM as "the best combination of eco-efficient techniques, methods, process or technology used in an industry sector or activity that demonstrably minimises the environmental impact of a generator of emissions in that industry sector or activity…. 'Eco-efficient' means producing more goods and services with less energy and fewer natural resources, resulting in less waste and pollution."

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies
		EPA VIC has agreed that although the PEM only formally applies to scheduled premises under the *Environment Protection Act 1970*, adoption of the PEM as a performance stand is considered appropriate for the project and is the overarching regulatory instrument that should be used to inform the GHG assessment methodology and approach.	environmental discharge.	
Transport Integration Act 2010	This Act requires that all decisions affecting the transport system be made within the same integrated decision-making framework and objectives	Relates directly to the draft EES Evaluation Objective of Transport Connectivity. Strategic planning decisions must have regard to the impact of planning on the transport objectives of the State of Victoria.	NA	NA
Local				
City of Melbourne	*City of Melbourne Zero Net Emissions by 2020 – update 2014* aims to set the City of Melbourne (in Council operations and services) as a carbon neutral city by the year 2020.	Best practice GHG mitigation measures adopted during design, construction and operation of Melbourne Metro to reduce GHG emissions would complement the City of Melbourne's strategy.	NA. Local requirements are taken as guides only for a State project.	NA
City of Port Phillip	*Toward Zero – Sustainable Environment Strategy 2007.* The City is committed to achieving and sustaining zero GHG emissions in Council operations and services by 2020, and achieving a 50 per cent reduction in per capita community GHG emissions by	Best practice GHG mitigation measures adopted during design, construction and operation of Melbourne Metro to reduce GHG emissions would complement the City of Port Phillip's strategy.	NA. Local requirements are taken as guides only for a State project.	NA

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies
	2020 (based on 2006 levels).			
City of Stonnington	*Sustainable Environment Strategy.* The City of Stonnington is committed to reducing GHG emissions from Council operations and services by 20 per cent by 2015, and 30 per cent by 2020, compared to 2005 levels.	Best practice GHG mitigation measures adopted during the design, construction and operation of Melbourne Metro to reduce GHG emissions would complement the City of Stonnington's strategy.	NA Local requirements are taken as guides only for a State project.	NA
City of Maribyrnong	*Carbon Neutral Action Plan (2008)* City of Maribyrnong achieved its target of zero carbon corporate emissions in June 2015.	Best practice GHG mitigation measures adopted during the design, construction and operation of the Western Turnback (West Footscray Concept Design) to reduce GHG emissions would complement the City of Maribyrnong' s Action Plan.	NA. Local requirements are taken as guides only for a State project.	NA
Other documents of relevance				
Melbourne Metro Sustainability Targets[7]	Defines the sustainability targets for the project: 'Energy': (1) Achieve reductions in GHG emissions by a minimum of 20 per cent below the base case (Scope 1 and Scope 2 emissions), excluding the use of renewable energy, for the infrastructure lifecycle. (2) Of the remaining GHG emissions footprint, source a minimum of 20 per cent of energy from renewable	Project would be required to implement best practice GHG abatement measures for both the construction and operational phases, in order to meet these targets. GHG abatement initiatives are described within this report. These mandatory targets would be passed onto detailed design and construction contractors, and would be met largely through implementation of the ISCA IS and Green Star rating tools (refer below).	NA	NA

[7] Refer Technical Appendix W *Sustainability Principles and Approach*

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies
	sources for the infrastructure lifecycle through either: • generation of onsite renewable energy; and/or • use of alternative fuels; and/or • purchase of renewable energy from an Australian Government accredited renewable energy supplier. Materials and Waste: (1) Achieve a 15 per cent reduction in materials lifecycle impacts (measured through EcoPoints) below the base case. (2) Reduce Portland cement content in concrete by minimum 30 per cent and replace with supplementary cementitious materials across all concrete used in the project compared to the base case.			
ISCA IS rating system (Infrastructure Sustainability Council of Australia – Infrastructure Sustainability)	Benchmarks the sustainability features of the design, construction and infrastructure lifecycle of the project. ISCA credits applicable to GHG emissions: Ene-1 Energy and carbon monitoring and reduction Ene-2 Energy and carbon reduction opportunities Ene-3 Use of Renewable Energy Mat-1 Materials	*Ene-1:* Monitoring and modelling to demonstrate the Concept Design achieves a reduction of GHG emissions below a reference footprint, for Scope 1, Scope 2[8] and land clearing across the infrastructure lifecycle (construction and operation phases). Rating level achieved is dependent on percentage of GHG emissions reduction. MMRA is committed to a minimum of 20 per cent reduction ('Level 2' rating). Concept Design documentation to include a monitoring and modelling report	NA. Achievement under the IS rating system is a voluntary opportunity/reward that MMRA is seeking for the project. The base case reference footprint and report would require verification from ISCA.	Base case model for Ene-1 and Mat-1 credits has been prepared as part of the Concept Design documentation. GHG modelling and monitoring for the purposes of the ISCA IS Actual 'Design' rating would be undertaken at the completion of the Detailed Design phase of the project. GHG modelling and monitoring for the purposes of the ISCA IS Actual 'As-Built' rating would be undertaken at the completion of construction.

[8] Refer Section 4.1 for definition of Scope 1 and Scope 2 GHG emissions.

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies
		that is subject to external auditing. *Mat-1*: Monitoring and modelling to demonstrate the Concept Design achieves a reduction in materials lifecycle impacts compared to a reference footprint, as determined by the Materials Calculator.		
Green Star *(Green Building Council of Australia)*	Encourages a new approach to designing and constructing buildings by rewarding sustainability best practice and excellence.	Applicable to all stations (Design and As Built). The Green Star rating assesses the sustainability attributes of a station's building across nine categories. Melbourne Metro is proposing to achieve a 5 star rating.	NA. Green Star rating is a voluntary opportunity/reward that MMRA is seeking for the project.	NA

4 Methodology

This section describes the methodology adopted for the GHG impact assessment for both the construction and operational phases of the project.

4.1 Carbon Footprinting

A carbon footprint is an assessment of the lifecycle GHG emissions associated with a product, service or event. All GHGs (such as methane and nitrous oxide, as well as carbon dioxide) are aggregated and reported as a single number of 'carbon dioxide equivalents', hence when talking about carbon footprinting we mean an aggregated calculation of all GHGs.

Increasing concentrations of GHGs in the atmosphere are known to contribute to global warming; hence being able to reduce these emissions across the lifecycle would reduce the potential impact of the project on global warming.

GHG emissions can be attributed to a number of sources, both direct and indirect. Common direct sources for this project during construction would be emissions associated with the combustion of fuel in on-site plant and equipment. Indirect sources include those attributed to the generation of electricity used on site. Also considered an indirect source (embodied as GHG emission) is the manufacture and transport of construction materials to site.

The key GHG emissions for the project during operation would be indirect emissions associated with the purchase of electricity used to operate trains (traction power), stations and tunnels.

Satisfying the objectives of SEPP AQM and the PEM would be met with Melbourne Metro's commitment to implementation of best practice GHG abatement during construction and operation. As such, modelling of GHG emissions has been undertaken considering both Business-As-Usual (BAU) and best practice GHG abatement scenarios to demonstrate the reduction in carbon footprint as a result of the implementation of best practice GHG abatement initiatives.

4.2 Definitions and Terminology

A number of key terms are used consistently throughout this impact assessment. It is essential to understand the meaning of these terms within the context of the methodology used for the assessment.

4.2.1 Baseline

The 'no Melbourne Metro' scenario has been used as the baseline scenario for the purposes of determining a baseline GHG inventory for the Impact Assessment. The 'no Melbourne Metro' scenario is compared with the 'with Melbourne Metro' scenario for several operational scenarios (years) as defined in Table 4-1.

2011 has been defined as the 'existing case' for the operational assessment, which is the latest VITM reference year.

4.2.2 Business-As-Usual (Base Case)

ISCA (2015) defines the base case as 'a reference design … that is a suitable, early design accepted by key stakeholders as being representative of the original concept for the infrastructure development and using BAU technologies.'

The base case is used as a reference point from which to measure quantifiable reductions that would be realised as a result of abatement initiatives. It is particularly important to ensure the base case is defined prior to the Request for Tender (RFT) stage to drive genuine reductions upon this agreed base case. Melbourne Metro BAU construction and operational scenarios referred to throughout this assessment ultimately represent the base case.

4.2.3 Best Practice

The *Protocol for Environmental Management (PEM) – Greenhouse gas emissions and energy efficiency in industry* (EPA Vic Publication 824) is an incorporated document of the SEPP (AQM). The PEM sets out requirements for the management of GHG emissions and energy consumption, and provides guidance to industry on the steps that must be taken to identify and evaluate opportunities to reduce GHG emissions through best practice energy efficiency and GHG emissions management. Further details on the requirements of the PEM are provided in Appendix A of this report.

The Melbourne Metro best practice construction and operational scenarios referred to throughout this assessment therefore represent the base case carbon footprint *minus* the GHG emissions 'saved' due to best practice GHG abatement initiatives being captured in the design.

It is noted that evaluation processes such as the IS rating system may be usefully applied to help ensure that best practice is achieved in construction and through continuous improvement of operation.

4.2.4 Impact Assessment Scenarios

Table 4-1 summarises the construction and operational scenarios that have been used in the GHG impact assessment to assess the effects of the project.

Table 4-1 Definition of Impact Assessment Scenarios

Phase	GHG scenario / footprint	Description	Study year/s
Construction	Melbourne Metro BAU Construction	GHG inventory for construction of the Concept Design, assuming BAU GHG abatement. Also referred to as the 'base case'.	Total construction
Construction	Melbourne Metro Best Practice Construction	GHG inventory for construction of the Concept Design, assuming best practice GHG abatement.	Total construction
Operation (transport only)	Existing case	Latest VITM reference year (2011). Used as reference year for the 'no Melbourne Metro' and 'with Melbourne Metro' transport scenarios.	2011
Operation	Melbourne Metro BAU Operation	GHG inventory for operation of the Concept Design, assuming BAU GHG abatement. Also referred to as the 'base case'. Includes effects of the passenger mode shift (VITM) as Scope 3 emissions.	'Day One' of opening (2026) Five years after opening (2031): PTV Extended Program[9] 20 years after opening (2046)

[9] The Melbourne Metro program business case identified a series of subsequent investments with benefits substantially relying on 'future-proofing' elements on the Melbourne Metro operational design. An 'Extended Program' including a range of these investments to enable the operations and passenger catchment of the Sunshine-Dandenong line to be expanded was therefore included in the business case to demonstrate the longer-term benefits of the Melbourne Metro investment (PTV, 2016). For the Melbourne Metro project, this primarily allows for the operation of Extended (10-car) HCMTs in timetable running.

Phase	GHG scenario / footprint	Description	Study year/s
Operation	Melbourne Metro Best Practice Operation	GHG inventory for operation of the Concept Design, assuming best practice GHG abatement. Includes effects of the passenger mode shift (VITM) as Scope 3 emissions.	'Day One' of opening (2026) Five years after opening (2031): PTV Extended Program 20 years after opening (2046)
Infrastructure lifecycle	Melbourne Metro 'whole of project'	Construction and operation over 100-year project design life. Excludes effects of the passenger mode shift (VITM).	Total construction and cumulative 100 years of operation (2026-2126)

The system boundaries of the GHG inventories for each of the scenarios defined above are further detailed in Section 4.6 and Section 4.7.

4.3 Carbon Footprinting Standards

The methodology of the GHG impact assessment follows the principles set out in the following documents:

- The Greenhouse Gas Protocol (GHG Protocol) by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI)
- ISO 14064-1:2006 Greenhouse gases – Part 1: Specification with guidance at the organisation level for quantification and reporting of greenhouse gas emissions and removals
- ISO 14040:2006 Environmental management – Lifecycle assessment – Principles and framework and ISO 14044:2006 Environmental management – Lifecycle assessment – Requirements and guidelines. These standards are applicable to the calculation of materials lifecycle impacts using the IS Materials Calculator (refer Section 4.6.3.3.1).

The GHG inventories for this assessment have been calculated in accordance with the principles of the internationally accepted GHG Protocol. According to the GHG Protocol, GHG emissions are split into three categories, known as 'Scopes'. Scopes 1, 2 and 3 are defined by the GHG Protocol and can be summarised as:

- **Scope 1** – Direct emissions of GHGs from sources that are owned or operated by a reporting organisation (*examples – combustion of diesel in company-owned vehicles or used in on-site plant and equipment*)
- **Scope 2** – Indirect emissions associated with the import of energy from another source (*examples – import of electricity from the grid, or heat*)
- **Scope 3** – Other indirect emissions, other than energy imports (above) which are a direct result of the operations of the organisation, but from sources not owned or operated by them and due to upstream or downstream activities (*examples include indirect upstream emissions associated with the extraction, production and transport of purchased construction materials; and business travel (by air or rail)*).

The Scope 1, 2 and 3 emissions can be best illustrated using Figure 4-1.

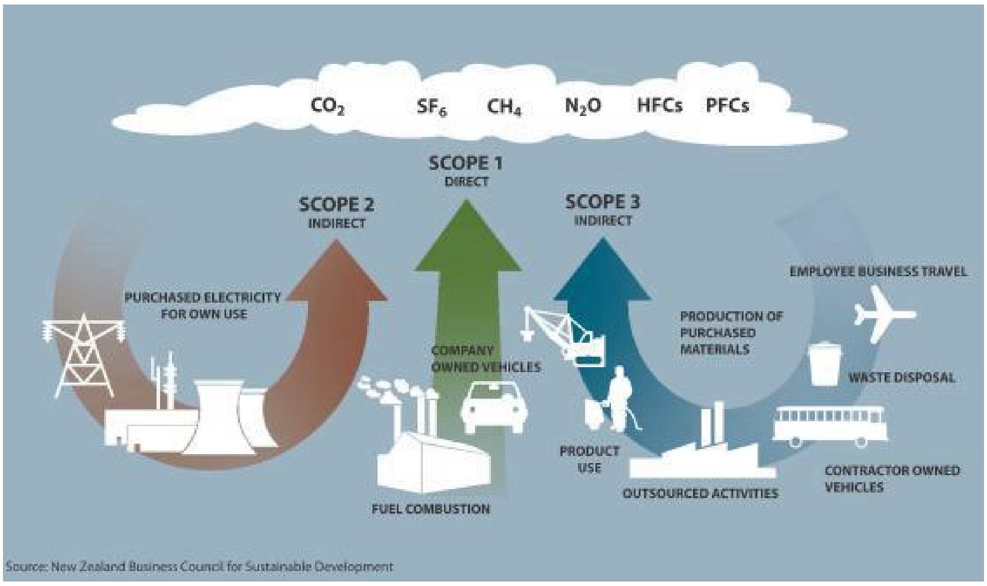

Figure 4-1 Overview of scopes and emission sources

Source: New Zealand Business Council for Sustainable Development, in EPA Victoria's greenhouse gas inventory management plan: 2012–13 update (Pub 1562, April 2014).

The GHG Protocol (and many other reporting schemes) requires the reporting of Scope 1 and 2 sources, whilst reporting of Scope 3 sources is optional. The reporting of 'significant Scope 3 emissions sources' is recommended by the GHG Protocol if they represent a material contribution to overall project GHG emissions. It should be noted that Scope 3 GHG emissions are not reported under the NGER Scheme but Scope 3 emissions factors are available through Australia's National Greenhouse Accounts Factors publications to support carbon footprinting (refer to Section 4.6.3.2).

For the purposes of this GHG impact assessment for Melbourne Metro, Scope 1, Scope 2 and significant Scope 3 emissions have been determined for all operating and construction scenarios. Scope 3 emissions have been included as they represent a material contribution to the overall GHG construction and operational footprints.

4.4 Risk Assessment

4.4.1 Overview

An Environmental Risk Assessment has been completed for potential environmental impacts of Melbourne Metro. The risk-based approach is integral to the EES as required by Section 3.1 of the Scoping Requirements for the EES.

The overall risk assessment process adopted was based on AS/NZS ISO 31000:2009, as illustrated in Figure 4-2.

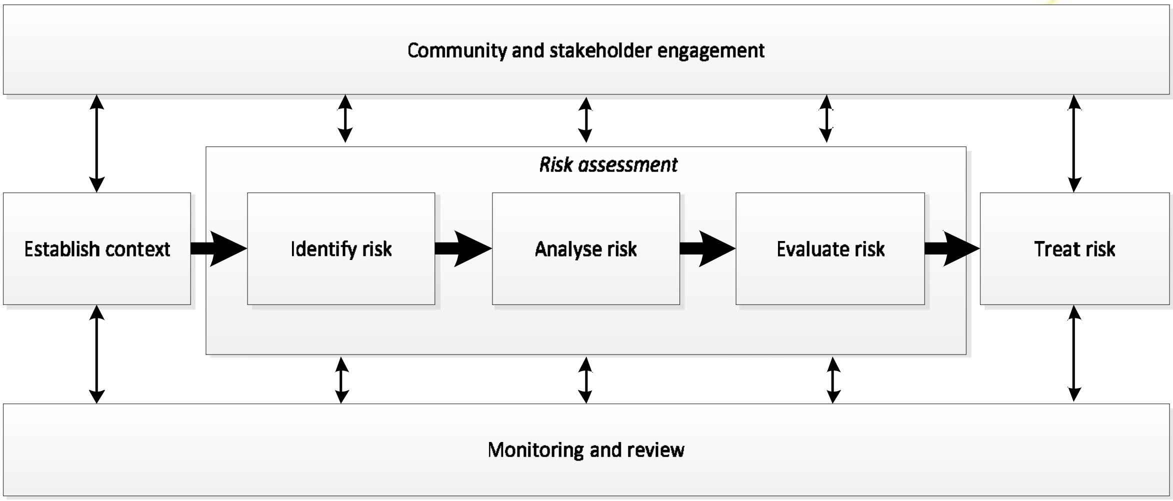

Figure 4-2 Overview of AS/NZS ISO 31000-2009 risk process

The following tasks were undertaken to determine the impact pathways and assess the risks:

- Setting of the context for the environmental risk assessment
- Development of consequence and likelihood frameworks and the risk assessment matrix
- Review of project description and identification of impact assessment pathways by specialists in each relevant discipline area
- Allocation of consequence and likelihood categories and determination of preliminary initial risks
- Workshops with specialist team members from related discipline areas focussing on very high, high and moderate initial risks to ensure a consistent approach to risk assessment and to identify possible interactions between discipline areas
- Follow-up liaison with specialist team members and consolidation of the risk register.

A more detailed description of each step in the risk assessment process is provided in Technical Appendix B *Environmental Risk Assessment Report.*

4.4.2 Context

The overall context for the risk assessment and a specific context for each specialist study is described in Technical Appendix B *Environmental Risk Assessment Report*. The context describes the setting for evaluation of risks arising from Melbourne Metro. The specific context for the GHG impact assessment follows:

> *GHGs absorb the sun's heat in the Earth's atmosphere and when accumulating at increasing levels, contribute to the warming of the planet, with potential adverse consequences into the future. A significant proportion of GHG emissions produced from human activities come from the combustion of carbon-based fuels. GHGs are generated at a local level but have potential impacts at a global level and therefore need to be considered in this context.*
>
> *Melbourne Metro has potential to generate GHGs from use of energy derived from combustion of carbon (e.g. coal, oil or gas). This could occur during construction from, for example, emissions from construction plant and equipment, or during operation from consumption of energy by trains or by station and tunnel ventilation and lighting systems. Operational GHG emissions associated with the project have been considered over the larger Melbourne metropolitan area, given the complexity of the project's influences on the regional ground-based transport network. Best practice GHG abatement measures have been incorporated into the Concept Design (e.g. regenerative braking on trains, regenerative braking on vertical transportation at stations, in-tunnel temperature monitoring and adaptive*

response for tunnels ventilation) and during construction (e.g. use of biofuels) to reduce GHG emissions across the infrastructure lifecycle of the project.

The likelihood rating criteria used in the risk assessment is shown in Table 4-2.

Table 4-2 Likelihood rating criteria

Level	Description
Rare	The event is very unlikely to occur but may occur in exceptional circumstances.
Unlikely	The event may occur under unusual circumstances but is not expected.
Possible	The event may occur once within a five-year timeframe.
Likely	The event is likely to occur several times within a five-year timeframe.
Almost Certain	The event is almost certain to occur one or more times a year.

The consequence criteria framework used in the risk assessment follows below in Table 4-3. This framework has been used to develop criteria specifically for the GHG impact assessment.

Table 4-3 Consequence framework

Level	Qualitative description of biophysical/ environmental consequence	Qualitative description of socio-economic consequence
Negligible	No detectable change in a local environmental setting.	No detectable impact on economic, cultural, recreational, aesthetic or social values.
Minor	Short-term, reversible changes, within natural variability range, in a local environmental setting.	Short-term, localised impact on economic, cultural, recreational, aesthetic or social values.
Moderate	Long-term but limited changes to local environmental setting that are able to be managed.	Significant and/or long-term change in quality of economic, cultural, recreational, aesthetic or social values in local setting. Limited impacts at regional level.
Major	Long-term, significant changes resulting in risks to human health and/or the environment beyond the local environmental setting.	Significant, long-term change in quality of economic, cultural, recreational, aesthetic or social values at local, regional and State levels. Limited impacts at national level.
Severe	Irreversible, significant changes resulting in widespread risks to human health and/or the environment at a regional scale or broader.	Significant, permanent impact on regional economy and/or irreversible changes to cultural, recreational, aesthetic or social values at regional, State and national levels.

GHG emissions leading to climate change is a global issue. However, the potential for GHG emissions to have a direct impact on the project lies in the costs associated with emissions, either directly (GHG abatement technologies and/or offsets) or indirectly (monitoring or reporting costs). Reporting and pricing thresholds are indicators of the relative importance of emission levels, and these have been used in the development of consequence criteria, as shown below. These consequence criteria are based on criteria that have been used on other major EIS/EES projects in Australia (e.g. Sydney Metro, Sunshine Coast Airport).

Separate consequence criteria have been defined for construction and operational phase risk assessments, and are provided in Table 4-4 and Table 4-5, respectively.

Table 4-4 GHG consequence rating criteria: construction

Level of Consequence	Consequence criteria
Negligible	Annual Scope 1 and Scope 2 GHG emissions for the construction of the project are below 5,000 t CO_2-e p.a. No obligation to monitor and report emissions and no financial liability for GHG emissions.
Minor	Annual Scope 1 and Scope 2 GHG emissions for the construction of the project are below the threshold required to report as a separate facility in NGER Scheme (25,000 t CO_2-e p.a.). No change in reporting obligations and no increased financial liability for GHG emissions (costs associated with reporting by the contractor are absorbed in current reporting activities).
Moderate	Annual Scope 1 and Scope 2 GHG emissions for the construction of the project are greater than the threshold required to report as a separate facility in NGER Scheme (25,000 t CO_2-e p.a.) The potential for some additional financial liability (new or additional costs associated with reporting by the contractor are experienced) and requirement to monitor and report emissions.
Major	A major level of GHG emissions associated with construction of the project as defined by Scope 1 and Scope 2 emissions representing a non-negligible proportion of Australia's total emissions (> 0.01 per cent but <0.1 per cent), or a non-negligible proportion of Victoria's total GHG emissions (> 1 per cent but < 5 per cent), excluding LULUCF[#]. A major estimated financial liability (e.g. offsetting of Scope 1 and Scope 2 emissions).
Severe	A significant level of GHG emissions associated with construction of the project as defined by Scope 1 and Scope 2 emissions representing > 0.1 per cent of Australia's total annual GHG emissions, or > 5 per cent of Victoria's total GHG emissions, excluding LULUCF[#]. A significant estimated financial liability (e.g. offsetting of Scope 1 and Scope 2 emissions).

[#] Land Use, Land Use Change and Forestry

Table 4-5 GHG consequence rating criteria: operational

Level of Consequence	Consequence criteria
Negligible	No change or a decrease in GHG emissions compared to the 'no Melbourne Metro' operational scenario. No additional financial liability (compared to existing reporting requirements of operator) for reporting of operational Scope 1 and Scope 2 GHG emissions.
Minor	An increase in annual Scope 1 and Scope 2 GHG emissions compared to the 'no Melbourne Metro' operational scenario, with operational emissions below the threshold required to report as a separate facility in NGER Scheme (25,000 t CO_2-e p.a.). Some additional financial liability (compared to existing reporting requirements of operator) for reporting of operational Scope 1 and Scope 2 GHG emissions.
Moderate	An increase in annual Scope 1 and Scope 2 GHG emissions compared to the 'no Melbourne Metro' operational scenario, with operational emissions greater than the threshold required to report as a separate facility in NGER Scheme (25,000 t CO_2-e p.a.). The potential for material financial liability (greater than ten per cent increase in reporting workload) and requirement to monitor and report emissions under NGER Scheme.

Level of Consequence	Consequence criteria
Major	A major increase in operational GHG emissions compared to the 'no Melbourne Metro' operational scenario and a major estimated financial liability. The increase in Scope 1 and Scope 2 GHG emissions represent a non-negligible proportion of Australia's total emissions (> 0.01 per cent but <0.1 per cent), or a non-negligible proportion of Victoria's total GHG emissions (> 1 per cent but < 5 per cent), excluding LULUCF#.
Severe	A significant increase in operational GHG emissions compared to the 'no Melbourne Metro' operational scenario and a significant and irrecoverable estimated financial liability. The increase in Scope 1 and Scope 2 GHG emissions represent > 0.1 per cent of Australia's total annual GHG emissions, or > 5 per cent of Victoria's total GHG emissions, excluding LULUCF#.

Land Use, Land Use Change and Forestry

The environmental risk assessment matrix used to determine levels of risk from the likelihood and consequence ratings is shown in Table 4-6.

Table 4-6 Risk Matrix

		Consequence rating				
		Negligible	Minor	Moderate	Major	Severe
Likelihood rating	Rare	Very Low	Very Low	Low	Medium	Medium
	Unlikely	Very Low	Low	Low	Medium	High
	Possible	Low	Low	Medium	High	High
	Likely	Low	Medium	Medium	High	Very High
	Almost Certain	Low	Medium	High	Very High	Very High

The risks identified as part of the GHG assessment are shown in Section 7. Where the identified risks are discussed throughout this impact assessment report, they have been cross referenced as **Risks #GH001** and **#GH002**, etc.

4.5 Sustainability Rating Tools

Along with the MMRA Sustainability Performance Targets (refer to Section 3), the Sustainability Management Plan (SMP) also requires aspects of the project to be certified under:

- ISCA IS (*Infrastructure Sustainability Council of Australia – Infrastructure Sustainability*) rating scheme, benchmarking the sustainability features of the design, construction and infra lifecycle of the project. Ratings are available for 'Design', 'As Built' and 'Operation' of infrastructure.
- Green Star Design & As-Built Melbourne Metro Rail Tool (*Green Building Council Australia (GBCA)*), for the rating of sustainability performance for the underground stations.

4.5.1 ISCA IS Rating Scheme

The ISCA IS rating scheme requires a base case to be set for the 'Ene-1: Energy and carbon monitoring and reduction' and 'Mat-1: Materials lifecycle impact measurement and reduction' credits, from which to measure performance improvement. This base case should represent business as usual (BAU) sustainability initiatives – i.e. the design, construction or operation of the project without the identified best practice sustainability initiatives implemented. Such a base case is typically developed for carbon footprinting.

For the purposes of Melbourne Metro, the ISCA base case for the 'Design' rating is Melbourne Metro Concept Design, however *without* best practice GHG abatement measures in place (i.e. adopts a concept/BAU design approach and assumes BAU GHG abatement initiatives having been incorporated into the design). For example, it is proposed that the traction energy element of the base case for Melbourne Metro be represented by the current MTM system of operation. Where MTM/PTV may be currently incorporating regenerative braking across some of its rolling stock, this would need to be captured in the base case.

The ISCA 'reference footprint' is then the estimated total GHG emissions (i.e. carbon footprint) for the construction and operational phases based on the ISCA base case.

MMRA has been in discussions with ISCA to confirm and verify the approach and assumptions of the ISCA base case (and reference footprint) for energy and materials.

4.6 Construction Phase Assessment Methodology

4.6.1 Construction Phase Emissions Calculation Methodology

For the construction phase, an overall GHG construction footprint has been determined using the construction methods as defined for the Concept Design (refer Chapter 6 of the EES) and/or adopting a BAU approach to GHG abatement; this has been referred to as the *Melbourne Metro BAU Construction Footprint*.

An additional GHG footprint for construction (*Melbourne Metro Best Practice Construction Footprint*) has also been determined, which assumes that the MMRA Sustainability Performance Targets/PTV Project Requirements would be achieved and the construction adopts best practice GHG abatement initiatives.

4.6.2 Construction GHG Assessment Boundary

The scope of the GHG inventory for the construction phase includes all direct and indirect GHG emissions associated with construction of Melbourne Metro using the construction methods defined for the Concept Design (refer to Chapter 6 of the EES). The inventory includes an assessment of all significant GHG sources (Scope 1, 2 and 3 emissions) associated with construction activities within Melbourne Metro construction boundaries and at potential ancillary sites/activities (where known and significant). Scope 3 emissions are also included for fuel consumption or purchase of electricity. Scope 3 emissions are often reported for these activities and refer to the indirect upstream emissions associated with the extraction, production and transport or distribution of electricity and/or fuel to the site.

The sources of GHG emissions included in the construction phase of the Melbourne Metro are provided in Table 4-7. A 'tick' (✓) denotes the emission source has been included in the inventory, whilst a 'cross' (×) denotes the emission source has been excluded. A 'dot' (•) denotes whether the emission is Scope 1, Scope 2 or Scope 3.

Table 4-7 System boundary: sources of direct and indirect GHG emissions – construction GHG inventory

Source of GHG emission (construction)	Activity	Included in inventory?	Direct	Indirect	
			Scope 1	Scope 2	Scope 3
Stationary fuel	Fuel consumed by construction plant/ equipment.	✓	●		●
Transport fuel	Fuel consumed for spoil/rock removal.	✓	●		●
Transport fuel	Fuel consumed by project vehicles around the project site.	✓	●		●
Transport fuel	Fuel consumed for construction materials delivery.	✓			●
Construction materials	Embodied emissions of materials used in construction.	✓			●
Construction materials	Embodied emissions of materials used in construction of rolling stock.[10]	✓			●
Purchased electricity	Electricity consumed in project offices (lighting and equipment).	✓		●	●
Purchased electricity	Electricity consumed in construction plant/equipment (e.g. tunnel boring machines (TBMs), roadheaders, dewatering).	✓		●	●
Transport fuel	Change in road traffic use by the public (fuel consumption) due to traffic impacts around construction zones (2021 VITM outputs).	✓			●
Purchased electricity	Change in tram network (purchased electricity) around construction zones (2021 VITM outputs).	✓			●
Carbon sinks	Land clearing/soil disturbance.	✓	●		
Liming	Offsite treatment of WASS[11] (application and mixing of calcic limestone).	✓			●
Stationary fuel	Fuel consumed by offsite plant/ equipment for treatment of WASS.	✓			●
Transport fuel	Employee/business air travel.	✘			●
Landfill	Construction waste disposed at landfill.	✘			●
Stationary fuel	Fuel consumed by construction plant/ equipment for ancillary infrastructure not within the Melbourne Metro Concept Design footprint e.g. Wider Network Projects.	✘	●		●

[10] Only includes difference in rolling stock between 'with Melbourne Metro' and 'no Melbourne Metro ' scenarios.
[11] Waste Acid Sulfate Soil: corresponds to disturbed potential acid sulfate soil (PASS) / actual acid sulfate soil (AASS) / acid sulfate rock (ASR).

Source of GHG emission (construction)	Activity	Included in inventory?	Direct	Indirect	
			Scope 1	Scope 2	Scope 3
Transport fuel	Employee commute (vehicles) from home to site.	✘			●

4.6.2.1 Activities Excluded

Where a source group/activity has been excluded from the GHG inventory, this determination is based on previous experience of similar transport projects[12] where the likely emissions are considered to be insignificant in comparison to the overall GHG inventory. Recommendations on significance limits vary between reporting schemes. Adopting the guidance provided by ISCA for the Energy and Carbon ('Ene-1') credit, any source of energy use or GHG emissions that is likely to account for more than five per cent of the infrastructure lifecycle footprint from Scope 1 and 2 and land clearing is considered significant and must be included. This has been adopted as the materiality threshold for the assessment. A similar method is used to identify significant sources of Scope 3 emissions.

Early works have been excluded from the GHG system boundary given the lack of detail provided in the high level early works concept arrangements, which would be required in order to provide construction materials quantities and define construction methods with any level of accuracy or certainty. Requirements relating to the reduction of GHG emissions during the early works would be provided in the early works tender documentation. This would include the requirements for the early works managing contractor to develop their own base case carbon footprint for the works, and develop a framework to reduce GHG emissions in accordance with the Melbourne Metro Sustainability Targets and the IS rating tool (the Managing Contractor would be required to register the early works with ISCA).

As noted above, construction activities outside of the Concept Design footprint have been excluded from the GHG inventory, to be consistent with the EES Scoping Requirements. This includes Wider Network Projects; for example, upgrades to commuter car parks at suburban stations, rail siding reserves, network capacity signalling improvements and resilience requirements, and the various turnbacks and stabling across the following lines (except for the Western Turnback which is included in the Concept Design):

- Sunshine to Dandenong Line
- Northern Loop
- Cross City line (Werribee and Sandringham Line)
- Frankston Loop Line.

Substation and cabling works at Arden have not been included in the construction GHG footprint given the GHG emissions associated with the fuel consumption and materials used for these works are considered to be immaterial compared to the overall construction carbon footprint. A discussion on SF_6 (Sulfur hexafluoride), an ozone depleting substance that is often used in circuit breakers within substations however is provided in Section 6.5.

[12] For example: Regional Rail Link (Vic), Sydney Metro (NSW), North West Rail Link (NSW)

4.6.3 Emission Factors and Data Sources

4.6.3.1 Melbourne Metro Design/Construction Teams

The construction GHG inventory has relied on details of construction logistics, materials quantities, fuel consumption, and indicative program from Melbourne Metro design and construction teams; including MMRA's Constructability Advisor and Cost Advisor.

Information regarding GHG best practice and eco-efficient practices with respect to GHG emissions and energy consumption has been sourced from outcomes of workshops held with the design teams and Environmentally Sustainable Design (ESD) team, and the technical design reports as part of the delivery of the Concept Design.

4.6.3.2 National Greenhouse Accounts

4.6.3.2.1 National Greenhouse Accounts (NGA) Factors

Under the *National Greenhouse Gas and Energy Reporting Act 2007*, corporations in Australia which trip thresholds for GHG emissions or energy production or consumption are required to measure and report data to the Commonwealth Government annually via the NGER scheme. Relevant to this project, the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* identifies a number of methodologies to account for GHGs from specific sources, including the National Greenhouse Accounts (NGA) Factors; refer DoE (2015a).

The NGA Factors are the most up-to-date and comprehensive document of GHG emissions factors determination in Australia, and are accepted as the most reliable source of emissions factors for the purposes of reporting under the NGER Scheme. As such, it is considered the NGA Factors are highly appropriate to this assessment.

GHG emissions associated with electricity consumption during construction are based on projected GHG intensity emissions factors published by DoE (2015b); refer to section 4.7.4.1.

4.6.3.2.2 Stationary and Transport Fuel Combustion

The NGA Factors are the primary source of GHG emissions factors used to determine emissions associated with fuel combustion during construction. The NGA Factors relevant to this assessment are provided at Appendix B of this report.

The fuel combustion emission factors have not been adjusted/scaled to account for future variations or (currently unknown) refinements in the science and determination of emissions factors or Global Warming Potential (GWP). Additionally, potential improvements in fuel / carbon efficiency have not been accounted for. The BAU scenario assumes all fuel consumed in trucks and construction plant/equipment during construction is diesel oil, i.e. insignificant quantities of gasoline (petrol), and no consideration is given in the BAU scenario to use of renewable fuels such as biodiesel as alternate fuel sources. Achieving the 20 per cent renewable energy target (refer to Table 3-1) would be achieved in part by the use of biodiesel blends with a minimum 20 per cent biodiesel content; this has been assumed for the *Melbourne Metro Best Practice Construction* scenario.

For transport fuel combustion, it is assumed all vehicles are post 2004 vehicles.

4.6.3.3 Construction Materials

4.6.3.3.1 IS Materials Calculator

Embodied energy/carbon in construction materials are calculated using GHG emissions factors. The emissions factors for materials are typically provided as kg CO_2-e per tonne of material, and represent all emissions associated with extraction, processing and manufacture of construction materials to the point of sale (i.e. 'cradle to manufacturer gate'). Emissions factors for fuel consumption (delivery of construction materials to site) are typically provided as kg CO_2-e per litre of fuel consumed.

In order to simplify the calculation of indirect GHG emissions associated with embodied energy/carbon from construction materials and for determining emissions associated with the transportation of such materials to the project sites, the Infrastructure Sustainability (IS) Materials Calculator (Microsoft Excel calculation sheet, V1.1, release date 20/02/2015) has been used for all significant materials for construction of Melbourne Metro.

The IS Materials Calculator is a support tool for the IS rating scheme – developed, administered and updated by ISCA. The Calculator includes calculated embodied GHG emissions factors for the 'cradle to manufacturer gate' for a wide range of typical construction materials and is based on the best available data from Australian lifecycle inventory databases in the following order of hierarchy:

i) Australian National Lifecycle Inventory Database (AusLCI) – the national, publicly accessible database managed by the Australian Lifecycle Assessment Society (ALCAS). Currently AusLCI contains a limited set of construction products

ii) Building Products Lifecycle Inventory (BP LCI) database – contains data representing national average production of approximately 120 building products, provided by the respective building product trade associations in a database hosted by the Australian Building Products Innovation Council (BPIC)

iii) Australasian Unit Process LCI3, developed for use with the LCA software SimaPro over the past 12 years and the AusLCI 'shadow database', a database managed by the ALCAS to fill most of the gaps in the supply chain not covered by the AusLCI and BP LCI.

All the above databases are developed following the ISO 14040:2006 and ISO 14044:2006 standards for LCA. Additionally, the IS Materials Calculator is a reputable and conservative method of calculating GHG emissions and assessing materials lifecycle environmental impacts for infrastructure projects.

The GHG emissions factors for all significant materials on the project as per the IS Materials Calculator, are provided in Appendix B of this report. Transport modes and the transport distances (km) to deliver the materials to the site have been determined and entered into the Calculator (entered as a one-way distance; noting that the factors included in the Calculator already include suitable assumptions about back-loading). Transportation assumptions have been defined in Section 6.3.2.6.

4.6.3.4 Clearing of Vegetation

While the loss of a carbon sink is not a true GHG *emission*, the net impact is that less CO_2 is being removed from the atmosphere and the net effect is that an equivalent amount of CO_2 would remain as a result (RMS & VicRoads, 2013). Hence, clearing of vegetation is considered as a Scope 1 emission source in this assessment.

GHG impacts associated with land clearing have been estimated using the *Report for Vegetation emissions methodology for road construction workbook* (RMS & VicRoads, 2013). This methodology takes into account the carbon that exists in the vegetation at the time of clearing and carbon that could have been sequestered in the future if the vegetation was not cleared. The methodology is considered a conservative estimation approach and assumes that:

- All carbon pools (i.e. woody, non-woody, debris and soil) are removed
- All carbon removed is converted to CO2 and released to the atmosphere
- Sequestration from revegetation of the project site is not included.

It is acknowledged that this is a conservative approach to estimating GHG emissions from vegetation removal and is considered to be a reliable tool for calculating loss of carbon sinks from construction of Melbourne Metro.

Land clearing emissions factors are based on the vegetation class and the 'maxbio' class of the vegetation which is determined from the project's geographical location. The maxbio class is derived from the Australian Greenhouse Office (AGO) and estimates the maximum tonnes dry vegetation matter per hectare for a specific location. The maxbio class for the project location was determined to be 2 (refer to Figure 2 of Attachment A: Appendix E of RMS & VicRoads (2013)). The land clearing emissions factors adopted for the Melbourne Metro are provided in Table 4-8.

Table 4-8 Land clearing emissions factors (RMS & VicRoads, 2013)

Vegetation class	Name	Scope 1 emission	Notes
D	Open Woodlands	209 t CO_2-e/ha	Based on Maximum Potential Biomass Class of 2. Assumed applicable for clearing of planted native vegetation (excluding grasses) within the project area.
I	Grassland	110 t CO_2-e/ha	Based on Maximum Potential Biomass Class of 2. Assumed applicable for clearing of exotic vegetation and native grasses within the project area.

Offsets from revegetation are not currently considered due to uncertainty of the exact impact areas and offset requirements. GHG emissions as a result of disposal of vegetation at landfill has not been included as it is likely that vegetation (predominantly grasses and gardens) would be able to be reused or left to decompose aerobically on site.

Areas and types of vegetation to be cleared (refer to Section 6.3.2.6) were provided by the project's terrestrial ecologist, which were also used as inputs to the Green Star Ecological Value Calculator.

4.6.3.5 Liming (Treatment of WASS)

The most significant source of GHG emissions associated with treatment of excavated spoil across the project is likely to comprise treatment for reuse and/or disposal of waste acid sulfate soil (WASS), which corresponds to disturbed potential acid sulfate soils (PASS), actual acid sulfate soils (AASS) and acid sulfate rock (ASR). The key sources of GHG emissions from this activity include CO_2 emissions from application of limestone ($CaCO_3$) to the spoil material. $CaCO_3$ is added to increase soil pH or reduce soil acidification. When $CaCO_3$ comes into contact with strong acid sources in the soil, a chemical reaction is triggered and some of the $CaCO_3$ degrades, releasing CO_2 emissions. Additionally, GHG emissions due to plant / equipment mixing the soil (stationary fuel consumption) would also be an emissions source (although to a lesser extent).

MMRA (2016) estimates that approximately 48,000 m^3 of PASS/AASS and 503,000 m^3 of ASR may require removal from across the project alignment (note; volumes are insitu and do not include bulking factor). This compares to estimated volumes of Prescribed Industrial Waste (PIW)[13] of 15,700 m^3 Category A spoil, 26,100 m^3 Category B spoil, and 91,400 m^3 Category C spoil.

Due to site constraints on the project alignment, it is unlikely that contaminated spoil and WASS would be treated on site. Rather, it has been assumed that offsite treatment at the receiving facility (for offsite reuse and/or disposal) would be the most likely course of action. However if the contractor determines there is sufficient space at a Temporary Stockpile Area (TSA) within another construction site then it could be transported to that site for treatment (MMRA, 2016). This assessment assumes that treatment (neutralisation) of WASS would be required, regardless of location, as a worst-case scenario (in terms of GHG emissions). Once treated, it may be possible the neutralised spoil could be reused elsewhere, or for landfill capping. The less conservative assumption (in terms of GHG emissions estimation) is that the WASS material is disposed directly at a licensed facility operating

[13] IWRG621, Soil Hazard Categorisation and Management (2010) provides the constituent thresholds of contaminants for categorisation of Fill Material and Category A, B & C PIWs.

under an EPA-endorsed Environmental Management Plan (EMP) which does require treatment prior to disposal. AJM JV note there is no opportunity for reuse under this disposal scenario.

GHG emissions due to offsite treatment of WASS would be captured as Scope 3 emissions as they are indirect emissions that are not under the direct influence of the contractor. The following provides a discussion on the methodology used to determine GHG emissions associated with treatment of WASS:

- Volumes provided in MMRA (2016) are based on possible 'high case' estimates, thereby providing a conservative position
- Indicative liming rates were obtained from laboratory reports of actual sampling and analysis undertaken across the project alignment during the site investigation phase; refer Technical Appendix Q *Contaminated Land and Spoil Management*. Liming rates were calculated and reported by the laboratory on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime
- The liming rate (dry weight basis) to be applied for this assessment was calculated to be 69 kg $CaCO_3$/t (95% upper confidence limit), or 186 kg $CaCO_3/m^3$ in-situ spoil (assuming a wet bulk density of 2.7 t/m^3)
- CO_2 emissions factors were obtained from IPCC (2006), which assumes the CO_2 emission factor for agricultural liming of 0.12 tonne CO_2 per tonne of $CaCO_3$. This is considered by USEPA to be a conservative estimate; e.g. refer USEPA (2016)
- Emissions from plant / equipment mixing the lime etc were also considered. This assumed two 165 HP dozers operating continuously for 10 hours per day, each day for four years. This is considered to be a conservative estimate
- Note that emissions from trucks hauling the spoil material have been included in the GHG inventory as direct Scope 1 emissions.

4.7 Operational Phase Assessment Methodology

The EES Scoping Requirements require that adequate design specification of all project components be described, including those components of the operational phase of the project that could give rise to GHG emissions. To adequately assess the operational impacts of the project an assessment of, the potential effects of the project (i.e. with Melbourne Metro) is provided relative to the 'no Melbourne Metro' scenario.

4.7.1 Victorian Integrated Transport Model (VITM)

The delivery of Melbourne Metro would have an impact on other transport modes, for example car users may be encouraged to switch to public transport if they are able to make their journey more easily by public transport than by car. This is known as the 'passenger mode shift'. GHG emissions associated with the indirect or knock-on effects to the road and public transport network in Melbourne as a result of the operation of the Melbourne Metro have been assessed using outputs from the Victorian Integrated Transport Model (VITM).

The VITM is the name given to PTV's four-step strategic traffic model. VITM, and its predecessor Melbourne Integrated Transport Model (MITM), have both been used extensively by PTV and VicRoads for the strategic modelling of transport projects located in metropolitan Melbourne.

Features of the VITM include:

- Four time periods (AM, Inter-peak, PM, and Off Peak)
- Road and public transport modes, taking into account projected population increases
- Five vehicle types (Car, Rigid Trucks, Articulated Trucks, B-double trucks, HPFV trucks)

- Use of outputs from the Melbourne Freight Movement Model[14] to forecast truck volumes
- Three public transport modes (Train (Metro and V/Line), Trams and Buses).

The key outputs from the VITM used as data inputs to the operational GHG inventory include:

- Confirmation of VITM system boundary
- For each transport mode and for the operational year scenario (i.e. 2011, 2026, 2031, 2046):
  - Road and rail vehicle / train type
  - Total annual Vehicle Kilometres Travelled (VKT)
  - Annual patronage for each transport mode, expressed as Passenger Kilometres Travelled (PKT).

VITM outputs have been included at Appendix C of this report.

The annualisation factors applied to daily VKTs for use in the GHG modelling are shown below in Table 4-9.

Table 4-9 VITM annualisation factors (PTV)

Time Period	Start	End	Number of periods annually
AM	7am	9am	250
PM	4pm	7pm	250
IP (inter-peak)	9am	4pm	349
OP (off-peak)	7pm	7am	349

The outputs of the VITM, including Vehicle Kilometres Travelled (VKTs) for all transport modes and vehicle type, are provided in Appendix C of this report.

PTV has also provided Passenger Kilometres Travelled (PKTs) for all VITM transport modes and scenarios. This is determined by multiplying the VKTs by average occupancy for that particular transport mode. The passenger occupancy assumptions adopted by PTV in the VITM are also provided in Appendix C of this report. Additional notes are:

- For public transport modes (trains, trams and buses), the VITM adopts occupancy values based on 'planning' seating capacity, which technically is an average load across all services in any hour; capacity varies by vehicle type
- Freight (truck) occupancy assumes an occupancy of 1.0, i.e. VKTs = PKTs
- Car occupancy factors are derived from VITM Occupancy Factors by Purpose averaged across all periods, and vary by daily time period (AM peak, off-peak, etc.).

The occupancy for the HCMTs, as adopted in the VITM for planning purposes (average load across all services in any hour), is show below in Table 4-10.

[14] The Melbourne Freight Movement Model was originally created in 2005/06. It is based on data supplied by over 400 businesses, 1,000 truck images and 3,000 truck tours (Eitzen, 2011).

Table 4-10 PTV Planning Load at Rated Performance

HCMT vehicle type	Seating Capacity
Standard (7-car)	1,100
Extended (9-car)	1,420
Extended (10-car)	1,570

4.7.2 Operational Baseline

The GHG inventory of the existing transport network that would be affected by the operation of Melbourne Metro is that defined within this section and adopts 2011 as the VITM 'reference year'. VITM data is updated on a five-yearly cycle and, as such 2011 has been selected as the most representative year for the VITM baseline (noting also that the VITM for this assessment was undertaken by PTV in 2015).

The 'no Melbourne Metro' scenario has been used as the baseline scenario for the purposes of determining a baseline operational GHG inventory for the GHG impact assessment. Comparison of the project versus no project is considered to be a useful approach to assess the longer-term operational impacts of the project, and is often used for State projects assessed under the *Environment Effects Act 1978* or the *Major Transport Projects Facilitation Act 2009*[15].

The baseline operational GHG inventory for the 'no Melbourne Metro' scenario has been aligned with the VITM 'no Melbourne Metro' (baseline) modelling scenarios, and is essentially the transport network *without* the Melbourne Metro for the given scenarios (years). The scenarios include:

- Latest VITM reference year (2011)
- 'Day One' of opening[16]
- Five years after commencement of operation (using 2031 VITM data: 'no Melbourne Metro')
- 20 years after commencement of operation (using 2046 VITM data: 'no Melbourne Metro').

The 'with Melbourne Metro' operational scenarios are therefore directly assessed against the 'no Melbourne Metro' baseline scenarios of:

- 'Day One' of opening[17]
- Five years after commencement of operation (using 2031 VITM data: PTV Extended Program)
- 20 years after commencement of operation (using 2046 VITM data).

Further discussion on the wider transport elements included in the operational GHG inventory is provided in Section 4.7.1.

4.7.3 Operational GHG Assessment Boundary

GHG emissions sources included in the operational GHG inventory are provided in Table 4-11. The source groups apply to both the 'with Melbourne Metro' and 'no Melbourne Metro' scenarios. A 'tick' (✓) denotes the emission source has been included in the inventory, whilst a 'cross' (×) denotes the emission source has been excluded. A 'dot' (•) denotes whether the emission is Scope 1, Scope 2 or Scope 3.

[15] For example: East West Link – Eastern Section, Western Highway Duplication, and Peninsula Link.
[16] Based on conversations with PTV, the 2026 'no Melbourne Metro' (baseline) scenario has been obtained as the linear interpolation of 2021 and 2031 baseline VITM outputs (PTV has not undertaken VITM modelling for 2026).
[17] PTV has developed transport demand forecasts for 2011, 2021, 2031 and 2046. As suggested by PTV, 'Day One' of opening results has been obtained as linear interpolation of hypothetical '2021 Day One' and '2031 Day One' VITM outputs provided by PTV.

The scope of the GHG inventory for the operational phase 'with Melbourne Metro' includes all direct and indirect GHG emissions associated with operation of the Concept Design. The effects of the passenger mode shift (measured by the VITM outputs) are considered as Scope 3 (indirect) emissions.

Where source groups have been excluded from the operational GHG inventory system boundary, this determination is based on previous experience of similar transport projects[18] where the likely emissions are considered to be insignificant in comparison to the overall GHG inventory and carbon footprint (i.e. less than five per cent), or where the associated GHG emissions are captured by another entity.

Table 4-11 System boundary: sources of direct and indirect GHG emissions – operational GHG inventory

Source of GHG emission (operational)	Activity	Included in inventory?	Direct	Indirect	
			Scope 1	Scope 2	Scope 3
Purchased electricity	Traction power (portal to portal).	✓		●	●
Purchased electricity	Electricity consumption at train stations.	✓		●	●
Purchased electricity	Electricity consumption within tunnels (ventilation and electrical).	✓		●	●
Purchased electricity	Traction power (wider rail network, as included in VITM).	✓			●
Vehicle emissions	Road based vehicles (as included in VITM). [19]	✓			●
Purchased electricity	Electricity consumed to operate trams (trams included in VITM).	✓			●
Transport fuel	Diesel consumed to operate V/Line services (V/Line included in VITM).	✓			●
Stationary fuel	Fuel consumption in plant/equipment used in permanent operations (e.g. station HVAC heaters).	✓	●		●
Transport fuel	Fuel consumption associated with transportation of materials, employee travel, and waste removal.	✘			●
Stationary fuel	Fuel consumed in plant/equipment used in maintenance operations.	✘	●		●
Transport fuel	Fuel consumption associated with maintenance vehicles (trucks, light utilities).	✘	●		●
Purchased electricity	Electricity consumption of trains/offices at rail sidings (Wider Network Projects).	✘		●	●
Landfill	Waste associated with operation of the Melbourne Metro (disposed at landfill; recycling).	✘			●

[18] For example: Regional Rail Link (Vic), Sydney Metro (NSW), North West Rail Link (NSW).
[19] GHG emissions for this activity are estimated for both the baseline ('no Melbourne Metro') and 'with Melbourne Metro' scenarios, to quantify the potential emissions avoided once passengers shift from road based transport modes to new train services provided by the Melbourne Metro. Road based vehicles include car, rigid and articulated truck, and bus.

The operational phase GHG inventory has been determined as an annual GHG inventory for both the ‘with Melbourne Metro’ and ‘without Melbourne Metro’ to align with the VITM scenarios previously defined.

As suggested by EPA Vic during the early stages of the GHG impact assessment, the operational GHG assessment has been undertaken by restricting the study area to the minimum necessary that would detect the impacts of the project. For the purposes of the VITM, VKTs for trains (Metro and V/Line) were provided for only those train lines which are affected by Melbourne Metro operation along Pakenham/Cranbourne and Sunbury lines (i.e. includes knock-on effects of lines through South Yarra and North Melbourne). It was considered that the use of VITM data that includes all other Metro rail corridors would obscure the impact of the project and make clear assessment more difficult. The Metro lines affected from operation of Melbourne Metro, and included in the VKTs for the GHG modelling, are illustrated as Figure 4-3.

For the ‘with Melbourne Metro’ scenarios, the operational phase GHG inventory for sources directly attributable to the operation of Melbourne Metro has been defined as all operations from portal to portal, including stations, tunnels and traction power within the tunnels.

4.7.4 Emission Factors and Data Sources

4.7.4.1 Melbourne Metro Concept of Operations

PTV has prepared a Concept of Operations (COO) – Heavy Rail report (V.11.1 (Draft) 4 November 2015). The COO report describes the operational concept and rationale underpinning the Melbourne Metro program by providing background and context for the program, including description of:

- The strategic context of the project from the Network Development Plan
- The ’no Melbourne Metro’ scenario
- The operational concept for the Melbourne Metro for ‘Day One’ of each stage or scope scenario required.

The COO also provides details of the rail network reconfiguration associated with the new corridor and stations, as shown previously in Figure 4-3.

4.7.4.2 National Greenhouse Accounts

GHG emissions factors for the baseline (2011) and future (2026 and 2046) operational scenarios have been based on current published references, e.g. DoE (2014b & 2015b). Refer to Section 4.6.3.2 for further details on the NGA Factors.

4.7.4.1 Greenhouse Gas Intensity Projections

Victoria represents the state with the highest GHG emissions intensity (GGI) for electricity generation/consumption, as it contains a significant share of electricity production through brown coal combustion. Brown coal is attributed the highest GHG emissions factor of the various fuels available for electricity production.

Victoria is expected to reduce GHG emissions over the next 20 years by around 0.91 per cent per annum, in contrast with other states such as Queensland and NSW which are projected to experience growth in emissions because of differing expectations around growth in renewable generation and growth of annual electricity demand in these areas (DoE (2015b)).

The latest published electricity Scope 2 GHG intensity emission factor for Victoria is 1.13 kg CO_2-e/kWh (DoE, 2015a). The GHG intensity is calculated as total emissions scaled by total generation, sent-out generation and energy demand. The emissions intensity is expected to decline over time as a result of coal generator retirements and incoming renewable generation required to meet the RET, and furthermore the Victorian Government's recent announcement that the VEET has been extended to new targets of 6.5 million t CO_2-e of abatement per annum in 2020.

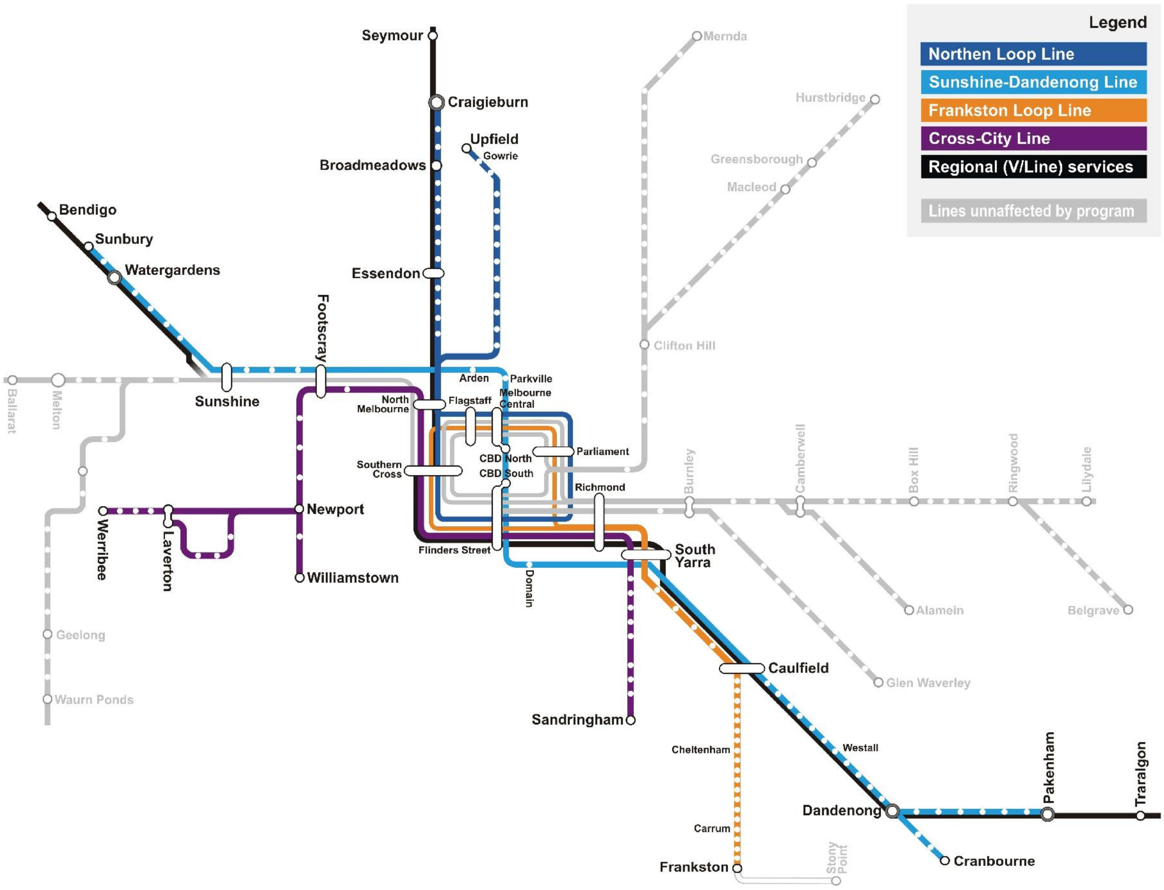

Figure 4-3 Metropolitan rail network at the completion of Melbourne Metro (Source: PTV, 2016)

While Victorian emission intensity is currently high, it is expected to drop faster than in most other states, particularly after about 2031. It was considered essential for the purposes of this assessment that a projection of marginal emissions intensity[20] be projected over at least the first twenty years of the project, in order to best estimate full fuel cycle (Scope 2 and 3) GHG emission from the consumption of electricity during operation of Melbourne Metro.

In estimating an appropriate GHG intensity for future operation, it is assumed that there would be no new coal generation in Victoria, which means that any new generation would come from gas fired sources or from renewable sources. It is considered that this is a reasonable assumption to make, given the state of current legislation and international policy. A conservative assumption is that there would be no further decline in GHG intensity projection beyond 2035-36; it is noted this is an unlikely scenario, however given further reductions in the GHG intensity beyond the DoE (2015b) projections are to be expected as Victoria continues to increase its use of renewable energy sources for the production of electricity.

GHG intensity factors adopted for the operational footprint are provided in Table 4-12, with future emissions projections (to 2034-35) sourced from DoE (2015b). This demonstrates the assumption of a general reduction in GHG intensity over time as explained above.

[20] Marginal emissions intensity, or marginal carbon intensity (MCI), is defined as the decrease in CO_2-e emissions in the electrical network in response to an infinitesimal decrease in electrical demand. MCI depends on the time and location of the applied demand reduction measure (Pardalos et al., 2012).

Table 4-12 Projected Victorian GHG intensity (GGI) factors

Year / projection	GHG intensity (kgCO_2-e/kWh)			Source/notes
	Scope 2	Scope 3	Full Fuel Cycle	
2006	1.23	0.10	1.33	Australian Greenhouse Office (2006).
2008	1.22	0.14	1.36	Department Climate Change (2008).
2015	1.13	0.13	1.26	NGA Factors (DoE, 2015a).
Construction (2018-2022)	1.08	0.13	1.21	Australia's emissions projections 2014–15 (DoE, 2015b).
Construction/ fit out (2023-2026)	1.07	0.13	1.20	Australia's emissions projections 2014–15 (DoE, 2015b).
2026	1.05	0.13	1.18	Australia's emissions projections 2014–15 (DoE, 2015b).
2031	1.03	0.13	1.16	Australia's emissions projections 2014–15 (DoE, 2015b).
2046	0.6	0.13	0.73	AJM JV projection from 2034-35, using 2034-35 GGI as per DoE (2015b).
Beyond 2046	0.6	0.13	0.73	No GHG intensity projection beyond 2046; assumes GHG intensities do not decline (conservative assumption).

4.7.4.2 Other Transport Emission Factors

Other transport emission factors and electricity/fuel consumption data have been sourced from the following:

- Electricity consumption data for the existing rolling stock has been sourced from MTM and from recent NGER reports submitted by MTM (MTM, 2015). This has been calculated as 22.8 kWh/VKT.
- Average tram electricity consumption: 1.97 kWh/ km. This is based on data received from Yarra Trams. Energy recovery from the traction system is approximately 40 per cent due to regenerative braking (based on data obtained from the 'B2' fleet).
- Fuel (diesel) consumption for V/Line trains: 200 L per 100 km. This is the average fuel consumption calculated from data received from V/Line for the 2014/15 financial reporting period, which includes fuel consumption across all of the existing V/Line fleet. Future fuel efficiency has been assumed to be the same as existing.

Average fuel consumption by road vehicle type (litres/100 km) sourced from Survey of Motor Vehicle Use, Australia, 12 months ended 31 October 2014 (ABS, 2015); refer to Table 4-13.

Table 4-13 Fuel consumption by road vehicle type (ABS, 2015)

Vehicle type	Litres / 100 km
Passenger vehicle	10.7
Rigid truck	28.4
Articulated truck	56.9
Bus	28.8

4.7.5 Operational Phase Emissions Calculation Methodology

For the operational phase, an annual GHG emissions footprint has been determined for 'Day One' of opening, five years after opening (2031 PTV Extended Program) and 20 years after opening (2046). This has been determined using the Concept Design details of the Concept Design and using VITM data and logistics provided by PTV.

The *Melbourne Metro BAU Operational Footprint* is the GHG footprint adopting a BAU approach to GHG abatement. Note that it is a PTV project design requirement for all new rolling stock operating on Melbourne Metro (i.e. HCMTs) to be fitted with regenerative braking capability, consistent with PTV's current HCMT Project[21]. Traction energy calculations for the *Melbourne Metro BAU Operational Footprint* assumes the traction energy scenario for the existing Metro network, which achieves approximately eight per cent existing regenerative braking energy across existing rolling stock capable of regenerative braking (Siemens and X'Trapolis vehicle types, which representing 71 per cent of total daily train movements). Therefore, resultant regenerative braking energy capability equates to 5.7 per cent across the Metro; this has been adopted as the BAU performance with regard to generate braking. A discussion on the likely savings to traction power consumption as a result of full regenerative braking being implemented on Melbourne Metro is provided at Section 6.4.2.4.

An additional GHG footprint for operation *(Melbourne Metro Best Practice Operational Footprint)* has also been determined which assumes that the MMRA Sustainability Performance Targets would be achieved during operation, with the adoption of best practice GHG abatement initiatives in the Concept Design (including the savings achieved from full regenerative braking capability and purchase of accredited GreenPower).

4.8 Functional Unit

The carbon footprints calculated in this report are calculated as tonnes CO_2-e over the construction duration (and also estimated as an annual emission) and as tonnes CO_2-e per annum for the operational phase.

A functional unit is often needed in carbon footprinting projects to ensure that any comparisons that are made (and therefore increases or reductions from a base case claimed) are fairly made. The functional unit represents the amount of utility the product/service/operation provides and allows different scenarios to be compared.

For the purposes of this project and this report, the functional unit is expressed as kilograms CO_2-e per passenger-kilometre-travelled (PKT), and can be provided for the 'with' and 'without' Melbourne Metro scenarios. It is considered that this is the most suitable indicator (functional unit) to assess the effects (benefits) of the project in terms of the knock-on effects to the wider transport network. The

[21] http://www.dtf.vic.gov.au/Infrastructure-Delivery/Public-private-partnerships/Projects/High-Capacity-Metro-Trains-Project

functional unit of kilograms (or grams) CO_2-e per PKT is often used in the transport sector to assess the relative difference in carbon efficiency between different transport modes in relation to passenger movement. This is illustrated later in Section 6.7.1.

The functional unit (GHG indicators) by which this assessment measures GHG emissions performance are summarised as:

- Annual CO_2-e emissions (tonnes per annum) during construction and operation, for the scenarios (years) defined
- Kilograms (or grams) CO_2-e per passenger-kilometre, for each operational scenario
- Annual (net) operational CO2-e emissions for each scenario compared to latest Victorian GHG inventories.

4.9 Stakeholder Engagement

As part of this assessment, the following specific engagement with stakeholders was undertaken.

Table 4-14 Summary of stakeholder engagement

Activity	When	Matters discussed / issues raised	Consultation outcomes
Meeting with EPA Vic	9 October 2015	Confirm methodology for GHG impact assessment is suitable for the regulatory (EES) process	• EPA Vic confirmed the proposed methodology (as stated in Section 4 of this technical report) was acceptable for use for the GHG impact assessment. • EPA Vic supports the methodology of a comparison of GHG emissions for 'with Melbourne Metro' and 'no Melbourne Metro' as a useful and valid approach to the GHG impact assessment. • Methodology needs to include the requirements of PEM: Greenhouse gas emissions and energy efficiency in industry (2002), including consideration of best practice. The comparison of emissions 'with' and 'without' Melbourne Metro does not fall within PEM requirements but is a useful approach to take and is often used for assessments under the *Environment Effects Act 1978.* • Agreed that the use of VITM data that includes **all** Metro rail corridors may obscure the impact of the project and make clear assessment more difficult. VITM data that extracts only the rail network affected by 'with Melbourne Metro' operation is preferred. • EPA Vic suggested a calculation of a 'breakeven period' would be beneficial to assess the impact of 'whole of project' GHG emissions. • Confirmed that PTV is the best source of obtaining traffic data/VITM, as PTV own the VITM models.

In addition to the specific agency and TRG engagement listed in the table above, general engagement and consultation with the community was also conducted as part of the EES development. Written feedback was obtained through feedback forms and the online engagement platform, and face-to-face consultation occurred at the drop-in sessions (refer to Technical Appendix C *Community and Stakeholder Feedback Summary Report* for further information). Although the community was given the opportunity to offer feedback in regards to GHG emissions from the construction and/or operation of the project, no comments were provided or concerns identified.

4.10 Assumptions and Limitations

All assumptions relating to methodology and GHG modelling calculations have been provided throughout Section 4 and the impact assessment (Section 6).

The limitations associated with this assessment are as follows:

- The methodology and results of this assessment are based on the accuracy and reliability of the activity data provided, VITM outputs, emissions data, and emissions calculation tools – many of which are based on third party information. Any information relied upon has been presumed accurate in preparing the assessment report
- A key limitation to the conclusions of this assessment is that likely reductions in the GHG intensity (of electricity generation) in Victoria are not projected beyond 2035, given the absence of any reliable (published) projections beyond this time period; refer to section 4.7.4.1 and DoE (2015b). Should a projection beyond 2035 be undertaken, this assessment would also need to consider continued future improvements in vehicle fuel efficiency and the possible uptake of electrical vehicles across Melbourne in future years. The possible combinations of future transport scenarios and energy consumption are numerous and are considered too complex to quantify with any level of certainty or reliability. As such, estimated future GHG emissions beyond 2035 are based on a GHG intensity for Victoria projected to 2035 (refer to section 4.7.4.1), with road-based transport fuel consumption based on current data and assumes petroleum-based fuels only
- No emissions were estimated for activities during the planning or design phases (e.g. consumption of electricity in offices, fuel consumption of plant/equipment used in investigative work). The exclusion of these emissions would not materially impact on the assessment as they are likely to represent less than one per cent of the total emissions for the ‘with Melbourne Metro’ scenario
- Averaging outputs between 2021 and 2031 baseline modelling runs, to obtain equivalent results for 2026 baseline, is considered to be acceptable given this average uses sensible model runs as endpoints for the interpolation. The key limitation to this approach is that the interpolation is usually used by PTV to estimate demand (i.e. population growth), as opposed to service of trains. Population growth is unlikely to be linear however, rather an exponential growth over time
- In the absence of transport (VITM) modelling beyond 2046, transport VKTs beyond 2046 (for the purposes of this GHG assessment) have been assumed to remain constant (i.e. contained mode shift) for the remainder of the 100-year design life of the project. This is unlikely to provide a true representation of the future trend in transport mode shift; however, it is also acknowledged there are too many uncertainties within Melbourne’s longer term transport network to provide any reliable conclusion in this regard. Limitations on this approach include no consideration is given to the introduction and uptake of electric vehicles in Melbourne and how this might affect road and public transport modes. Traction power of Siemens, Comeng and X’Trapolis rolling stock (operating outside of Melbourne Metro tunnels) has been estimated based on a pro rata of existing rolling stock VKTs with actual existing electricity consumption data provided by MTM. An allowance has been made to take into account future energy savings due to staged implementation of regenerative braking on HCMTs and other electric fleet operating on the wider network, as the system is gradually upgraded to capture such initiatives. These details are provided in Section 6.4.2.4

- No consideration is given in the passenger mode shift assessment to the sourcing of renewable energy (e.g. purchase of accredited GreenPower) by PTV or future operator to reduce GHG emissions associated with operation of trains (traction energy) *outside* of the Melbourne Metro tunnels.

Additionally, there are a number of transport and construction factors isolated or excluded from the 'with Melbourne Metro' scenario. These include:

- Ancillary externalities, including changes to the road network (e.g. changes in toll regimes, signals, new infrastructure), which impact on Melbourne Metro optimum benefits
- Internal business factors – e.g. procurement model; varying procurement models for part or all of the project might drive a range of operating paradigms which could influence the utilisation of Melbourne Metro
- Construction methods, which could vary according to procurement model and design innovation encouraged through tender phase. For simplicity, the GHG inventory for the construction of Melbourne Metro has been based on the construction methods defined for the Concept Design (refer to Chapter 6 *Project Description*).

5 Regional Context

5.1 Overview

As highlighted in earlier sections of this report, GHG emissions associated with the project must be considered over the larger Melbourne metropolitan area, given the complexity of the project's influences on the regional ground-based transport network.

Figure 1-3 shows the extent of the regional system boundary that has been used to define the operational GHG inventory for both the 'no Melbourne Metro' and 'with Melbourne Metro' scenarios.

5.2 Greenhouse Gases and Climate Change

5.2.1 Sources and Effects of Greenhouse Gases

There are two ways that GHG such as carbon dioxide (CO_2) are emitted into the Earth's atmosphere: natural sources and anthropogenic (human) sources. Approximately 43 per cent of all naturally produced CO_2 emissions come from ocean-atmosphere exchange (IPCC, 2007). Other important natural CO_2 sources include decomposition, ocean release, animal and plant respiration, forest fires and volcanoes. The main anthropogenic sources of GHG emissions are burning of fossil fuels to generate electricity, deforestation, intensive livestock farming, use of synthetic fertilisers and industrial processes.

Before the industrial revolution, CO_2 concentrations in the atmosphere remained quite steady for thousands of years. Although the output from humans of 26 Gt of CO_2-e per annum is small compared to the 680 Gt moving through the carbon cycle each year (largely as a result of natural processes), it adds up because the land and ocean cannot absorb all of the extra CO_2; only 40 per cent of this additional CO_2 is absorbed. The rest remains in the atmosphere and, as a consequence, atmospheric CO_2 is at its highest level in 15 to 20 million years (Tripati et al., 2009). As such, natural processes are becoming out of balance as a result of anthropogenic activities and sources of CO_2-e.

GHGs in the atmosphere trap some of the outgoing infra-red radiation which is emitted from the Earth's surface. They absorb infra-red radiation and emit this as heat. Based on recent Earth System Models[22], there is high confidence in the global scientific community that total radiative forcing is positive, and has led to an uptake of energy by the climate system (IPCC, 2013). The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750.

The agreement at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP), held in Paris in late 2015 resulted in agreements aimed at 'holding the increase in the global average temperature to well below 2 C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change' (Phillips, 2015). The Paris COP reached an agreement (Activity 4) 'so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases [i.e. achieve net zero GHG emissions] in the second half of this century' (UNFCCC, 2015).

[22] Earth System Models (ESMs) integrate the interactions of atmosphere, ocean, land, ice, and biosphere to estimate the state of regional and global climate under a wide variety of conditions (Heavens et al., 2013).

5.2.2 Definition: Global Warming Potential

Global warming potentials (GWPs) are used to compare the abilities of different GHGs to trap infra-red radiation in the atmosphere and re-emit this energy as heat. GWPs are based on the radiative efficiency (energy-absorbing/re-emitting ability) of each gas relative to that of CO_2, as well as the effective residence time (years) of each gas relative to that of CO_2 in the atmosphere. In broad terms, multiplying a mass of a particular gas by its GWP gives the mass of CO_2 emissions that would produce the same potential warming effect over a given period; for example, GWP_{100} refers to the global warming potential of a particular gas that would produce the same potential warming effect of CO_2 emissions over 100 years. The GWP provides a means to convert emissions of various gases into a common measure, which is denoted as carbon dioxide equivalents (CO_2-e).

The generally accepted authority on GWPs is the Intergovernmental Panel on Climate Change (IPCC); refer to Myhre et al. (2013). The IPCC regularly updates its estimates of GWPs for key GHGs. At the 2014 Conference of the Parties meeting in Warsaw, Poland, countries agreed to adopt updated GWPs published in the IPCC's 2007 Fourth Assessment Report (IPCC, 2007). From 2015 onwards these GWP would be used for national inventory reporting in Australia (DoE, 2014a), although the latest published GWPs in DoE (2015a) have not yet been updated to reflect the IPCC 2014 GWPs. GWPs for the most common GHGs, as per Australia's National Greenhouse Gas Accounts (DoE, 2015a) are provided in Table 5-1. DoE (2015a) apply these GWPs to convert emissions to a CO_2-e total, and have therefore been used in this GHG assessment.

Table 5-1 100-Year global warming potential estimates (DoE, 2015a)

Greenhouse Gas	GWP_{100}
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298
Hydrofluorocarbons (HFCs)	
HFC-23	14,800
HFC-125	3,500
HFC-134a	1,430
HFC-143a	4,470
HFC-152a	124
HFC-227ea	3,220
HFC-236fa	9,810
Perfluorinated compounds (PFCs)	
Perfluoromethane (CF_4)	7,390
Perfluoroethane (C_2F_6)	12,200
Sulphur hexafluoride (SF_6)	22,800

As shown above, the latest adopted GWP_{100} for CH_4 is 25, and for N_2O is 298. This means that emissions of 1 tonne of CH_4 and N_2O are respectively equivalent to emissions of 25 and 298 tonnes of CO_2 (t CO_2-e).

5.2.3 Major Anthropogenic Greenhouse Gases

This sub-section provides brief descriptions of the major GHGs produced or influenced by human activities: Carbon dioxide (CO_2); Methane (CH_4); Nitrous oxide (N_2O); Synthetic halocarbons; Sulfur hexafluoride (SF_6); and some other gases. CO_2 is likely to be the most significant GHG associated with the Melbourne Metro, with the major sources of CO_2 emissions arising from:

- Combust of fuels during construction (both on-site and transportation)
- Indirect CO_2 emissions associated with construction materials (embodied carbon)
- Emissions associated with the generation of purchased electricity used during operation.

The global atmospheric concentrations of CO_2, CH_4, and N_2O have all increased since 1750 due to human activity.

Various lines of evidence (IPCC, 2013) acknowledge that CO_2 is the most important anthropogenic gas contributing to climate change, representing approximately 77 per cent of the total global GHG emissions (primarily from fossil fuel combustion). Land-use change provides another significant but smaller contribution. Australia's per capita GHG emissions are among the highest in the world, being more than four times the world average, and primarily the result of our reliance on coal-generated electricity (Garnaut, 2008).

Although there is a lower proportion of CH_4 in the atmosphere than CO_2, CH_4 has a GWP 25 times that of CO_2. The major sources of CH_4 are enteric fermentation in cattle, rice growing and leakages during natural gas production, distribution and use. While natural processes currently remove CH_4 from the atmosphere at almost the same rate as it is being added, CH_4 concentrations are likely to rise over the next 100 years.

Atmospheric N_2O concentrations have increased by 15 per cent during the past 200 years and the gas can persist in the atmosphere for up to 100 years. Major sources of N_2O include industrial processes, fertiliser use and other agricultural activities, including land clearing. Some N_2O emissions during construction or operation of Melbourne Metro are likely to occur as a result of fuel combustion and minor land clearing activities; however these emissions would be relatively small in comparison to CO_2 emissions.

The GHG impact assessment also investigates whether other GHGs (HFCs, CFCs, PFCs) may be associated with the construction or operation of the Melbourne Metro, and their degree of materiality.

Sulfur hexafluoride (SF_6) is a synthetic gas and ozone depleting substance (ODS). The Greenhouse Challenge Discussion Paper *Sulfur Hexafluoride and the Electricity Supply Industry*, issued by the Australian Greenhouse Office in 2001, states that SF_6 emissions can occur from its use in metal processing and the electricity supply industry. While the quantities of emissions of this gas are currently comparatively small to those generated during the combustion of fossil fuels, its GWP is 22,800 times that of CO_2. The main use of SF_6 globally is in electricity transmission and distribution, which accounts for approximately 80 per cent of use, and is often used in circuit breakers within substations. Most of the SF_6 used in the electrical equipment is used in gas insulated switchgear and circuit breakers, although some SF_6 is used in high voltage gas-insulated transmission lines and other equipment. A qualitative assessment of SF_6 and ODSs associated with the project is provided in Section 6.5.

6 Impact Assessment

6.1 EES Evaluation Objectives

The draft EES evaluation objectives and assessment criteria (and indicators where relevant) that are relevant to this assessment are provided in Table 6-1.

Table 6-1 Draft EES evaluation objectives and assessment criteria – GHG assessment

Draft EES evaluation objectives	Assessment criteria	Indicator
Transport: Connectivity objective: To enable a significant increase in the capacity of the metropolitan rail network and provide multimodal connections, while adequately managing effects of the works on the broader transport network, both during and after the construction of the project. **Project description and context**: Describe aspects of the operational phase of the project that could give rise to environmental effects, including with regard to … greenhouse gas emissions.	Identification of best practice initiatives to reduce greenhouse gas (GHG) emissions across the construction and operational phases of the project, below a Business-As-Usual reference footprint	• Predicted reduction in GHG emissions (as indicated by percentage reduction) of best practice greenhouse gas abatement construction and operational, compared to BAU GHG abatement scenario. • Predicted reduction in GHG emissions (as indicated by grams CO_2-e per passenger kilometre) of Melbourne's transport system with the Melbourne Metro (at opening and 20 years from opening) compared with the 'no Melbourne Metro' scenario.

6.2 Existing conditions

6.2.1 Existing Transport Network

The baseline GHG inventory for the 'no Melbourne Metro' scenario has been aligned with the VITM 'no Melbourne Metro' modelling scenarios. This includes the existing transport network, assessed using data from the latest VITM reference year (2011). The GHG emissions determined from this scenario are included in Section 6.4.2.1.

6.2.2 Metro Trains Melbourne

MTM is the current operator of the electric rail network in Melbourne. MTM reports its annual GHG emissions to the Clean Energy Regulator under the NGER Scheme.

MTM reported the following Scope 1 and Scope 2 GHG emissions for the most recent NGER reporting periods; refer to Table 6-2.

Table 6-2 MTM reported GHG emissions, NGER scheme 2010-2014

Reporting Year	Total Scope 1 Emission (t CO_2-e)	Total Scope 2 Emission (t CO_2-e)	Total Net Energy consumed (GJ)
2010-11	6,225	511,238	1,587,410
2011-12	5,987	517,031	1,627,699

Reporting Year	Total Scope 1 Emission ($t\ CO_2$-e)	Total Scope 2 Emission ($t\ CO_2$-e)	Total Net Energy consumed (GJ)
2012-13	5,815	530,522	1,693,026
2013-14	6,028	504,277	1,634,622

The total annual reported Scope 2 GHG emissions are likely to be attributed to electricity purchased to operate the rolling stock and stations. The operational GHG emissions stated in this section refer to emissions across the entire Metro network and as such, the existing Metro network (and associated GHG emissions) cannot be used as a baseline reference for the operational phase of Melbourne Metro, which is only portal to portal of the Melbourne Metro rail tunnels.

6.3 Melbourne Metro Construction

6.3.1 Project Components

The estimated Scope 1, Scope 2 and Scope 3 emissions for the construction of the Melbourne Metro are provided in Section 6.3.2. The construction components included within the construction GHG assessment include:

- Construction of the Melbourne Metro tunnels and portals, including:
  - Operation of TBMs and roadheaders, including conveyors and dewatering plant (electricity purchased from the grid) and removal of spoil by trucks
  - Civil construction works, including transportation of materials to/from site
  - Tunnel fit out
- Construction of stations, including:
  - Civil construction works, including transportation of materials to/from site and removal of spoil by trucks
- Construction of Western Turnback – Chapter 6 *Project Description* of the EES includes construction of a third platform and track at West Footscray station, with modifications to existing concourse
- Construction of new rolling stock (HCMTs) associated with the operation of Melbourne Metro.

For further descriptions of the activities identified above, refer to Chapter 6 *Project Description.*

6.3.2 GHG Emissions Associated with Construction

6.3.2.1 Summary

It is estimated that total GHG emissions from construction of Melbourne Metro would be approximately 642 kt CO_2-e, assuming BAU construction techniques/methods and GHG abatement (*Melbourne Metro BAU Construction Footprint* defined in Section 4.6.3.4) and does *not* include the 20 per cent renewable energy requirement (PTV Project Requirement) which is considered a best practice GHG abatement initiative. All assumptions are provided in Section 6.3.4. A summary of emissions by Scope is presented in Table 6-3, with a more detailed analysis of the emission sources provided in the following subsections.

Table 6-3 Summary of GHG emissions from construction: *Melbourne Metro BAU Construction Footprint*

Emission source	Project activity	GHG emissions (kt CO_2-e)			
		Scope 1	Scope 2	Scope 3	Total
Transport fuel	Spoil removal by trucks	14.4	-	0.7	**15.1**
Transport fuel	Materials delivery	-	-	14.3	**14.3**
Transport fuel	Site vehicles	5.5	-	0.3	**5.8**
Stationary fuel	Construction plant/equipment	59.6	-	3.1	**62.7**
Loss of carbon sinks	Excavation and disturbance of vegetation (includes lay down areas)	0.4	-	-	**0.4**
Liming / Stationary fuel	Offsite treatment of WASS (application and mixing of calcic limestone).	-	-	23.6	**23.6**
Purchased electricity	Construction plant and equipment (e.g. TBMs)	-	77.7	9.3	**87.0**
Purchased electricity	Construction site offices	-	3.4	0.4	**3.8**
Embodied carbon in materials	Stations, materials lifecycle GHG impact	-	-	298.2	**298.2**
Embodied carbon in materials	Tunnels and portals, materials lifecycle GHG impact	-	-	111.5	**111.5**
Embodied carbon in materials	Rolling stock HCMTs (Melbourne Metro contribution), materials lifecycle GHG impact	-	-	19.6	**19.6**
TOTAL		**79.9**	**81.1**	**481.0**	**642.0**

A summary of the total construction emissions (Scopes 1, 2 and 3) by emission source for the *Melbourne Metro BAU Construction Footprint* is provided in Figure 6-1.

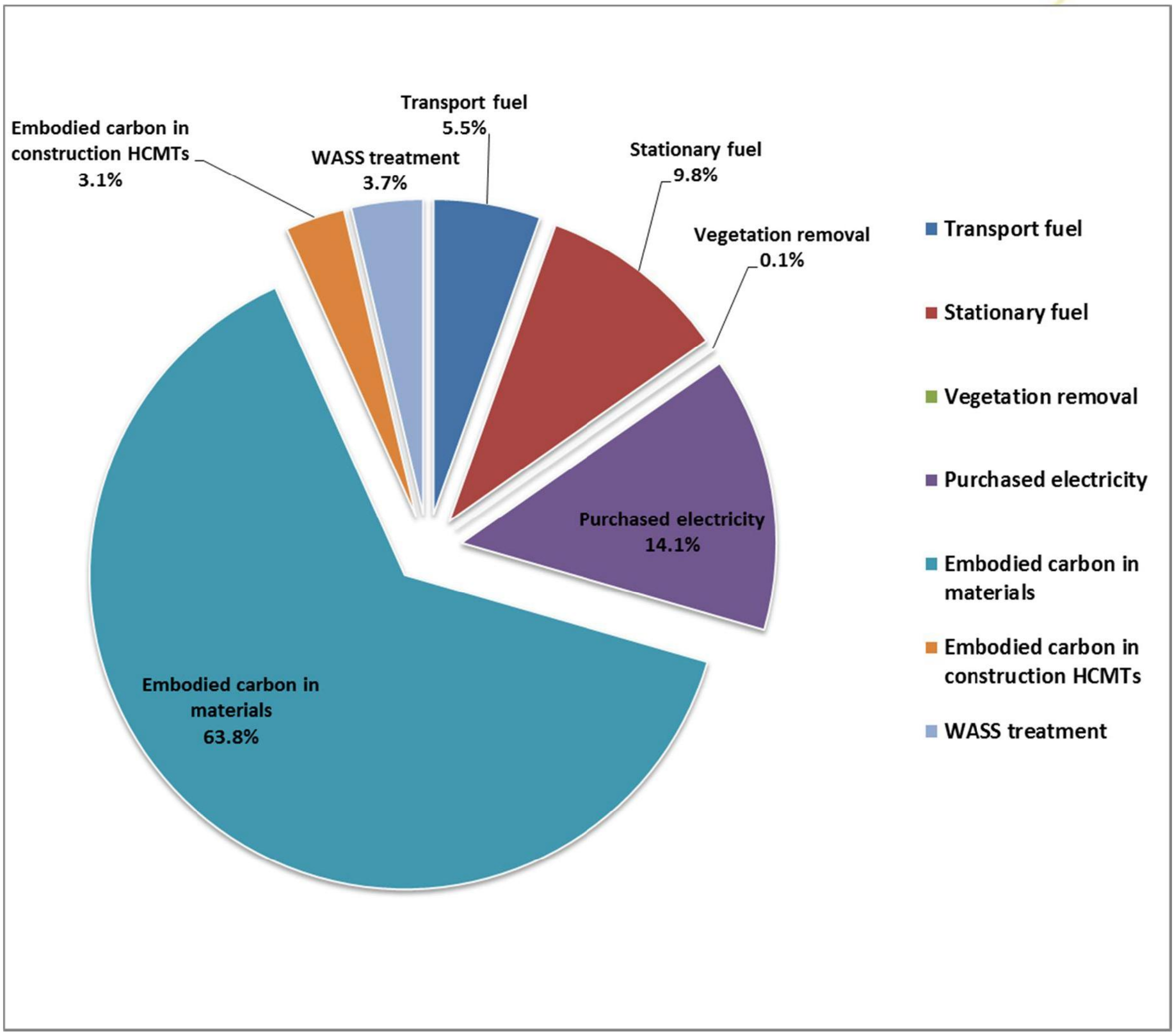

Figure 6-1 Summary of construction GHG emissions by activity type

(Melbourne Metro BAU Construction Footprint)

6.3.2.2 GHG Modelling Considerations and Assumptions

Detailed modelling assumptions specific to each GHG emissions source/activity have been included in the following sections, as relevant to that activity or GHG emissions source.

6.3.2.3 Purchased Electricity (Scope 2 Emissions)

6.3.2.3.1 Tunnel Boring Machines

Assumptions regarding the tunnel boring machines (TBMs) and associated plant/equipment, as confirmed with the Constructability Advisor, include:

- Achievement of ten horizontal metres per day; TBM tunnel length 6,800 m; two tunnels
- 20 hours/day operation (includes conveyors and dewatering plant)
- TBM power rating of 2,500 kW (per TBM). Assuming a power factor of 0.9, other equipment includes: conveyor power requirement of 2,000 kVA (rating of 1,800 kW); dewatering and cooling closed loop power requirement of 500 kVA (rating of 450 kW)
- TBMs and conveyors operate at an average 50 per cent load (average over the duration of construction); dewatering at 100 per cent load.
- Total energy consumption over construction:
  - TBMs: 34,000 MWh

– Conveyors: 24,480 MWh
– Dewatering and cooling closed loop: 12,240 MWh
– Total: 70,720 MWh.

This is considered to be a conservative estimate of the energy required.

6.3.2.3.2 Roadheaders

The section of Melbourne Metro tunnels running between CBD North station and CBD South station are proposed to be mined tunnels; excavation would be undertaken using roadheaders. Roadheaders have a boom-mounted cutting head mounted on a crawler travelling track and it has been assumed this would be used as the primary excavation equipment. The roadheaders are also expected to be electrically driven, however they do not have the same power requirements as a TBM. The following assumptions have been adopted for the roadheaders:

- Assumptions regarding plant performance have been based on a MRH-S300A Type roadheader, with specification sheet provided by the MMRA Constructability Advisor
- Two mined tunnel sections between CBD North and CBD South, each tunnel estimated to be 680 m horizontal distance; achievement of ten horizontal metres per day (based on the assumption of a typical roadheader advance rate of 300 m/month)[23]
- Required power of 550 kVA (specification states ‘more than 500 kVA’ required, therefore 550 kVA has been assumed). This equates to 495 kW assuming a power factor of 0.9
- Roadheaders operate at an average 80 per cent load (average over the duration of construction)
- Total energy consumption over construction: 1,077 MWh.

6.3.2.3.3 Shotcrete Pumps

Shotcrete pumps would likely be used for the stations and tunnel construction. The following operational assumptions have been adopted:

- Electricity operate electrical load: 11 kW, operating at 100 per cent load factor
- Total number of operating hours: 9,256 hours (as advised by the MMRA Cost Advisor)
- Total electrical energy consumed: 101.8 MWh.

6.3.2.3.4 Construction Site Offices

Electricity consumption in construction site offices has been estimated using the following assumptions:

- Energy benchmark of 7.5 W/m^2 and 15 W/m^2 for lighting and equipment, respectively, based on the Building Code of Australia (BCA) JV3 protocol for office building, and discussions with AJM JV Electrical services design team, reflecting LED lighting
- Total floor area of 4,000 m^2 across all construction offices
- Average power assumption of 12 hours per day, 365 days per year
- Eight years of construction (includes construction, fit out and commissioning).

6.3.2.3.5 Overall Considerations

No consideration is given within the *Melbourne Metro BAU Construction Footprint* to the use of renewable energy sources to supplement power supply to the TBMs. The *Melbourne Metro Best Practice Construction Footprint* assumes that the Contractor would source 20 per cent of all electricity purchased TBMs and equipment from accredited GreenPower.

[23] http://www.infomine.com/publications/docs/InternationalMining/Chadwick2012j.pdf

6.3.2.4 Materials Lifecycle GHG Impacts

6.3.2.4.1 Structural Concrete

A Materials and Durability report (AJM JV, 2015a) has been produced specifying the material requirements for structural elements on Melbourne Metro. The following concrete grades (specified by Cylinder Strength) have been adopted in the Concept Design for key elements, as listed in Table 6-4, and apply (generally) to the GHG model (although it is noted the grade/strength for each individual structural element has been provided by AJM JV structural engineers within the construction materials workbooks).

Table 6-4 General concrete grades adopted

Element	Grade / strength
Internal Structures: walls, columns, suspended slabs, beams and stairs	40 MPa
External/buried elements or reinforced concrete exposed to the Ground and groundwater (retaining walls, roof and base slabs)	40 MPa
Tunnel linings exposed to ground and groundwater	50 MPa
Non-structural elements other than those specified above	40 MPa

The concrete strength grades defined within the Melbourne Metro BAU Construction Footprint comprise 40 MPa and 50 MPa concrete and assumes zero per cent Supplementary Cementitious Materials (SCM). The 40 MPa and 50 MPa 'reference' concrete mixes (0 per cent SCM) adopted within the IS Materials Calculator for the BAU Construction Footprint align with the GBCA reference mixes, and represent the Portland cement content concrete strength grades as defined in AS 1379-2007 *Specification and supply of concrete*. The Portland cement content adopted for the 'reference mixes' are therefore 440 kg/m^3 and 550 kg/m^3 for 40 MPa and 50 MPa concrete, respectively.

No consideration in the BAU scenario is given to recycled concrete aggregate (RCA).

The *Melbourne Metro Best Practice Construction Footprint* assumes a minimum 30 per cent reduction in Portland cement is achievable, by means of 30 per cent SCM. As per the IS Materials Calculator emissions factors in Appendix B of this report, reductions in GHG emissions are estimated to be 23-24 per cent from incorporation of 30 per cent SCM in 40 MPa and 50 MPa concrete. Proposed concrete mix designs suitable for a 100-year life have been covered in AJM JV (2015a) and were assessed during the Concept Design with at least 25 per cent SCM, to enable comparison (AJM JV, 2016). These were: (a) a mix with 25 per cent fly ash, (b) a mix with 30 per cent fly ash, (c) a mix with 65 per cent blast furnace slag and (d) a ternary mix with 25 per cent fly ash and 25 per cent slag. Significant reductions in CO_2-e emissions would therefore be achieved by partial replacement of cement with fly ash and/or slag or replacement of virgin aggregate with recycled concrete aggregate for the example mixes; refer also **Risk #GH001**.

6.3.2.4.2 Stations

The estimated quantities of materials and Scope 3 embodied GHG emissions for the stations construction (*Melbourne Metro BAU Construction Footprint*) is provided in Table 6-5.

Table 6-5 Embodied carbon in construction: stations (*Melbourne Metro BAU Construction Footprint*), kt of material

Material	Domain (kt)	Arden (kt)	Parkville (kt)	CBD North (kt)	CBD South (kt)	Total (kt)	GHG (kt CO_2-e)
Concrete, 40 MPa[1]	123.8	168.8	144.1	156.3	143.0	735.9	138.1
Concrete, block fill, pump mix	-	-	5.2	14.4	13.9	33.5	6.3

Material	Domain (kt)	Arden (kt)	Parkville (kt)	CBD North (kt)	CBD South (kt)	Total (kt)	GHG (kt CO_2-e)
Steel rebar[2]	17.0	21.4	17.8	21.2	19.2	96.7	153.8
Total							**298.2**

[1] As indicated in Table 6-4, only 40 MPa strength concrete has been assumed for stations construction.
[2] Steel bar reinforcement.

6.3.2.4.3 Tunnels and Portals (including Western Turnback)

Scope 3 GHG emissions for embodied carbon in materials for the tunnels, portals, cross passages and emergency shafts and western turnback construction is provided in Table 6-6. This includes only the significant quantities of materials used in tunnel fit out (and has been limited to only those materials within the IS Materials Calculator).

Table 6-6 Embodied carbon in construction: tunnels/portals/cross passages/emergency access shafts, incl. Western Turnback (*Melbourne Metro BAU Construction Footprint*)

Material	IS Materials Calculator descriptor[24]	Quantity (kt)	GHG emissions (kt CO_2-e)
Concrete, 40 MPa	Concrete Strength Grade 40 MPa	203.0	38.1
Concrete, 50 MPa	Concrete Strength Grade 50 MPa	134.4	32.2
Shot Crete, 40 MPa	Concrete Strength Grade 40 MPa	34.6	6.5
Grout	Recycled Crushed Concrete/ Masonry	108.4	0.02
Steel rail lines	Steel Rail Lines	0.9	1.1
Steel rebar [1]	Steel Reinforcing Bar	20.9	33.3
Steel rock bolts	Steel Reinforcing Bar	0.21	0.24
Steel, tunnel fit out [2]	Steel Angle	0.04	0.046
Aluminium [3]	Aluminium	0.001	0.026
Total			**111.5**

[1] Steel bar reinforcement
[2] ROCB Insulated Cantilever Support
[3] Contact line: Conductor Beam (ROCB)

6.3.2.4.4 Summary of Materials Lifecycle Impacts

A summary of the total embodied GHG emissions from construction (by material type), and materials delivery, as aggregated in the IS Materials Calculator, is provided in Table 6-7 and Figure 6-2.

[24] This represents the best match within the IS Materials Calculator to define the material used.

Table 6-7 Summary of materials lifecycle impacts (*Melbourne Metro BAU Construction Footprint*)

Construction material	GHG emissions (kt CO_2-e)		
	Tunnels	Stations	Total
Concrete, 40 MPa – 0% SCM	44.6	144.4	189.0
Concrete, 50 MPa – 0% SCM	32.2	-	32.2
Steel	34.7	153.8	188.5
Aluminium	0.03	-	0.03
Grout	0.02	-	0.02
Materials delivery	4.8	9.4	14.3
Total	**116.3**	**307.7**	**424.0**

6.3.2.5 Construction of Rolling Stock

'Day One' of operation of Melbourne Metro would involve the operation of 59 Standard (7-car sets) HCMTs in timetable running, with a total of 62 HCMTs within the rolling stock fleet. The HCMT is a new metropolitan train for future use on the Melbourne rail network including Melbourne Metro (Melbourne Metro would only operate HCMTs – i.e. no other rolling stock would be utilised within the tunnels). The trains are planned to be able to carry 1,100 passengers at rated performance (7-car sets), with the ability to be lengthened to 10-cars carrying 1,570 passengers at rated performance. It is expected by 2031 that Extended HCMT (10-car) operation would have been at least partially implemented on the Sunbury and Cranbourne/Pakenham corridor (with a mix of Standard HCMT and Extended HCMT operating on all lines) (PTV, 2015). By 2046 (20 years after opening), it is proposed that only Extended HCMTs would be in timetable running on Melbourne Metro. For the purposes of this assessment and for determining embodied emissions from construction of HCMT rolling stock, it has been assumed all HCMT trains are 7-car train sets as the future operational split of Standard/Extended HCMTs over time would vary and has not yet been determined (PTV, 2015).

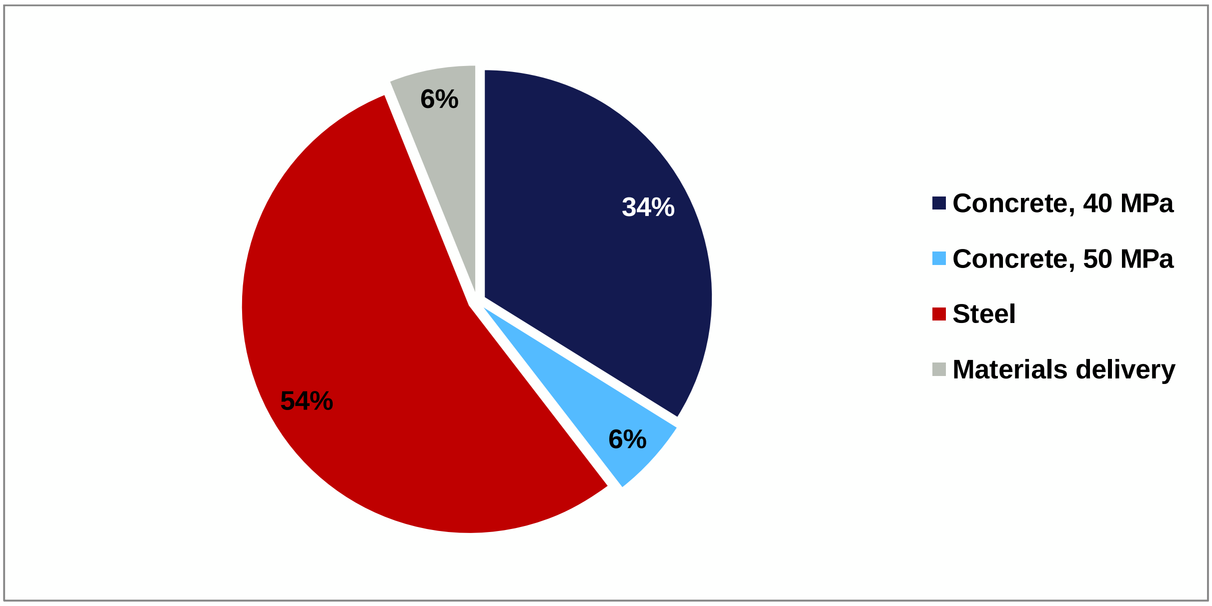

Figure 6-2 Summary of embodied GHG emissions footprint by emissions source

Melbourne Metro BAU Construction Footprint

For the case of 'no Melbourne Metro', 37 HCMTs would be in timetable running along the Cranbourne-Pakenham Rail Corridor as part of the Cranbourne-Pakenham Line Upgrade (CPLU), which is currently under development by the Victoria Government. Therefore, the embodied carbon from the construction of new rolling stock has been determined for both the ‘with Melbourne Metro’ and ‘no Melbourne Metro’ scenarios, with the incremental contribution from the ‘with Melbourne Metro’ scenario being the difference between the two scenarios. This is summarised in Table 6-8.

The following assumptions have been adopted for construction of the HCMTs:

- Assumed the mass of new HCMTs is 100 per cent steel (for ease of calculation), with energy content for steel assumed to be 2.65 tonnes CO_2-e/tonne steel (average of emissions factors for steel as per the IS Materials Calculator)
- Mass and configuration of HCMT set (driving motor car, motor car, trailer) has been obtained from HCMT spec sheets (PTV HCMT Project)
  - 7-car HCMT train set comprises 2 x motor cars, 2 x driving motor cars, and 3 x trailer cars
  - Total mass of 7-car train set calculated to be 296 tonnes
- Energy consumption during manufacture of rolling stock, and transportation of vehicles to Melbourne (if constructed outside of Melbourne), has not been included in the Scope 3 emissions.

6.3.2.5.1 Interaction with Victorian Rolling Stock Strategy

Ongoing planning for the staged implementation of the HCMT fleet is aligned to the Victorian Rolling Stock Strategy announced by the Victorian Government in May 2015, which identifies an expected delivery of 100 HCMT trains in the period 2015–2025. This strategy includes allowance for procurement of HCMT trains beyond the 62 trains identified to support the operation of Melbourne Metro, with objectives expanded to also accommodate growth and to enable retirement of the oldest trains in the existing fleet prior to Melbourne Metro (PTV, 2015).

Table 6-8 Construction of rolling stock – embodied carbon (Scope 3 GHG emissions)

Parameter	‘No Melbourne Metro’	‘With Melbourne Metro’ (Day One)	Difference
Number of HCMTs in rolling stock fleet	37	62	25
Number of cars per train	7	7	0
Mass 7-car set train [25]	296 tonnes	296 tonnes	0
Scope 3 GHG emissions (t CO_2-e)	29,023	48,633	19,610

6.3.2.6 Fuel Combustion

The following assumptions have been adopted for the estimation of GHG emissions from fuel consumption during construction:

- Includes stationary fuel consumption from plant/equipment on site for construction of tunnels, cross passages, emergency access shafts, portals, and stations. The following assumptions have been made with respect to stationary fuel consumption for the *Melbourne Metro BAU Construction Footprint*:
  - All plant and equipment consume diesel oil, with no consideration given to the use of biodiesel
  - Activity rates (total hours of operation) for each plant/equipment type have been sourced from the Melbourne Metro Cost Advisor

[25] Assumed all steel. Refer to Chapter 6.4.1.3 for all assumptions.

- Average fuel consumption rates have been determined from fuel consumption inventories and handbooks, e.g. Sattiraju (2010) and Caterpillar handbook
  - Water carts and road sweepers have been categorised as transport fuel consumption
  - GHG emissions factors have been sourced from Department of Environment (2015a); refer to Appendix B of this report.

- Includes transportation fuel consumption for removal of spoil/rock
  - Based on the estimated split of construction trucks by type over the project duration, as provided in Technical Appendix D *Transport* (Source: Advisian); i.e. 33 per cent of all truck movements have been assumed to be spoil trucks.
  - Equates to 154,869 'round trip' truck movements hauling spoil/rock, assuming a 30 per cent bulking factor (MMRA, 2016)
  - Truck volumetric capacity assumed by location (dense m^3):
    - Eastern and Western Portal sites (truck only) = 6.5
    - All other locations (truck & dog) = 12.5
  - A BAU distance to spoil/rock disposal and/or treatment site of 30 km has been adopted, which assumes possible spoil locations in outer metropolitan Melbourne
  - All spoil/rock removed from site is via articulated truck, which assumes an average fuel consumption of 56.9 litres/100 km, sourced from (ABS, 2015)
- Fuel consumed during the transportation of construction materials to site (Scope 3 emissions) adopts the following assumptions:
  - A BAU distance to both cement plant and steel plant has been assumed as 30 km from the construction zones (single direction), which assumes possible cement and steel plant locations in outer metropolitan Melbourne
  - The potential use of a purpose built cement batching plant at Arden has not been accounted for in the BAU scenario
  - Cement Truck load capacity assumed to be 14.6 tonne (6.1 m^3). Steel/Prefab Delivery Truck load capacity has been assumed to be the same as for Cement Truck
- No consideration is given in the BAU case to use of biodiesel renewable fuels (such as biodiesel) as an alternate fuel source for either stationary or transport fuel, or implementation of hybrid plant / equipment and electric / hybrid vehicle fleet
- Employee vehicles used during shift (e.g. 4WD utility vehicles, tradesmen vans). Fuel consumption for these vehicles assumes 50 km/day travel around the project area over a 10-hour 'day' shift, average fuel consumption for 'commercial vehicle' of 12.1 L / 100 km (ABS, 2015)
- The Melbourne Metro Best Practice Construction Footprint assumes a 'B20' biodiesel blend could be easily used within plant and equipment on site ('stationary fuel consumption'). It is assumed this equates to an equivalent of 20 per cent replacement with biodiesel. B20 is the most common biodiesel blend; it is popular because it represents a good balance of cost, GHG emissions, cold-weather performance and materials compatibility (AFDC, 2015). Use of B20 offers a 19-20 per cent reduction in GHG emissions, compared to standard petroleum diesel. This is largely due to GHG emissions from the biodiesel fraction being negligible in comparison to that from diesel. Emissions factors for biodiesel have been based on DoE (2015a); refer Appendix B of this report. Note that Scope 3 emissions factors (upstream effects) for biofuels such as biodiesels and ethanol are highly dependent on individual plant and project characteristics, and therefore have not been estimated (DoE, 2015a).

6.3.2.7 Land Clearing

The calculated areas of land clearing during construction, as determined by Melbourne Metro terrestrial ecologist, are identified in Table 6-9. The vegetation class within the RMS & VicRoads (2013) handbook considered to be best representative of the vegetation to be cleared is provided.

The land clearing emission factor for 'Grassland' has been adopted as the most suitable emission factor for the majority of vegetation to be cleared across Melbourne Metro area. Note that the use of 'Grassland' in this section does not refer to the interpretation of 'Grassland' under either Commonwealth (*Environment Protection and Biodiversity Conservation Act 1999*) or State (DEPI *Permitted clearing of native vegetation – Biodiversity assessment guidelines*) biodiversity requirements.

The largest area which may require clearing comprises the patch of 'grassland' at Fawkner Park and Domain Parklands. There are smaller patches of native and/or exotic grassland, however these patches also comprise exotic gardens; as such, a conservative assumption is that the areas to be cleared fully comprise grassland. The level of accuracy with regard to these consideration assumptions is considered to be immaterial to the overall contribution of GHG emissions from land clearing.

Table 6-9 Land clearing GHG emissions from loss of carbon sinks

Land type	Assumed vegetation class (RMS & VicRoads, 2013)	Potential vegetation impact area (m^2)	Emissions Factor (t CO_2-e/ha)	Scope 1 emissions (t CO_2-e)
Planted native vegetation	Open Woodlands - Vegetation Class D	6,339	209	132
Exotic vegetation	Grassland - Vegetation Class I	26,337	110	290
Total	**-**	**32,676 m^2 (3.27 ha)**	**-**	**422**

6.3.3 Sustainability Performance Targets and Requirements – Best Practice Construction

With the consideration of the sustainability performance targets and requirements for the project, the following would be applicable to the construction GHG emissions footprint:

- PTV Project Requirement: at least 20 per cent of electricity consumed during construction shall be generated by a Victorian Government-accredited GreenPower renewable energy source
- Melbourne Metro Sustainability Target: Concept Design to achieve reductions in GHG emissions (Scope 1 and Scope 2) by a minimum of 20 per cent below the base case over the lifecycle of the project (construction and operation), excluding the use of renewable energy.[26]

Construction GHG emissions would be given a high priority with reductions to be in line with local, State and Commonwealth GHG emissions reduction targets. In order to meet these requirements and targets, the following examples are best practice GHG abatement initiatives that would need to be considered and implemented (among others), or have already been captured in the Concept Design; refer to **Risk #GH001**.

[26] MMRA is committed to reducing GHG emissions based on the BAU base case and has set minimum targets for the project and will be investigating opportunities to increase these targets (particularly when reviewing renewable energy or new technologies). The reduction target is based on the PTV Project Requirements for construction and the IS Rating Tool credit levels within the Energy Theme. There is opportunity for delivery partners to improve their performance regarding carbon emissions reductions, if this is possible and cost effective.

Scope 1 and 2 Emissions

- Consider the use of biofuels (e.g. biodiesel 'B20' blend) for construction plant and equipment
- Identify spoil disposal and/or reuse options and locations that are closer to the project alignment (e.g. reduction of one-way distance to spoil reuse/disposal location from 30 km (BAU base case) to 20 km would reduce GHG emissions from this activity by 33 per cent)
- Consider implementation of hybrid plant/equipment and electric/hybrid vehicle fleet
- High efficacy and energy efficient Light Emitting Diode (LED) construction lighting for night-time works
- Intelligent controls/sensors for lighting
- Purchase of GreenPower.

Assuming that this requirement and target is met, the GHG emissions associated with energy consumption during construction (sum of Scope 1 and 2 emissions, excluding land clearing) would reduce from 160.6 kt CO_2-e to 128.4 kt CO_2-e; this assumes that 20 per cent of all energy requirements during construction would be sourced from renewable energy sources (e.g. biofuels and accredited GreenPower).

Scope 3 Emissions

- It is estimated steel would represent approximately 54 per cent of the total embodied GHG emissions from materials used in construction of the project. A best practice initiative that has been captured in the Concept Design to reduce the quantity of steel includes use of steel fibres instead of steel bar reinforcement (rebar) in the segmental lining of the tunnels where feasible, thus reducing quantities of steel required (35 kg/m^3 of concrete versus 135 kg/m^3 of steel reinforcement). Given this initiative could be applied 'wherever feasible' it has been assumed for the *Melbourne Metro Best Practice Construction Footprint* this is likely to be feasible across 50 per cent of the tunnel length. For example, for the tunnels crossing adjacent to the existing Federation Square foundations, it is unlikely that steel fibre reinforced concrete (SFRC) could be implemented given a higher reinforcement density using additional reinforcing steel bar would be required
- Construction of Melbourne Metro would involve large quantities of concrete, the manufacture of which involves generation of CO_2-e emissions (refer to section 6.3.2.4 and **Risk #GH001**). Ordinary Portland Cement (OPC) has much higher embodied GHG emissions than alternative concrete mixes which have lower carbon intensity cement products (compared to OPC), such as sulphur-enhanced concrete or the incorporation of fly ash. In order to improve the sustainability of the project it is necessary to consider how emissions could be reduced through mix design and use of supplementary cementitious materials (SCM). Investigations undertaken during the Concept Design indicate that concrete mixes using fly ash and blast furnace slag are possible while maintaining concrete strength and durability specifications. For example, the *Melbourne Metro Best Practice Construction Footprint* assumes 30 per cent fly ash which is considered to be achievable for this project, achieving reductions of 23-24 per cent in embodied GHG emissions in concrete, compared to zero per cent SCM. Reducing the OPC content in concrete by 30 per cent across all concrete used in the project compared to the reference footprint has been captured in Concept Design and specifications).

  Impact on Curing Requirements

  Since curing has a profound effect on the durability of the concrete elements, it is important that compromises in curing methods and duration are not made. Freshly cast concrete must be protected from premature drying. Curing is particularly important for concrete containing fly ash and/or slag. VicRoads Section 610 (VicRoads, 2013) requires an additional two days of curing (other than steam and radiant heat curing) for concrete with Type GB (blended) cement. Steam and heat curing can improve rate of strength gain but are not necessarily advantageous for durability. Post-curing can improve durability of such concrete. (AJM JV, 2015c)

- Replacement of virgin (coarse) aggregate with recycled concrete aggregate (RCA) or crushed slag aggregate (captured in Concept Design)
- Use of Post Tensioned (PT) beams and slabs to ground and concourse levels of stations significantly reduces the quantity of the conventional steel reinforcement (captured in Concept Design)
- Other techniques to reduce the mass of reinforcing steel, e.g. optimal fabrication techniques such as reinforcing carpets, special mesh, prefabricated reinforcement cages
- Glass fibre reinforced polymer (GFRP) reinforcement could be used in certain situations such as breakthrough locations for TBMs, e.g. at shafts, which are temporary structures. GFRP reinforced concrete locations for this purpose is known as Soft Eyes. It is used instead of steel reinforcement and facilitates easier breakthrough. The Soft Eyes are temporary structures with a required life of approximately six months.

Total GHG emissions from construction under this best practice scenario would reduce to approximately 543 kt CO_2-e from the BAU scenario total emissions of 642 kt CO_2-e.

This includes embodied energy in materials, representing 68 per cent of the *Melbourne Metro Best Practice Construction Footprint* (including construction of rolling stock). A summary of emissions by Scope for the *Melbourne Metro Best Practice Construction Footprint* is presented in Table 6-10, which compares with emissions estimated for the *Melbourne Metro BAU Construction Footprint*; refer to Figure 6-2.

Table 6-10 Summary of GHG emissions from construction: *Melbourne Metro Best Practice Construction Footprint*

Emission source	Project activity	GHG emissions (kt CO_2-e)		% Reduction
		BAU base case	Best practice	
Transport fuel	Spoil removal by trucks	15.1	12.1	20%
Transport fuel	Materials delivery	14.3	11.4	20%
Transport fuel	Site vehicles	5.8	4.6	20%
Stationary fuel	Construction plant/equipment	62.7	50.1	20%
Loss of carbon sinks	Excavation and disturbance of vegetation (includes lay down areas)	0.4	0.4 *	0% *
Liming / Stationary fuel	Offsite treatment of WASS (application and mixing of calcic limestone)	23.6	23.6 **	0% **
Purchased electricity	Construction plant and equipment (e.g. TBMs)	87.0	69.6	20%
Purchased electricity	Construction site offices	3.8	3.1	20%

Emission source	Project activity	GHG emissions (kt CO_2-e)		% Reduction
		BAU base case	Best practice	
Embodied carbon in materials	Stations, materials lifecycle GHG impact	298.2	264.5	11%
Embodied carbon in materials	Tunnels and portals, materials lifecycle GHG impact	111.5	84.4	24%
Embodied carbon in materials	Rolling stock HCMTs (Melbourne Metro contribution), materials lifecycle GHG impact	19.6	19.6	0%
TOTAL		**642.0**	**543.4**	**15%**

* This is a conservative assumption and does not consider potential revegetation, replanting or offsetting, which is likely to occur. As these details have not been confirmed, for simplicity the best practice scenario assumes no reduction from the BAU base case.

** This is a conservative assumption and assumes that the contractor is unable to influence any reduction in GHG emissions associated with the neutralisation of WASS, for potential reuse of the WASS material. If direct disposal without treatment was permissible (through an EPA endorsed EMP), although it would significantly reduce GHG emissions associated with this activity, this is not considered to be an optimal sustainability initiative for the project as it would not allow for any beneficial reuse of the material. Direct disposal is typically 'last' on the waste hierarchy.

6.3.4 Key Issues

In the EES, technical studies consider the key issues associated with the Concept Design and the proposed alternative design options, for each precinct.

The key issues identified with the construction of the proposed infrastructure (either Concept Design or alternative design options), with respect to construction GHG emissions, are provided in Table 6-29. The issues have been cross referenced to the relevant risk issue identified in the risk assessment (refer to Section 7).

Table 6-11 Key issues associated with operation of the Concept Design

Description	Issue	Risk #
Materials lifecycle GHG impacts	Embodied carbon in construction materials (Scope 3 emissions) represents 67 per cent of the overall construction BAU carbon footprint. Approximately 1,100 kt of concrete and shotcrete is estimated to be required to construct the tunnels and stations, which contributes significantly to the overall construction GHG footprint; it equates to 221 kt CO_2-e of embodied carbon, representing 34 per cent of the construction BAU carbon footprint. Sustainability initiatives to reduce the OPC content in concrete by 30 per cent across all concrete used in the project (compared to the reference footprint) have been incorporated into the Concept Design and Sustainability Project Performance Requirements. The Contractor would also be required to achieve a minimum 15 per cent reduction in materials lifecycle GHG impact, below the base case.	***GH001***

Description	Issue	Risk #
Reduction of GHG emissions from purchased electricity	The TBMs and roadheaders, together with conveyors, dewatering and cooling closed loop, would consume approximately 71.9 GWh of electricity over the duration of construction, corresponding to 87.0 kt CO_2-e (Scope 2 and 3) emissions. Additionally, it is estimated approximately 3.2 GWh of electricity would be consumed for operating construction site offices (lighting and electrical). Achieving the PTV Project Requirement of sourcing a minimum 20 per cent of energy from renewable sources during construction would require the Contractor to source approximately 15 GWh of electricity from accredited GreenPower during construction. Additional GHG reductions may be able to achieved through energy efficient construction methods and logistics (e.g. operation of TBMs), which aims to minimise energy consumption in the first instance.	***GH001***

There are no significant issues with the proposed alignment or infrastructure at each precinct (either Concept Design or alternative design options), with respect to construction GHG emissions. For example, whether the vertical alignment of the tunnels (Precinct 1) is above or below the CityLink tunnels is considered to be immaterial to the construction GHG footprint.

6.4 Melbourne Metro Operation

6.4.1 Project Components

Section 6.4 provides an assessment of the GHG emissions associated with the operation of the Melbourne Metro, compared to the 'no Melbourne Metro' scenario, i.e. including the effects of the passenger mode shift.

A GHG inventory has been calculated for each of the operational scenarios defined in Table 4-1, consistent with the VITM scenarios.

Within Section 6.4, the Melbourne *Metro BAU Operational Footprint* refers to the calculated GHG inventory for operation of Melbourne Metro assuming BAU sustainability initiatives. The *Melbourne Metro Best Practice Operational Footprint* refers to the calculated GHG inventory for operation of Melbourne Metro assuming best practice sustainability initiatives, and assumes the project achieves its Sustainability Targets of 20 per cent reduction in Scope 1 and Scope 2 GHG emissions (excluding the use of renewable energy), and additionally sourcing of 20 per cent renewable energy (**Risk #GH002**).

6.4.2 GHG Emissions Associated with Operation

6.4.2.1 Traction Energy

6.4.2.1.1 Summary of HCMT Movements

The GHG system boundary for traction energy associated with the direct operation of Melbourne Metro is from portal to portal of Melbourne Metro tunnels. Operational emissions from traction energy of HCMTs beyond the portals (i.e. Metro network) are considered an indirect (Scope 3) emission and is captured within the inventory of GHG emissions from the passenger mode shift (refer To section 6.4.2.4).

Daily HCMT movements for the year of opening, five years after opening (Extended Program), and 20 years after opening scenarios have been provided by PTV; refer Table 6-12. In the absence of transport (VITM) modelling beyond 2046, VKTs for HCMTs beyond 2046 (for the purposes of this assessment) have been assumed to remain constant (at 2046 train movement numbers) for the remainder of the 100-year design life of the project.

Table 6-12 Daily HCMT Movements (Source: PTV (2015) and PTV (2016))

Scenario	AM peak hour (peak direction)	AM peak 2-hours (peak direction)	Inter-peak and counter-peak (tphpd)#	Other off-peak (tphpd)[1]	HomeSafe overnight service [2] (tphpd)#	HCMT type
Day One Melbourne Metro (7-car HCMT only)						
Total suburban from East	19	35	6	6	2	7-car
Total suburban from West	18	31	6	6	2	7-car
Sum (2026)	**37**	**66**	**12**	**12**	**4**	
2031 (Extended Program: combined Standard and Extended HCMTs)						
Pakenham service	9	17	3	3	Refer "Total suburban from East"	10-car
Cranbourne service	6	12	3	3	Refer "Total suburban from East"	7-car
Dandenong service	6	6	-	-	Refer "Total suburban from East"	7-car
Westall service	-	2	-	-	Refer "Total suburban from East"	7-car
Total suburban from East	21	37	6	6	2	
Sunbury service	6	9	3	3	Refer "Total suburban from West"	10-car
Watergardens service	8	14	-	-	Refer "Total suburban from West"	10-car
Melton service	9	15	3	3	Refer "Total suburban from West"	10-car
Total suburban from West	23	38	6	6	2	
Sum (2031)	**44**	**75**	**12**	**12**	**4** [3]	
2046 (Extended HCMT only)						
Total suburban from East	21	37	6	6	2	10-car
Total suburban from West	23	38	6	6	2	10-car
Sum (2046)	**44**	**75**	**12**	**12**	**4** [3]	

[1] Trains per hour per day.
[2] HomeSafe overnight service level between what would currently be Last Service on Friday/Saturday night and the corresponding First Service on Saturday/Sunday morning.
[3] Assumed same as 'Day One' Melbourne Metro, given number of HomeSafe services not provided for 2046.

The applicable time periods and durations that correspond to the time periods defined above, assumed for the calculation of daily VKTs, are summarised below in Table 6-13. These are as per existing PTV (VITM) assumptions.

Table 6-13 PTV time periods within VITM

Time period	Start	End	Hours
Peak 2-hour AM	07:00	09:00	2
Peak 2-hour PM	16:00	18:00	2
Counter-peak	18:00	19:00	1
Inter-peak	09:00	16:00	7
Off-peak PM	19:00	01:00	6
Off-peak AM	05:00	07:00	2
HomeSafe	01:00	05:00	4

6.4.2.1.2 Proposed Sunshine – Dandenong Extended Program

The Extended Program is expected to be otherwise independent of development plans for metropolitan and regional lines outside the Sunshine – Dandenong corridor as shown in Figure 6-3. Subsequently, implementation of the Extended Program would not require major reconfiguration of the network, in terms of delivering the service.

PTV has modelled the Extended Program in the 2031 VITM 'with Melbourne Metro' scenario.

6.4.2.1.1 Regenerative Braking Capability

As mentioned in Section 4.7.5, it is a PTV project design requirement for all new HCMTs operating on Melbourne Metro to be fitted with regenerative braking capability. Traction energy modelling undertaken for the project during the Concept Design demonstrates an energy saving (compared to the base case) of approximately 25-27 per cent due to the unrestricted implementation of regenerative braking energy with the proposed traction system configuration within Melbourne Metro tunnels. The regenerative braking energy scenario adopted for the purposes of the GHG modelling is the scenario *with* an inverter, which allows for regenerative energy to be used in both the DC and AC network.

Average traction energy, expressed as kWh per VKT, has been calculated based on AJM JV traction energy modelling outputs, train patronage (i.e. train load) and the above assumptions. This is shown in Table 6-14 for both BAU regenerative braking (as per existing MTM capability; refer to section 4.7.5) and proposed regenerative braking (as per the Concept Design). The results below for the HCMTs compares to an average electricity consumption (calculated) of 22.8 kWh/VKT for the existing MTM 6-car rolling stock, which currently operates with BAU regenerative braking.

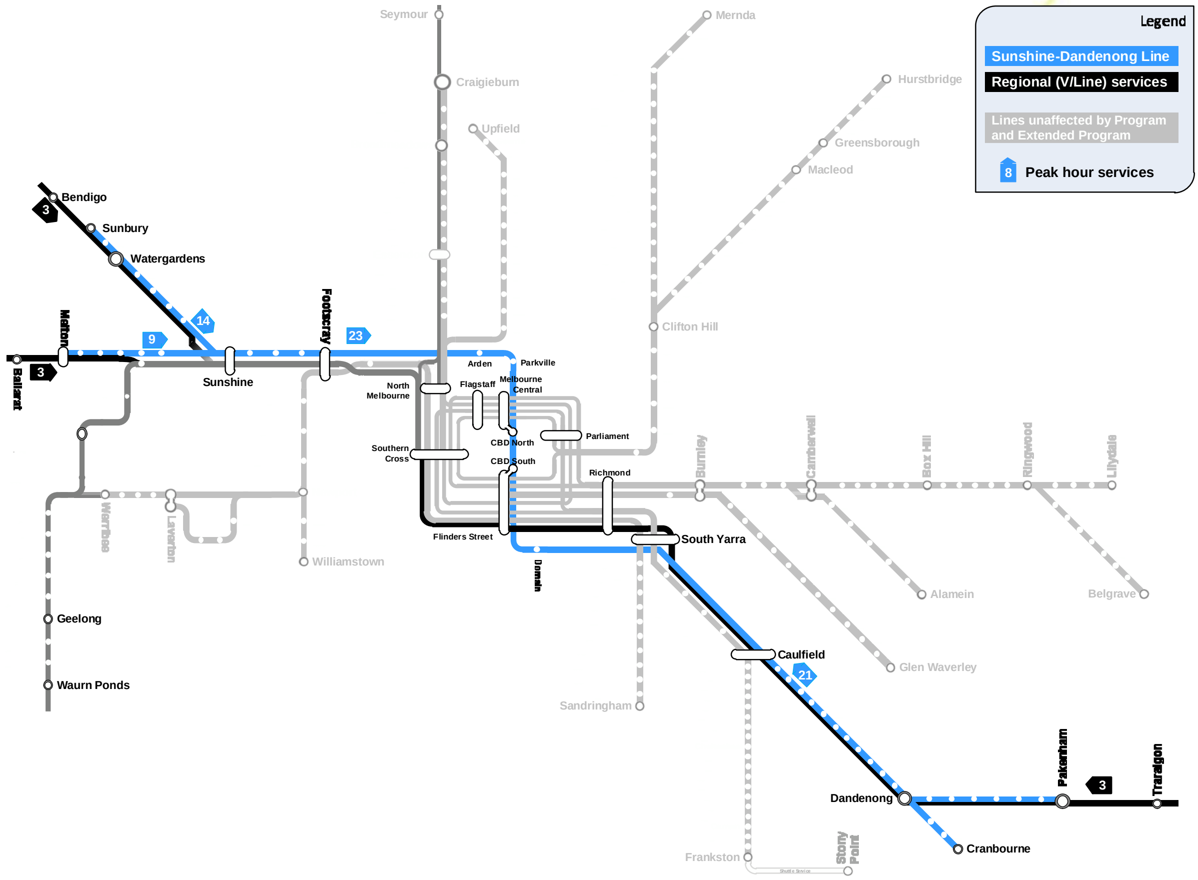

Figure 6-3 Metropolitan rail network with Extended Program (Source: PTV, 2016)

Table 6-14 Traction energy consumption (kWh/VKT), Melbourne Metro tunnels

HCMT type	BAU regenerative braking, kWh/VKT	Concept Design (best practice) regenerative braking, kWh/VKT	Energy saving (from BAU) due to Concept Design regenerative braking
7-car	33.7	25.2	25%
10-car	46.8	34.1	27%

Although the 10-car HCMT is heavier than the 7-car HCMT (and therefore consumes more power per VKT), it also carries more passengers, which counteracts the additional power consumption. This can be best illustrated by expressing power consumption in terms of passenger kilometres travelled (PKT). An assessment of kWh/PKT is therefore provided in Table 6-15 for the existing (6-car) fleet, 7-car HCMT and 10-car HCMT.

Table 6-15 Traction energy consumption (kWh/VKT and kWh/PKT), Melbourne Metro tunnels

HCMT type	Planned Load	Average electricity consumption, BAU regenerative braking		% difference in kWh/PKT between Existing and HCMT[1]	Average electricity consumption, best practice regenerative braking		% reduction in kWh/PKT between Existing and HCMT
		kWh/VKT	kWh/PKT		kWh/VKT	kWh/PKT	
Existing 6-car	800 (approx.)	22.8	0.0285	-	22.8 2	0.0285	-
7-car	1,100	33.7	0.0306	-7.6%	25.2	0.0229	**19.4%**
10-car	1,570	46.8	0.0298	-4.6%	34.1	0.0218	**23.6%**

[1] Negative indicates an increase.

[2] 'Day One' of opening energy consumption (kWh/VKT) of Siemens, Comeng and X'Trapolis rolling stock has been assumed the same as existing. The existing stray current issues associated with regeneration are still likely to exist at 'Day One' of opening for the existing traction power network (including the surface level traction power for the Sunshine – Dandenong line). Refer to Section 6.4.2.4.1 for further discussion.Table 6-15 demonstrates that there is an estimated reduction in energy consumption, per PKT compared to the existing 6-car fleet, and with implementation of best practice regenerative braking of 19.4% for operation of the 7-car HCMT and 23.6% for operation of the 10-car HCMT.

It is worth noting that as well as the consideration of energy consumption in terms of VKT and PKT, the HCMTs would also have greater performance than the existing 6-car trains, in terms of acceleration and braking. This means that the HCMTs should have shorter intermediate run times (total travel time minus dwell at stations), which allows for significant improvements in operational performance of the trains.

The incremental annual traction energy consumption over the first 20 years of operation (for both BAU and best practice regenerative braking) is provided in Table 6-16. Calculated annual GHG emissions are provided for the Concept Design (best practice) scenario only. 2046 estimates are based on VITM outputs for 2046 which assume Extended HCMTs only in timetable running. Results do not include the additional initiative of sourcing 20 per cent renewable energy e.g. purchase of accredited GreenPower; this would be additional GHG abatement on top of the results presented in Table 6-16.

GHG emissions have been calculated using the projected GHG emissions intensities as provided in Table 4-12. Annual traction energy increases comparatively quickly over the first five years of operation as the Melbourne Metro moves toward an Extended Program of operation, which includes the Extended HCMT rolling stock. Note that the Victorian GHG intensity is currently high and is expected to drop significantly after about 2031. 2031 therefore approximately represents the year with the highest GHG emissions from traction energy; thereafter, emissions are expected to reduce over time, as shown in Table 6-16

Additional assumptions relating to the calculation of GHG emissions from traction energy include:

- Trains consist of Standard and Extended HCMTs rolling stock only (future train services data provided by PTV)
- Traction energy modelling has been undertaken for the vertical and horizontal alignment as defined for the Concept Design.

Table 6-16 Traction energy with regenerative braking capability (BAU and Concept Design)

Year	GWh p.a.			kt CO_2-e p.a. (Concept Design)		
	Base Case (BAU)	Concept Design (best practice)	% Reduction	Scope 2	Scope 3	Total
2026	38.6	28.9	25%	30.3	3.8	34.1
2027	41.2	30.7	25%	32.2	4.0	36.2
2028	43.9	32.6	26%	34.0	4.2	38.2
2029	46.6	34.4	26%	35.7	4.5	40.2
2030	49.2	36.3	26%	37.5	4.7	42.2
2031	51.9	38.1	27%	39.3	5.0	44.2
2032	52.2	38.3	27%	38.4	5.0	43.3
2033	52.5	38.5	27%	37.4	5.0	42.4
2034	52.7	38.7	27%	36.5	5.0	41.5
2035	53.0	38.9	27%	35.6	5.1	40.6
2036	53.3	39.0	27%	34.6	5.1	39.7
2037	53.5	39.2	27%	33.7	5.1	38.8
2038	53.8	39.4	27%	32.7	5.1	37.8
2039	54.1	39.6	27%	31.7	5.1	36.8
2040	54.4	39.8	27%	30.7	5.2	35.9
2041	54.6	40.0	27%	29.7	5.2	34.9
2042	54.9	40.1	27%	28.7	5.2	33.9
2043	55.2	40.3	27%	27.7	5.2	32.9
2044	55.4	40.5	27%	26.6	5.3	31.9
2045	55.7	40.7	27%	25.6	5.3	30.9
2046 – 2126	56.0	40.9	27%	24.5	5.3	29.8
Total over first 20 years				**683.0**	**103.3**	**786.3**
Total over 100 years				**2,645.4**	**528.5**	**3,173.9**

Traction energy associated with operation of the HCMTs represents by far the largest source of GHG emissions associated with the infrastructure lifecycle of the project due to the higher energy requirements of HCMTs, when compared to existing rolling stock (**Risk #GH002**).Table 6-14 demonstrates that the average traction power requirement for the 10-Car HCMT (measured as kWh/VKT) is 39 per cent higher than for the 7-Car HCMT for the Concept Design regenerative braking scenario. A discussion on the energy efficiency of the 7-car and 10-car HCMTs, using the functional unit of kWh (or CO_2-e emissions) per passenger kilometre travelled is provided in Section 6.7.1. The benefits of the project are better realised using this functional unit, which can be lost when looking just at VKTs.

6.4.2.2 Stations Operation

Electricity usage considered in this assessment includes sources such heating (gas boilers) ventilation and air conditioning (HCAC), lighting, use of equipment (e.g. ticket machines), vertical transportation (escalators and lifts), fire systems and station hydraulics (e.g. pumps) for all of the five train stations.

Heating, Ventilation and Air-Conditioning (HVAC) modelling was undertaken by the AJM JV Mechanical Design team for two stations using energy simulation software IES. Parkville station was selected as the representative 'cut-and-cover' station and CBD North as the representative 'cavern' station. Deemed to Satisfy (DTS) energy modelling was undertaken for the CBD North and Parkville stations and provides results for a minimum compliance scenario (i.e. base case), and assumes the HVAC base case scenario of no platform screen doors (PSDs).

For CBD South, Domain and Arden stations, approximate floor areas were calculated for all stations using concourse and platform dimensions; calculated floor areas are provided in Table 6-17. Note: this does not include any consideration of whether the floor area is either public space or back of house. The modelling outputs for CBD North and Parkville were then applied pro rata to the other stations to estimate their equivalent energy requirements.

Table 6-17 Calculated (approximate) floor areas – Melbourne Metro stations

Station	Total approximate floor area (m^2)
Domain	11,220
Arden	14,840
Parkville	14,300
CBD North	16,940
CBD South	16,335

The estimated annual electricity usage and annual GHG emissions associated with the operation of stations (based on BAU design considerations) is provided in Table 6-18 Note: these estimates represent a BAU energy footprint for the underground stations design, and do not include the GHG abatement initiatives already included in the Concept Design; these are assessed in section 6.4.3 effects of these initiatives.

Assumptions adopted for the determination of GHG emissions from stations operation include:

- Patron occupancy profiles (percentage occupancy by hour of day) for stations energy modelling have been developed for concourse and platform areas based on empirical annual user demand profiles provided to AJM JV for existing stations within the CBD (Melbourne Central and Flinders Street). Flinders Street Station profile was selected for use in the modelling
- Patronage during the 1am to 5am periods for stations on Saturday and Sunday has been assumed to be five per cent of peak levels; to account for the newly introduced operating timetable over Friday and Saturday nights
- Patronage for the concourse areas has been assumed to be equal to that for the platforms based on AJM JV advice.

Table 6-18 Annual GHG emissions (tonnes CO_2-e p.a) – stations operation: *Melbourne Metro BAU Operational Footprint*

Station	Annual energy consumption (MWh)	Scope 1 (tonnes CO_2-e p.a.)	Scope 2 (tonnes CO_2-e p.a.)[27]	Scope 3 (tonnes CO_2-e p.a.)	Total (tonnes CO_2-e p.a.)
Arden	1,918	17	1,649	239	**1,904**
Parkville	2,623	16	2,262	331	**2,609**
CBD North	3,720	36	3,142	461	**3,639**
CBD South	3,764	35	3,183	467	**3,685**
Domain	2,218	13	1,914	280	**2,207**
TOTAL	**14,243**	**117**	**12,149**	**1,779**	**14,045**

6.4.2.2.1 Best Practice GHG abatement – Stations

Best practice GHG abatement initiatives that have been captured in the Concept Design (or are to be further investigated during Detailed Design) for the stations that are not included in the *Melbourne Metro BAU Operational Footprint* (base case) are:

- Geothermal piling (incorporates pipework for a geothermal heat exchange system) – *to be further investigated during Detailed Design*
- Regenerative power on vertical transportation (elevators and escalators) – *captured in Concept Design*
- Variable speed drive escalators that enable a 'slow-mode' when not in use – *captured in Concept Design*
- Solar PV – *likely*. The space available for solar PV is limited to rooftops at Domain, Arden and Parkville stations and ventilation shafts system-wide. Rooftop PV would make some contribution to offset the station electrical use. The limited solar PV which would be installed on ventilation shafts would be suited to supply small local features such as decorative lighting, water features or the like. Transparent PV film could be installed for entry canopies at CBD North and CBD South
- Kinetic energy harvesting – *possible to likely*. Kinetic energy harvesting is the process of converting kinetic energy, such as from pedestrians' footsteps into electricity. Piezoelectric mats would be used at ticketing gates throughout all stations; with the kinetic energy harvesting being used to operate electric gates and turnstiles.

High Efficiency Lighting

Artificial lighting would be a large user of energy in each station. Correct lighting product selection and layout can reduce energy use significantly over a base/industry standard. The design would therefore aim to use the most efficient technologies and products available, which may include linear fluorescent, metal halide, LED, etc.

Against a base/industry standard, the lighting products selected for the Concept Design would translate to direct energy savings of greater than 20 per cent as a result of fixture efficiency. These targets are currently achievable but should be monitored throughout the life of the project to ensure that fixture efficiency is at the forefront of the industry.

The Concept Design also aims to reduce the number of fixtures required and the energy used by ensuring that the required maintained lux[28] levels are not exceeded by a significant amount. User

[27] Emissions based on an averaged GHG intensity between 2026 and 2046 (projected).
[28] The lux is the unit of illuminance and luminous emittance, measuring luminous flux per unit area. One lux is equal to one lumen per square metre.

perception of brightness would be managed through design principles such as wall lighting, uniformity, etc.

6.4.2.3 Tunnels Operation

This section includes energy consumption and GHG emissions associated with operation of the tunnels; and emergency access shafts between Domain and South Yarra stations and between the Yarra River and Domain stations and the western portal and eastern portal.

6.4.2.3.1 Tunnel Ventilation

The considerations and BAU assumptions regarding the usage of the Tunnel Ventilation System (TVS) are as follows:

- 2025-2050: regular operation of Track Extraction System (TES) fans for 20 hours/day for three months of the year (summertime ventilation). This would be required in any BAU design where in-tunnel monitoring is not installed. The Melbourne Metro Concept Design proposes in-tunnel temperature monitoring as a best practice initiative to understand temperature regime and for adaptive response to critical temperature events, which means that the TES fans would only operate as required (rather than for 20 hours/day as per the base case); refer **Risk #GH002**. As in-tunnel monitoring is a unique initiative in Australia for underground metro rail operation, it is considered that near-continuous operation of the TES fans over summertime months is a valid assumption for the *Melbourne Metro BAU Operational Footprint*
- Maximum tunnel ventilation operation is designed for year 2050, at which time it is assumed that the fans would run continuously (20 hours/day) at 100 per cent of their capacity for six months of the year (summertime ventilation)
- All fans: regular weekly test, running for a maximum of two hours/week (upper limit)
- Tunnel ventilation fans: irregular operation (outside of summer) for six hours/month for tunnel worksite ventilation, train congestion, dust clearance, TVS maintenance, or smoke control
- Controls: continuous energy consumption for Programmable Logic Controllers (PLCs) and panels; intermittent energy consumption for damper operations. Assumed to be a total of 110 kWh/day for all TVS controls.

Annual energy consumption associated with the TVS is provided in Table 6-19.

Table 6-19 Annual energy consumption (MWh p.a.) over 100-year design life –TVS (*Melbourne Metro BAU Operational Footprint*)

Tunnel section[1]	2025-2049	2050-2126
Arden	688.7	1163.2
Parkville	722.2	1196.7
CBD North	664.6	1139.1
CBD South	667.5	1142.0
Domain	722.2	1196.7
East Vent	91.3	91.3
Total MWh p.a. (full system)	**3,556.5**	**5,929.0**

[1] The station provided in the first column represents the midpoint of the tunnel section that these data refer to; for example, the ‘Parkville tunnel section’ refers to the tunnel section from halfway between Arden and Parkville stations, to halfway between Parkville and CBD North stations.

Total estimated annual GHG emissions (2025 and 2050) for the TVS, assuming a BAU operating scenario, are provided in Table 6-20.

Table 6-20 Annual GHG emissions (kt CO_2-e), 2025 and 2050 –TVS (*Melbourne Metro BAU Operational Footprint*)

Year	Scope 2 (tonnes CO_2-e p.a)	Scope 3 (tonnes CO_2-e p.a)	Total
2025	3,524	436	3,960
2050	3,437	745	4,182

6.4.2.3.2 Tunnels and Portals Electrical

Tunnel lighting and power (includes cross passages, western and eastern portals) represent other operating features of the tunnel that would consume electricity.

Energy efficient tunnel lighting has also been included in the Concept Design. This includes designing the lighting system to use energy efficient lighting (e.g. LEDs, low light, zoning and controls) while meeting lighting requirements and procurement requirements. Maintained tunnel lighting would be provided along the entire length of the tunnel, comprising linear LED luminaires at a nominal spacing of 10 m between centres. All cross passages along the tunnel would be provided with normal and emergency lighting (LED luminaries).

Electrical loads for tunnel (and station) drainage are relatively low in comparison to the other tunnel electrical loads. Tunnel drainage includes the operation of pumps located at low point sumps within the tunnel and at the end of platforms (duty/standby configuration). The pumps would only be used during periods of underground (tunnel) flooding, routine service of fire protection systems, or during periods of maintenance as required.

The estimated annual GHG emissions associated with tunnels and portals electrical and drainage are provided in Table 6-21.

Table 6-21 Annual GHG emissions (kt CO_2-e) – tunnels and portals electrical (*Melbourne Metro BAU Operational Footprint*)

Annual energy consumption (MWh)	Scope 1 (tonnes CO_2-e p.a)	Scope 2 (tonnes CO_2-e p.a)[29]	Scope 3 (tonnes CO_2-e p.a)	Total (tonnes CO_2-e p.a)
4,308	**-**	3,743	560	4,303

6.4.2.4 Passenger Mode Shift

The delivery of Melbourne Metro would have an impact on the road network, as it attracts travellers to public transport by providing extra capacity for travel into inner Melbourne. Car users may be encouraged to switch to public transport if they find that, once Melbourne Metro is built and operational, they are able to make their journey more easily by public transport than by car (PTV, 2016). This is known as the 'passenger mode shift'.

GHG emissions associated with the indirect or knock-on effects to the road and public transport network in Melbourne as a result of the operation of the Melbourne Metro (i.e. passenger mode shift), are considered as a Scope 3 emissions sources.

PTV (2016) forecasts that the number of public transport trips is likely to increase by nearly 11,000 passengers in the morning peak period with the implementation of Melbourne Metro. The increase in public transport trips includes a number of people switching from travel by private vehicles to train

[29] Emissions based on an averaged GHG intensity between 2026 and 2046 (projected).

services. Car travel is estimated to reduce by around 9,000 vehicle trips in the morning peak by 2031 as a result of Melbourne Metro. There is an overall reduction in the number of motorised trips undertaken by car or public transport (person trips). This is because people switching to public transport tend to trip chain[30] by walking, whereas car users tend to drive when trip chaining. As a result, there is a reduction in the number of car VKTs and vehicle hours travelled. It is estimated that about 780,000 private car VKTs – or 39,000 hours – would be saved on an average weekday in 2031 as a result of the Melbourne Metro Extended Program (PTV, 2016).

6.4.2.4.1 Traction Energy – Wider Network

Traction energy of trains operating outside of Melbourne Metro tunnels has also been included within the GHG inventory as part of the passenger mode shift (Scope 3 emissions), for both 'with' and 'without' Melbourne Metro transport scenarios using the VITM outputs.

As described in Section 6.3.2.5, the HCMTs are planned to be able to carry 1,100 passengers at rated performance (7-car), with the ability to be lengthened to 10-cars carrying 1,570 passengers at rated performance for future operation as part of the Extended Program. The Extended HCMT fleet is included in the 2031 and 2046 'with Melbourne Metro' scenarios only. The 2046 'with Melbourne Metro' scenario assumes Extended HCMT rolling stock only would be in timetable running within the Melbourne Metro tunnels, consistent with PTV (2015). For the case of 'no Melbourne Metro', 37 Standard (7-car) HCMTs would be in timetable running along the Cranbourne-Pakenham Rail Corridor (CPLU) in 2026.

A comparison of the daily VKTs for the HCMT train sets associated with the 'with Melbourne Metro' scenario has been directly compared to the 'no Melbourne Metro' scenario; this is provided in Table 6-22, Table 6-23 and Table 6-24 for the 'Day One' of opening, 2031 and 2046 scenarios, respectively.

Note that the HCMT (7-car) daily movements in 2026 have been obtained as the interpolation of the VITM '2021 Day One' and '2031 Day One' VITM outputs, as per discussions with PTV during the preparation of this assessment (VITM modelling has not been undertaken by PTV for 2026).

Note that this data refers to HCMT movements across *all train lines* affected by operation of the Melbourne Metro as part of the wider Metro (i.e. does not refer solely to daily train movements within the Melbourne Metro tunnels; this has been assessed previously in Section 6.4.2.1).

As previously mentioned in Section 4.7.4.1, only those train lines (and therefore train VKTs) that are affected by the project have been included in this analysis, so as to not obscure the impact of the project. The hours of day defining each time period has been previously defined at Table 4-9.

Table 6-22 Comparison of daily HCMT train set movements across Metro network – 'Day One' of opening (2026)

Fleet type	2026 'no Melbourne Metro'				2026 'with Melbourne Metro'			
	AM	IP	PM	OP	AM	IP	PM	OP
HCMT 7-car	81	90	122	72	84	90	125	72
HCMT Extended	0	0	0	0	0	0	0	0

[30] Trip chaining is making an incidental trip along the way, such as doing shopping or getting a coffee.

Table 6-23 Comparison of daily HCMT train set movements across Metro network – Extended Program (2031)

Fleet type	2031 'no Melbourne Metro'				2031 'with Melbourne Metro'			
	AM	IP	PM	OP	AM	IP	PM	OP
HCMT 7-car	95	108	142	72	50	36	75	0
HCMT Extended	0	0	0	0	58	72	87	72

Table 6-24 Comparison of daily HCMT train set movements across Metro network – 20 years after opening (2046)

Fleet type	2046 'no Melbourne Metro'				2046 'with Melbourne Metro'			
	AM	IP	PM	OP	AM	IP	PM	OP
HCMT 7-car	111	108	165	72	126	144	189	72
HCMT Extended	0	0	0	0	73	72	110	72

Electricity consumption (kWh) of future rolling stock on the wider network assumes the following:'

- Day One' of opening energy consumption (kWh/VKT) of Siemens, Comeng and X'Trapolis rolling stock has been assumed the same as existing
- Likely reductions in electricity consumption of future rolling stock as staged implementation of regenerative braking occurs across the Metro network is based on the following assumptions and advice provided by MTM and AJM JV Rail Systems Design team:
  - Base case (BAU) assumes approximately 8 per cent regenerative braking capability for X'Trapolis and Siemens roiling stock (existing MTM regenerative braking capability). Regenerative braking capability is currently 'turned down' to avoid creating additional stray current problems on the network. Comeng trains have an electric brake which regenerates into an on board resistor bank, but it does not export regenerative energy back onto the DC traction power network. It is likely that Comeng trains would be retired around the time of opening of Melbourne Metro (or shortly thereafter)
  - 2026 scenarios: the stray current issues associated with regeneration are still likely to exist for the existing traction power network (including the surface level traction power for the Sunshine – Dandenong line), unless PTV modifies the surface level traction power network to include inverters to transfer the regenerative energy into the 22kV AC transmission network or back to the HV supply authority
  - PTV would need to upgrade the substations to cater for the Extended HCMTs, so it is considered reasonable to assume inverters would be installed for HCMTs in the 2031 'with Melbourne Metro' scenario (refer to Section 6.7.1) when the Extended HCMT fleet is likely to be gradually introduced on the Sunbury – Packenham railway line
  - 2046 scenarios: assumes PTV modifies the surface level traction power network to include inverters to transfer the regenerative energy into the 22kV AC transmission network or back to the HV supply authority; i.e. assumes HCMTs, X'Trapolis and Siemens trains on the wider network are able to achieve an equivalent level of regenerative braking to that of HCMTs within Melbourne Metro tunnels (approximately 30 per cent), both with and without Melbourne Metro
  - This assumes the future Melbourne train network in 2046 is as efficient as the new Melbourne Metro tunnels, and ensures that any benefit gained from the upgrade of the network is captured (to accommodate the future rolling stock and regenerative braking capability in allowing it to be a more modern and efficient system).

- Likely reductions in electricity consumption of future rolling stock as lighter weight materials become available are not considered.

6.4.2.4.2 Summary by Transport Mode

The annual CO_2-e emissions calculated for each transport mode during operation of Melbourne Metro is presented in Table 6-25 for each VITM model scenario; this is compared to the 'no Melbourne Metro' scenario. Negative values (for 'contribution from Melbourne Metro') indicate GHG emissions 'saved' as an indirect result of the project's operation. Note: this does *not* include traction energy of HCMTs operating within the Melbourne Metro tunnels which is included within the project (portal to portal) carbon footprint (refer To section 6.4.2.1). Scope 2 GHG intensity projections for future electricity consumption have been used for these calculations; the methodology and assumptions regarding this projection have been detailed in Section 4.7.4.1.

Assumptions and limitations relating to the determination GHG emissions from the various transport modes include the following:

- Fuel consumption rates (diesel) in V/Line locomotives has been based on fuel consumption data and VKTs provided by V/Line for 2014/15, and has been assumed constant for future V/Line fleet
- Fuel consumption emission factors (L /100 km) for road vehicle types have not been adjusted or scaled to account for future variations or (currently unknown) refinements in carbon emissions abatement technology within vehicle engines, nor does the future scenarios consider electric vehicles (battery and/or solar) being included within the VKTs for cars
- Fuel consumed in cars and trucks for both existing and future transport scenarios is gasoline (petrol) and diesel, respectively, i.e. this is a conservative future estimate, and does not include consideration of LPG, ethanol or biodiesel
- Electricity consumption (kWh) of existing and future trams has been assumed to be the same across all tram types (i.e. regardless of seating or crush capacity). Recovery of kinetic energy from regenerative braking is assumed to be approximately 40 per cent based on data obtained from Yarra Trams for the 'B2' fleet
- Fuel consumption per VKT from articulated bus (year 2031 and beyond) and SkyBus has been assumed to be identical to that of a standard metropolitan bus.

It is noted that no Extended HCMTs would be in timetable running on Melbourne Metro in 2026. Over time, Extended HCMT services would commence timetable running on the Sunbury to Cranbourne/Pakenham railway lines (via Melbourne Metro), as part of PTV's Extended Program. This explains the significant increase in GHG emissions due to traction power, from 2026 to 2046.

Melbourne Metro would allow for a much larger fleet of Standard and Extended HCMT rolling stock to operate across the Metro, and significantly higher VKTs of the HCMTs, compared to the 'without Melbourne Metro' scenario (refer Section 6.4.2.4). Additionally, the future operation of the Cranbourne–Packenham line (without the project) does not include the Extended HCMT rolling stock, and utilises standard (7-car) HCMT rolling stock only. As such, GHG emissions associated with increased electricity consumption from operation of the HCMTs dominate the overall carbon footprint for the 'with Melbourne Metro' scenario, and results in an overall increase in GHG emissions compared to the 'without Melbourne Metro' scenario. This, however, does not take into account future 'greening' of the electricity market (beyond 2035) and a reduction in the GHG intensity associated with electricity consumption, as previously discussed in Section 2.4.3, which would significantly reduce GHG emissions (in reality) associated with operation of the Metro rolling stock.

Table 6-25 Annual CO_2-e emissions by transport mode (Scope 3) – 'with Melbourne Metro' versus 'no Melbourne Metro'

Transport mode shift (excludes Melbourne Metro tunnel traction energy)	2011 (kt CO_2-e p.a.)	'Day One' (kt CO_2-e p.a.)			2031 'Extended Program' (kt CO_2-e p.a.)			2046 (kt CO_2-e p.a.)		
		No Melbourne Metro	With Melbourne Metro	Contribution from Melbourne Metro	No Melbourne Metro	With Melbourne Metro	Contribution from Melbourne Metro	No Melbourne Metro	With Melbourne Metro	Contribution from Melbourne Metro
Metro – traction power (outside of Melbourne Metro tunnels) #	313	491	533	42	503	576	73	253	371	118
V/Line – diesel	42	71.9	72.3	0.4	72.8	72.3	*-0.5*	95	92	*-3*
Cars	6,024	7,412	7,397	*-15*	7,910	7,873	*-36*	9,134	9,065	*-69*
Trucks	2,183	3,348.2	3,347.6	*-0.6*	3,936	3,935	*-1.0*	5,925	5,920	*-5*
Trams #	59	58.9	59.1	0.2	60.2	60.9	0.6	40.0	40.1	0.1
Bus	73	113.3	113.0	*-0.3*	125.2	124.9	*-0.3*	155.1	154.8	*-0.3*
Net transport	**8,695**	**11,495**	**11,523**	**27**	**12,608**	**12,643**	**35**	**15,603**	**15,643**	**40**

Emissions reported here as full fuel cycle electricity consumption (i.e. Scope 2 plus Scope 3 emissions).

Considering CO_2-e emissions per passenger kilometre travelled (PKT) across all transport modes is a better indicator to mark the benefits of the project in terms of moving more people more efficiently. This is discussed further in Section 6.7.1.2, and notes that the project by 2046 provides a marginal improvement in CO_2-e emissions per PKT compared to the 'without Melbourne Metro' scenario, when considering the movement of people across all transport modes around the Melbourne metropolitan area.

6.4.2.4.1 Increasing Capacity on Melbourne's Rail Network

Melbourne Metro would deliver a major capacity uplift across the Melbourne rail network. This reconfiguration would allow for the independent operation of all lines and support the transformation of the metropolitan rail network into a metro-style service with the capacity to move more people in peak periods and deliver more reliable, more frequent and less crowded services. Importantly, it would provide the 'spine' for future expansions of the network to keep pace with Melbourne's growth, including the extension of the metropolitan rail network to Melbourne Airport, Melton, Rowville and Wallan. The implications of this reconfiguration are discussed in more detail in Chapter 6 *Project Description* of the *EES*.

On its first day of operations, Melbourne Metro would expand the capacity of the network by over 39,000 passengers in each two-hour peak period each morning and afternoon. There would be an estimated 60 per cent capacity uplift over the 2-hour peak period along the Sunbury line, compared to the base case of 'no Melbourne Metro'.

Melbourne Metro would facilitate further capacity uplifts across the network by enabling more trains to travel to and from the CBD. After making a number of wider network enhancements, e.g. Melton electrification and future projects enabled on the Sunshine – Dandenong Line, the Extended Program if delivered, would enable further capacity for 41,000 passengers per peak period to be introduced on the Sunshine – Dandenong Line progressively from 2031 as required. Further details regarding the wider network enhancements are described in the MMRA Business Case (DEDJTR, 2016).

The net increase in GHG emissions as a result of the project, compared to the 'no Melbourne Metro' scenario, is therefore directly related to the capacity uplift described above.

Notwithstanding, the effects of the passenger mode shift is that the operation of the project removes 281.8 million VKTs of cars from Melbourne roads per annum (at 2046), and similarly nearly 4.4 million VKTs of trucks per annum from Melbourne roads (at 2046). This is based on PTV forecasts using the VITM.

The most noticeable reduction in GHG emissions across all transport modes is cars, with GHG emissions 'savings' of 15 kt CO_2-e per annum in 2026, 36 kt CO_2-e per annum in 2031 and 69 kt CO_2-e per annum in 2046. It is also noted that cars have the highest VKTs than any other transport mode. The impact of the project is that it also removes trucks from Melbourne roads with a reduction of 5 kt CO_2-e per annum in 2046. The reduction in truck VKTs is attributable to more direct routes being made available to trucks as result of cars being removed from previously congested (direct) routes.

6.4.3 Operational Summary and Sustainability Performance Targets and Requirements

The Melbourne Metro BAU Operational Footprint assumes operation of Melbourne Metro with BAU GHG abatement initiatives. This is summarised in Table 6-26 for the 2026, 2031 and 2046 operational scenarios. This does not include the 20 per cent renewable energy requirement which is considered as a best practice GHG abatement initiative, and is captured in the *Melbourne Metro Best Practice Operational Footprint.*

Table 6-26 Annual operational GHG emissions (kt CO_2-e p.a.): *Melbourne Metro BAU Operational Footprint*

Operation by scope	Scope 1			Scope 2			Scope 3			TOTAL		
	2026	2031	2046	2026	2031	2046	2026	2031	2046	2026	2031	2046
Traction energy (portal to portal)	-	-	-	40.5	53.5	33.6	5.0	6.7	7.3	**45.5**	**60.2**	**40.9**
Stations and tunnels electrical	-	-	-	17.0	16.6	9.7	2.1	2.1	2.1	**19.1**	**18.7**	**11.8**
Stations HVAC	0.1	0.1	0.1	1.9	1.8	1.1	0.2	0.2	0.2	**2.2**	**2.2**	**1.4**
Tunnels ventilation	-	-	-	3.6	4.0	3.2	0.4	0.5	0.7	**4.1**	**4.6**	**3.9**
Melbourne Metro subtotal	**0.1**	**0.1**	**0.1**	**63.0**	**76.0**	**47.6**	**7.8**	**9.6**	**10.3**	**70.9**	**85.7**	**58.0**
Passenger mode shift	-	-	-	-	-	-	27.2	35.1	39.7	**27.2**	**35.1**	**39.7**
TOTAL Operation	**0.1**	**0.1**	**0.1**	**63.0**	**76.0**	**47.6**	**35.0**	**44.7**	**50.0**	**98.0**	**120.8**	**97.7**

In order to meet the project sustainability performance targets and requirements, the following examples are best practice GHG abatement initiatives that would need to be considered and implemented during operation (among others). Note that these are initiatives that have either already been captured in the Concept Design, or are initiatives that would be included in tender documentation for contractors to consider implementation of during Detailed Design (**Risk #GH002**):

- Traction energy: regenerative braking on rolling stock to provide energy back into the electrical supply (captured in Concept Design)
- Geothermal piling: incorporates pipework for a geothermal heat exchange system (to be further investigated in Detailed Design)
- Regenerative power on vertical transportation: elevators and escalators (captured in Concept Design)
- Solar photovoltaics (PV) at Domain, Parkville and Arden stations, and transparent PV film for entry canopies at CBD North and CBD South; PV at ventilation shafts system-wide
- Optimise HVAC between stations and tunnels, e.g. air handling units (AHUs) to include bypass for reduced pressure drop opportunity; expanded temperature bands within transient spaces; platform screen doors (captured in Concept Design)
- Zone areas of Heating, Ventilation and Air-Conditioning (HVAC) system to deal with separate areas that are known to have different occupancy periods and requirements (captured in Concept Design).

A detailed list of GHG abatement initiatives already included in the Concept Design, or those to be further investigated in Detailed Design, is provided in Section 8.

Table 6-27 provides annual energy consumption for the project (portal to portal), assuming best practice GHG abatement in design.

Table 6-27 Annual energy consumption: *Melbourne Metro Best Practice Operational Footprint*

Activity	2026, GWh p.a.	2031, GWh p.a.	2046, GWh p.a.
Stations and tunnel electrical [1]	12.9	12.9	12.9
Stations HVAC [1]	2.2	2.2	2.2
Tunnels ventilation	2.8	3.1	4.3
Subtotal, excluding traction energy	*17.9*	*18.3*	*19.4*
Traction energy (portal to portal)	28.9	38.1	40.9
Total, including traction energy	**46.8**	**56.4**	**60.3**

[1] 2026, 2031 and 2046 energy consumption assumption assumed to be the same.

Assuming that the project requirements and targets are met, 20 per cent of all energy requirements during operation would need to be sourced from renewable energy sources. Achieving this requirement and GHG abatement would, for example, require Melbourne Metro to source the following minimum quantities of electricity per annum from accredited GreenPower, during operation:

- 3.6 GWh per annum during first year of opening (2026) and increasing up to 3.9 GWh per annum after 20 years of operation (2046), for operation of stations and tunnels (excluding traction power)
- 5.8 GWh per annum during first year of opening (2026) and increasing up to 8.2 GWh per annum after 20 years of operation (2046), for traction power.

The *Melbourne Metro Best Practice Operational Footprint* assumes operation of Melbourne Metro with the best practice GHG abatement initiatives mentioned above and detailed in Section 8 (i.e. achieves the minimum 20 per cent reduction in Scope 1 and 2 GHG emissions from best practice design initiatives); these have been captured in the estimation of best practice energy consumption provided in Table 6-27. Refer also to **Risk #GH002** for a discussion on the risk of not meeting these requirements.

Annual operational GHG emissions for the *Melbourne Metro Best Practice Operational Footprint* are provided below in Table 6-28 and Figure 6-4 for 2026, 2031 and 2046. This includes best practice GHG abatement for traction energy which assumes best practice regenerative braking (25-27 per cent reduction in energy consumption compared to the BAU case) plus 20 per cent reduction from purchase of accredited GreenPower.

Table 6-28 Annual operational GHG emissions (kt CO_2-e p.a.) – *Melbourne Metro Best Practice Operational Footprint*

Operation by scope	Scope 1			Scope 2			Scope 3			TOTAL		
	2026	2031	2046	2026	2031	2046	2026	2031	2046	2026	2031	2046
Traction energy (portal to portal)	-	-	-	24.3	31.4	19.6	3.0	4.0	4.3	**27.3**	**35.4**	**23.9**
Stations and tunnels electrical	-	-	-	13.6	13.3	7.8	1.7	1.7	1.7	**15.3**	**15.0**	**9.4**

Operation by scope	Scope 1			Scope 2			Scope 3			TOTAL		
	2026	2031	2046	2026	2031	2046	2026	2031	2046	2026	2031	2046
Stations HVAC	0.1	0.1	0.1	1.5	1.5	0.8	0.2	0.2	0.2	**1.8**	**1.7**	**1.1**
Tunnels ventilation	-	-	-	2.9	3.2	2.6	0.4	0.4	0.6	**3.3**	**3.6**	**3.1**
Melbourne Metro subtotal	**0.1**	**0.1**	**0.1**	**42.2**	**49.4**	**30.8**	**5.2**	**6.2**	**6.7**	**47.6**	**55.7**	**37.6**
Passenger mode shift	-	-	-	-	-	-	27.2	35.1	39.7	**27.2**	**35.1**	**39.7**
TOTAL operation	**0.1**	**0.1**	**0.1**	**42.2**	**49.4**	**30.8**	**32.4**	**41.3**	**46.4**	**74.7**	**90.8**	**77.3**

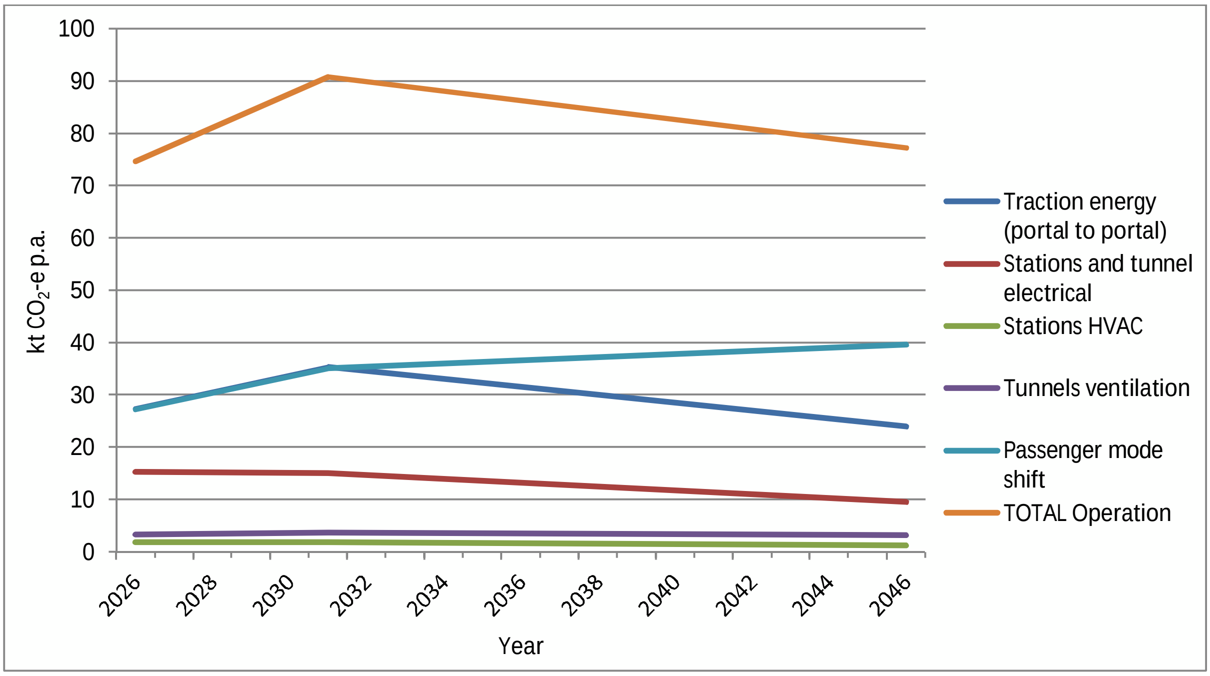

Figure 6-4 Annual operational GHG emissions (first 20 years) Melbourne Metro Best Practice Operational Footprint

Total GHG emissions from operation under this scenario (*Melbourne Metro Best Practice Operational Footprint*) would reduce net annual operating GHG emissions of the project (portal to portal), from the BAU scenario (base case), to 47.6 kt CO_2-e per annum in 2026 and to 37.6 kt CO_2-e per annum in 2046. The reduction in GHG emissions over time is due to the forecasted decline in GHG intensity of electricity generation in Victoria.

MMRA is committed to reducing GHG emissions based on the BAU base case and has set a 'Level 2' achievement as the minimum target for the project against the ISCA 'Ene-1' credit (refer Table 3-1). Although this assessment assumes a 20 per cent reduction in Scope 1 and 2 operational emissions from the BAU scenario (base case) for the purposes of calculating a best practice scenario, preliminary modelling of GHG emissions undertaken as separate package of work to support the IS rating scheme suggests that the Concept Design may be able to achieve reductions much greater than this target (in the vicinity of 30-40 per cent reduction over the infrastructure lifecycle, from the

BAU base case). There is opportunity for delivery partners to improve their performance regarding carbon emissions reductions (**Risk #GH002**), if this is possible and cost effective. It is possible that further collaborations could take place during the contractor transaction phase to ascertain the feasibility of stretching the Ene-1 credit to achieve a 'Level 3' rating (>25 per cent reduction in Scope 1, 2 and 3 emissions).

A summary of the total Melbourne Metro operational emissions (Scope 1, 2 and 3) by emission source for the *Melbourne Metro Best Practice Operational Footprint*, considering only the project footprint portal to portal, is provided in Figure 6-5 and Figure 6-6 for 2026 and 2046, respectively.

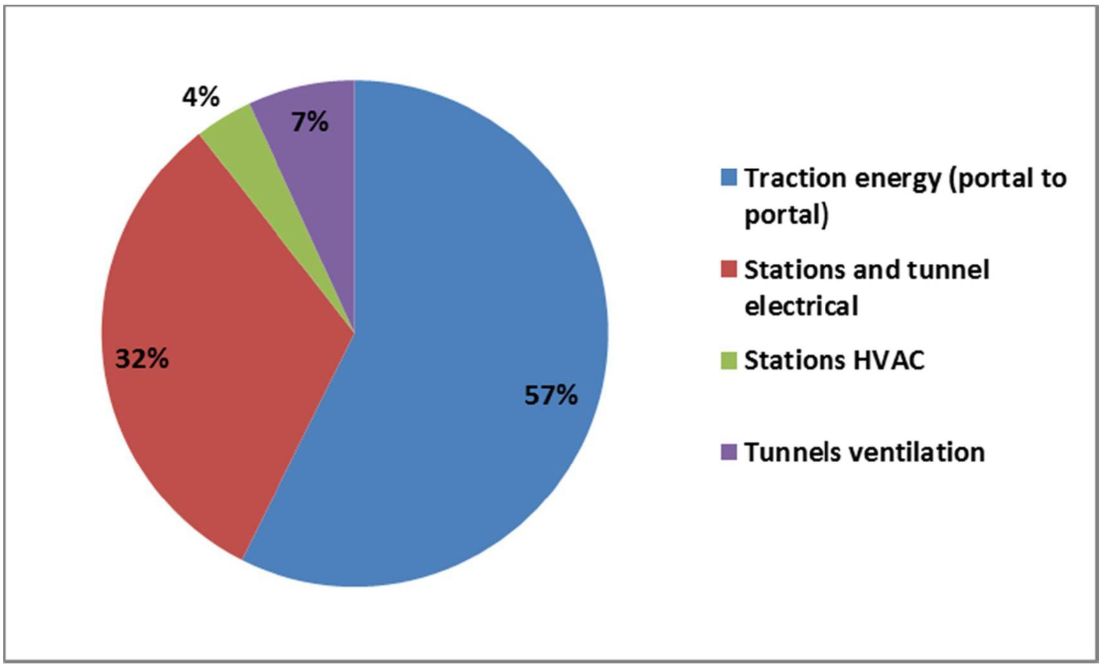

Figure 6-5 Summary of operational GHG emissions by activity type, 'Day One' of opening – best practice

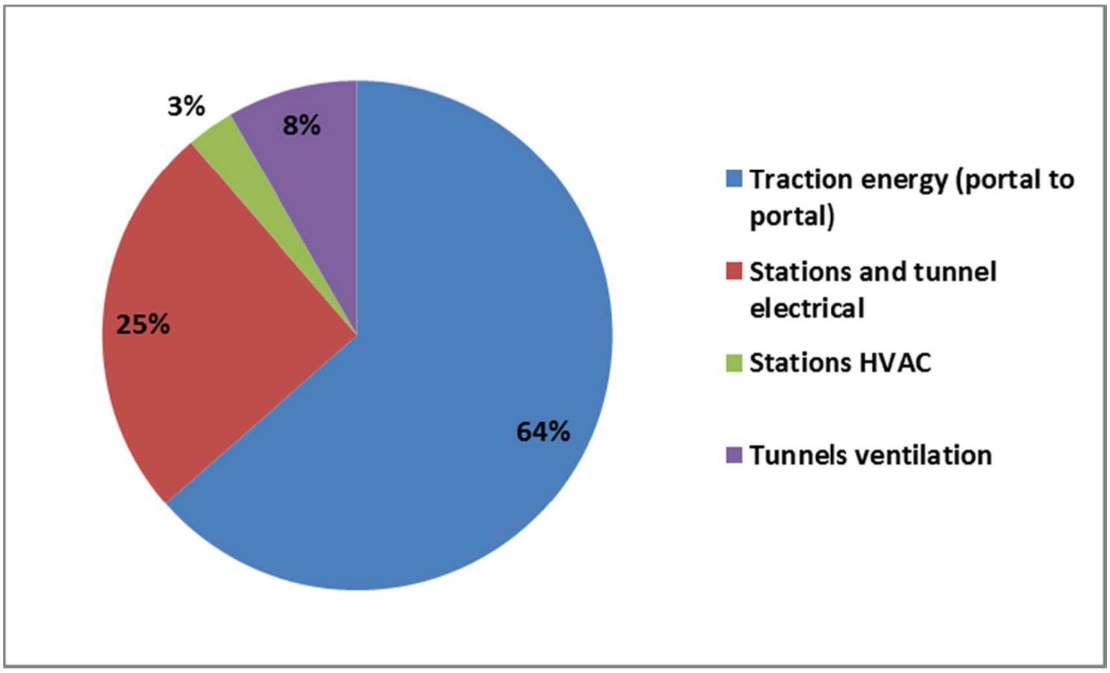

Figure 6-6 Summary of operational GHG emissions by activity type, 20 years after opening (2046) - best practice

6.4.4 Key Issues

The key issues identified with the operation of the proposed infrastructure (either Concept Design or alternative design options), with respect to operational GHG emissions, are provided in Table 6-29. The issues have been cross referenced to the relevant risk issue identified in the risk assessment (refer to Section 7).

Table 6-29 Key issues associated with operation of the Concept Design

Description	Issue	Risk #
GHG emissions associated with traction energy represent the highest source of GHG emissions associated with the lifecycle of the infrastructure.	There would be a net increase in GHG emissions associated with operation of the project compared to the 'no Melbourne metro' baseline scenario, when considering regional emissions across all transport modes within the Melbourne Statistical Division. This is due to GHG emissions associated with traction energy of HCMTs, which have a significantly higher energy consumption compared to existing rolling stock. The capture of best practice regenerative braking capability in the Concept Design, and the requirement to source a minimum 20 per cent of energy from accredited GreenPower, would mitigate the risk of this impact.	***GH002***

6.5 Ozone Depleting Substances

Sulfur hexafluoride (SF_6) is an ozone depleting substance (ODS) that is often used in circuit breakers within substations. The GWP_{100} for SF_6 is 22,800 (DoE, 2015a); this means that emissions of 1 tonne of SF_6 are equivalent to 22,800 tonnes of CO_2 emission. All air-insulated substations proposed for the project would utilise switchgear with vacuum circuit breakers to avoid the use of SF_6, also noting that MTM does not allow the use of SF_6 in the existing Melbourne Underground Rail Loop (MURL) without an exemption (this is in the context of medium voltage distribution, not 66 kV sub-transmission). All circuit breaker disconnectors however do contain a very small quantity[31] of SF_6, even in air-insulated substations – this is unavoidable.

SF_6 would be used in the Intake Substation 66kV circuit breakers located above ground (outside the tunnels) due to space limitations. This is normal electricity industry practice. SF_6 would be avoided where practical and the project would ensure that any equipment used meets ISO 14010 *Environmental management: lifecycle assessment – principle and framework*.

A separate environmental benefit is the use of dry type transformers throughout the tunnels. The 66 kV transformers would however still require oil (typically mineral oil) during operation.

To the best of MMRA's knowledge, no other ODSs would be used on site during the construction or operation of the project. If, during the detailed design and construction phases, it is found that ODSs would be used they would be handled according to the relevant legislation, including the:

- *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Commonwealth); and
- Industrial Waste Management Policy (Protection of the Ozone Layer), gazetted 2001.

[31] Estimates of the pressure loss for each individual gas compartment would not exceed 0.1 per cent per year. Each gas-filled compartment comes equipped with static filters that are capable of absorbing any water vapour that penetrates into the switchgear installation for a period of at least 25 years. (Siemens, pers.comm Nov. 2015)

6.6 Whole of Project

The Basis of Design for Melbourne Metro consists of a 100-year project design life (i.e. 100 years of operation). Considering the infrastructure lifecycle of the project (construction and operation), Figure 6-7 provides a summary of the project's total GHG emissions, adopting best practice GHG abatement measures.

Reasonable assumptions have been made with regard to a declining GHG intensity over time (to 2046); refer to Table 4-12. Otherwise all other annual operational footprints have been assumed to remain constant from 2046.

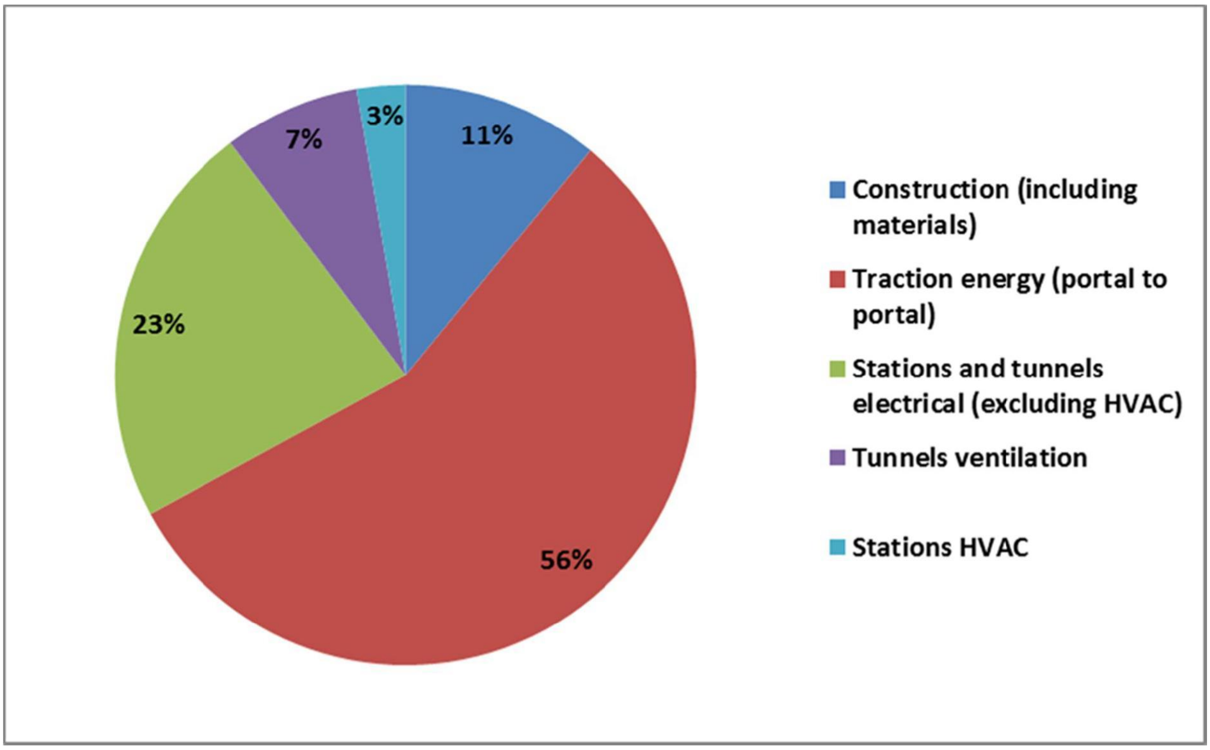

Figure 6-7 Split of GHG emissions over the infrastructure lifecycle (best practice)

6.7 GHG Indicators and Functional Unit

6.7.1 CO_2-e per Passenger-Kilometre-Travelled

The definition of the functional unit relevant to the project has been previously discussed in Section 4.8. The functional unit for Melbourne Metro can be expressed as kilograms (or grams) CO_2-e per passenger-kilometre-travelled (PKT).

6.7.1.1 Melbourne Metro (Portal to Portal)

A summary of the calculations used to determine the functional unit across the project's operational footprint is provided in Table 6-30. This is based on a pro rata of VITM outputs (PKTs) for the total HCMT rolling stock across Metro, to determine PKTs for HCMTs only operating within the Melbourne Metro tunnels.

Annual operating GHG emissions for 2026, 2031 and 2046 assume the summation of annual operational emissions across Melbourne Metro stations, tunnels and traction energy (portal to portal) for these years, respectively. The functional unit therefore considers the *total* annual operational carbon footprint of the project portal to portal (i.e. not just GHG emissions due to traction energy).

The sourcing of 20 per cent renewable energy has been applied to best practice traction energy calculations.

Table 6-30 Calculation of Functional Unit

Indicator	Source	Year of opening (2026)	Extended Program (2031)	20 years after opening (2046)
HCMT 7-car VKTs, total	VITM (PTV)	7,865,970	2,181,594	7,649,274
HCMT 7-car VKTs, Melbourne Metro tunnels	calculated	1,145,317	311,017	-
% Melbourne Metro P tunnels	calculated	15%	15%	-
HCMT 7-car PKTs, total	VITM (PTV)	2,516,608,866	734,443,270	2,768,965,104
HCMT 7-car PKTs, Melbourne Metro tunnels	calculated	366,428,287	106,937,869	-
HCMT 10-car VKTs, total	VITM (PTV)	-	7,689,001	8,408,555
HCMT 10-car VKTs, Melbourne Metro tunnels	calculated	-	886,057	1,197,238
% Melbourne Metro tunnels	calculated		12%	14%
HCMT 10-car PKTs, total	VITM (PTV)		3,193,048,283	4,790,452,202
HCMT 10-car PKTs, Melbourne Metro tunnels	calculated	-	367,956,961	682,080,256
total PKTs, Melbourne Metro tunnels	calculated	366,428,287	474,894,830	682,080,256
kt CO2-e p.a. (operation, BAU)	calculated	70.9	85.7	58.0
kt CO2-e p.a. (operation, best practice)	calculated	47.6	55.7	37.6
kilograms CO2-e per PKT (BAU)	calculated	**0.193**	**0.180**	**0.085**
kilograms CO2-e per PKT (best practice)	calculated	**0.130**	**0.117**	**0.055**

The functional unit (GHG indicator) for the operation of the project, for all sources portal to portal and assuming best practice GHG emissions abatement, is therefore 0.130 kg CO_2-e per PKT in 2026, 0.117 kg CO_2-e per PKT in 2031, and reducing to 0.055 kg CO_2-e per PKT by 2046 with the operation of Extended HCMT rolling stock only.

This compares to 0.15 kg CO_2-e per PKT for cars (projected to 2030) and approximately 0.09 kg CO_2-e per PKT for the projected national average for passenger rail (projected to 2030), as shown in Figure 6-8 (TfNSW, 2012). Note that the national average functional unit for passenger rail would be based on the varying GHG emissions intensities across all states and territories for electricity generation. As previously discussed in Section 4.7.4.1, Victoria has the highest GHG intensity, with projections noting that any significant reduction is unlikely to occur for several years. This explains why the calculated functional unit for the project in 2026 and 2031 is higher than the national average, despite the benefits of the project in terms of moving high numbers of people more efficiently.

The GHG intensity of different transport modes varies over time and also geographically, even in the same city. Caution is needed when comparing the GHG intensity of different transport modes; for example, people tend to make shorter trips within cities, and average road vehicle occupancies (the number of persons carried per vehicle including the driver) tend to be lower because a significant proportion of travel is single-occupancy trips to and from work.

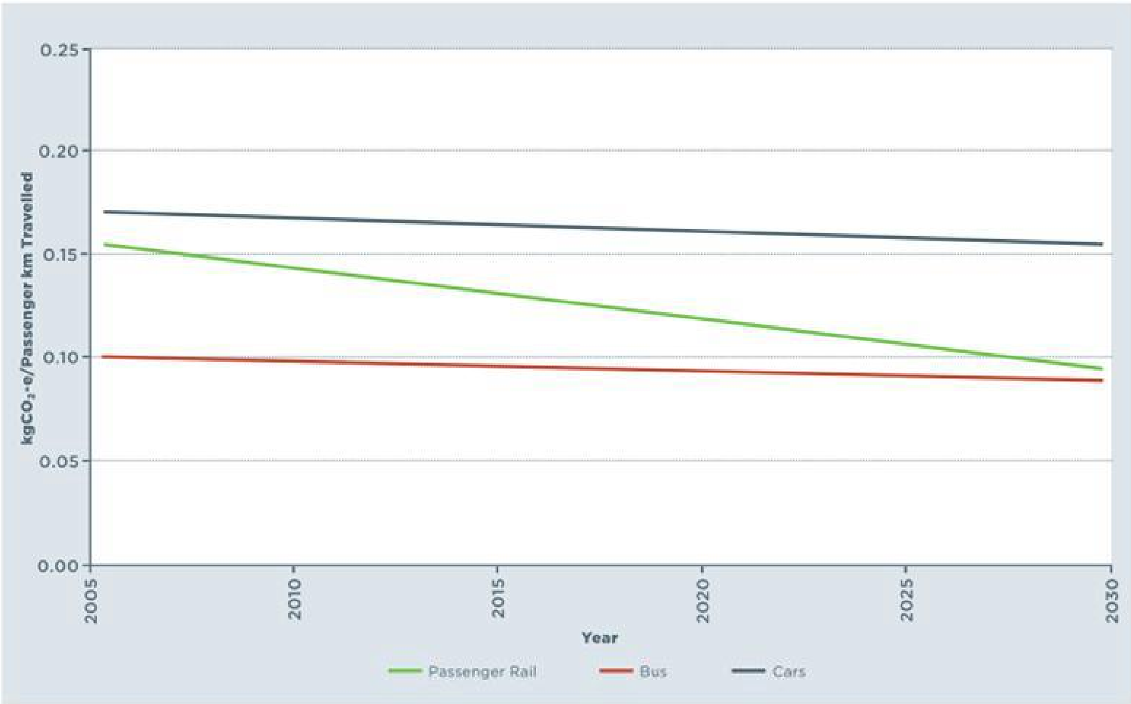

Figure 6-8 National average carbon emissions per passenger kilometre travelled for cars, bus and rail

(Source: Transport for NSW (2012), Sustainability Benefits Report)

6.7.1.2 Passenger Mode Shift

The functional unit (kilograms CO_2-e per PKT) has also been calculated for passenger movements across the Metro network ('with' and 'without' Melbourne Metro; affected lines only), as well as for all other transport modes included in the VITM (both public and private transport modes) to provide a net GHG indicator across the entire Melbourne transport network. Considering CO_2-e emissions per PKT across all transport modes is a better indicator to assess the overall carbon efficiency of the project, due to the knock-on effects of the project on other transport modes.

This functional unit is presented in Table 6-31 using PKTs provided by PTV for each of the VITM scenarios. The units of the functional unit are shown as *grams* CO_2-e per passenger kilometre travelled to best illustrate the change.

The first row of the table ('All transport modes') assesses total CO_2-e emissions and total PKTs across the entire Melbourne transport network (using affected railway lines only) as modelled in the VITM, and best illustrates the carbon efficiency of the transport system as a whole. This is calculated by summing the annual estimated (modelled) GHG emissions (kt CO_2-e) across all transport modes, and dividing by the total PKT across all transport modes (as provided in the VITM outputs). An assessment of the relative difference (increase or reduction) of the functional unit across all transport modes 'with Melbourne Metro' compared to 'without Melbourne Metro' is also provided. A 'positive' percentage difference indicates an increase in CO_2-e/PKT compared to the 'without Melbourne Metro' scenario, and a 'negative' percentage difference indicates an reduction in CO_2-e/PKT compared to the 'without Melbourne Metro' scenario.

In the second row, 'Metro trains' *includes* traction energy within the Melbourne Metro tunnels, with incorporation of best practice regenerative braking.

Assumptions regarding future implementation of regenerative braking across the wider network have been detailed in Section 6.4.2.4.1. Traction energy of HCMTs operating within Melbourne Metro tunnels has been included. The average occupancy values for each transport mode are provided in the VITM tables at Appendix C of this report (refer to earlier discussion in Section 4.7.1)

When considering the movement of people around the Melbourne metropolitan area and CO_2-e emissions per PKT across all transport modes, the net GHG indicator (as indicated by the first row in Table 6-31) is that the project provides a net reduction of 1.2 grams CO_2-e per PKT compared to the 'without Melbourne Metro' scenario after 20 years of operation (2046); this means there would be approximately a 1 per cent reduction in GHG emissions per PKT across the entire Melbourne transport network, compared to the 'no Melbourne Metro' scenario. This demonstrates that the project allows for a greater carbon efficiency of transport operation (considering both public and private transport modes) across Melbourne as the project moves toward operating as a fully Extended Program i.e. making full use of the Extended HCMTs in timetable running along the new Sunshine to Dandenong Line. This is not surprising given the benefits of the project allowing for significant improvements in capacity for public transport and moving more people out of cars and onto passenger rail. This is where the real benefit of the project can be seen, which is lost when looking just at VKTs.

6.7.1.1 Discussion on Sensitivity of Results

The level of accuracy presented for the functional unit above are highly dependent on a number of inputs, including modelled (forecasted) transport movements as provided by PTV (i.e. VITM outputs), and outputs from traction energy modelling provided by the AJM JV Rail Systems Design team. Both of these inputs are predictions based on a number of third-party modelling assumptions and considerations, which in themselves would have a range of values averaged into the modelling. As such, caution should be taken about making absolute conclusions about the results presented. The results provide an indication of the likely transport mode effects of the project, to the best of AJM JV's knowledge at the time of preparing this assessment and with the data available.

A sensitivity check was undertaken on the above results to check the results for a range of assumptions and deviation in inputs. For example, should the VITM outputs (patronage, as expressed by PKTs; or VKTs) comprise a level of accuracy of +/- 20 per cent, the functional unit is also likely to shift in the order of +/- 20 per cent given the calculated CO_2-e emissions from traction energy are directly proportional to VKTs. The conclusion however, that the project provides a net reduction of CO_2-e emissions per PKT compared to the 'without Melbourne Metro' scenario, is unlikely to change if all other variables remain constant.

Should staged implementation of full regenerative braking capability across the Metro network (Section 6.4.2.4.1) occur much later (or not all) for the 'without Melbourne Metro' scenario, the functional unit (CO_2-e per PKT) for the 'without Melbourne Metro' would increase from the results presented here – and would therefore possibly provide a greater margin of benefit compared to the 'with Melbourne Metro' scenario (as indicated by the functional unit).

Conversely, the results and conclusions presented here are fairly insensitive to the level of accuracy in the traction energy modelling outputs; for example, should traction energy modelling results of HCMTs operating within Melbourne Metro tunnels be 20 per cent greater than that provided in this assessment, the functional unit for the 'with Melbourne Metro' scenario would not increase significantly and as such the conclusions presented would likely remain the same.

6.7.1 Victorian GHG Inventory Comparison

Victoria's total (net) GHG emissions, excluding land use, land-use change and forestry (LULUCF), over 2009-2013 is shown below in Figure 6-9. Note: 2013 represents the latest year of published sectoral analysis of GHG emissions in Victoria, as per DoE (2015e)..

Table 6-31 Functional unit across all transport modes (VITM), with and without Melbourne Metro (best practice regenerative braking)

Transport mode	Functional Unit (grams CO_2-e per PKT)									
	2011	2026 'with Melbourne Metro'	2026 'without Melbourne Metro'	2026, % difference	2031 'with Melbourne Metro'	2031 'without Melbourne Metro'	2031, % difference	2046 'with Melbourne Metro'	2046 'without Melbourne Metro'	2046, % difference
All transport modes	**206.7**	**204.6**	**203.6**	**+0.5%**	**204.9**	**204.8**	**+0.1%**	**207.9**	**209.1**	***-0.6%***
Metro trains (including HCMTs)	141	117	107	nc	99	96	nc	45	36	nc
V/Line	46	28.76	28.5	nc	27	23	nc	22	20	nc
Cars [1]	168	166.1	166.2	nc	165.8	165.9	nc	166.5	166.6	nc
Trucks [2]	1,116	1,189	1,189	nc	1,197	1,197	nc	1,218	1,218	nc
Trams	121	75	72	nc	68	65	nc	32	31	nc
Buses	125	101	102	nc	96	97	nc	81	83	nc

[1] Car Occupancy Factors derived from VITM Occupancy Factors by Purpose averaged across all periods (average occupancy is 1.46-1.48); refer Appendix C of this report.
[2] Note that PTV assumes a freight occupancy of 1; PKTs are therefore the same as VKTs.
nc = not calculated.

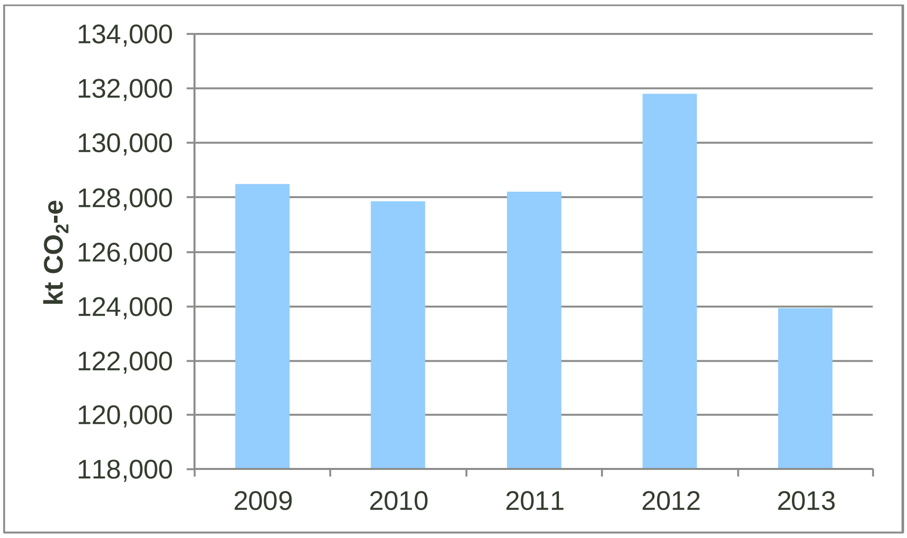

Figure 6-9 Net CO_2-e emissions (kt) for Victoria from National Greenhouse Gas Inventory (AGEIS)

In 2013, Victoria's total GHG emissions (excluding LULUCF) were 123,900 kt CO_2-e, which represents a 22.9 per cent contribution to national GHG emissions (DoE, 2015e).

The sectoral composition of Victoria's greenhouse gas emissions (excluding LULUCF) for 2013 is shown in Figure 6-10. Stationary energy (emissions from the energy sector excluding transport energy) is the largest source of emissions representing around 63 per cent of Victoria's total GHG emissions, then followed by transport representing around 18 per cent of total GHG emissions.

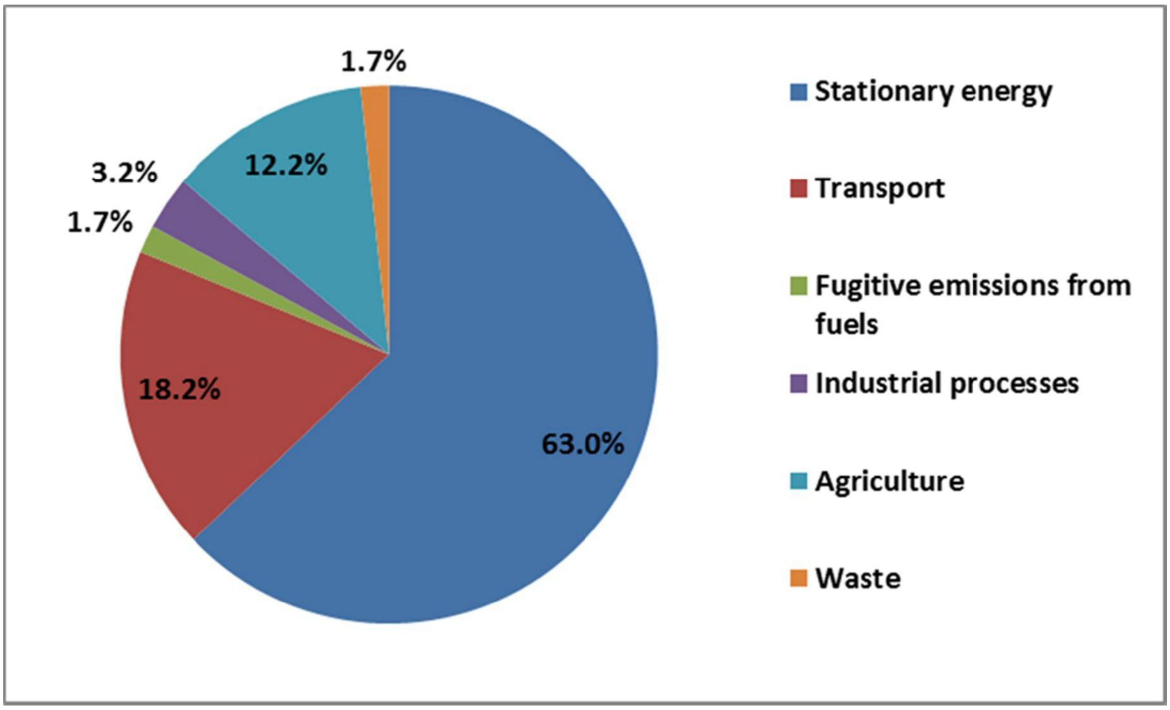

Figure 6-10 Victoria's greenhouse gas emissions by sector for 2013 (DoE, 2015e)

With inclusion of Scope 3 emissions from the passenger mode shift, the maximum annual operational GHG emissions of approximately 121 kt CO_2-e p.a. (occurring in 2031) for the *Melbourne Metro BAU Operational Footprint* (refer Table 6-26) represents approximately 0.10 per cent of Victoria's net CO_2-e emissions (using 2013 inventory). With the adoption of best practice sustainability initiatives, net annual operational emissions in 2031 would represent 0.07 per cent of Victoria's net CO_2-e emissions (using Victoria's 2013 inventory). This is considered to have a negligible contribution to regional GHG emissions.

6.8 Benefits and Opportunities

The impact of the operation of the project is that it provides greater capacity across the Metro network to move more people more efficiently. As such, the knock-on effects of the project are that it removes 281.8 million VKTs of cars from Melbourne roads per annum (at 2046), and similarly nearly 4.4 million VKTs of trucks per annum from Melbourne roads (at 2046). This is based on PTV forecasts using the VITM. With the inclusion of additional reductions from Bus VKTs, this equates to a reduction of road transport GHG emissions of 74,500 tonnes CO_2-e per annum (at 2046), compared to the 'no Melbourne Metro' scenario.

When considering CO_2-e emissions per PKT across all transport modes, it is estimated the project by 2046 would provide a marginal improvement in CO_2-e emissions per PKT compared to the 'without Melbourne Metro' scenario, when considering the movement of people around the Melbourne metropolitan area. This is not surprising given the benefits and passenger mode shift of the project, which allows for significant improvements in capacity for public transport and moving more people out of cars and onto passenger rail.

6.9 Impact Assessment Summary

6.9.1 Concept Design

The Concept Design is consistent with the draft EES evaluation objective defined at Section 6.1. This relates to the Transport Connectivity objective, with the EES assessment criteria being 'identification of best practice initiatives to reduce GHG emissions across the infrastructure lifecycle of the project'. The reasons for this assessment are:

- Best practice GHG abatement initiatives have been included and proposed in the Concept Design (refer to Section 8), in accordance with PEM requirements.
- MMRA has established clearly defined sustainability targets for the project (including PTV Project requirements for construction) which aim to achieve reductions in energy consumption and Scope 1 and Scope 2 GHG emissions by minimum 20 per cent below a BAU reference footprint (base case) over the lifecycle of the project (including construction and operation). Additionally, a minimum of 20 per cent of all energy consumed on the project (construction and operation) must be from renewable energy sources.
- The functional unit for the operation of the project, for all GHG emissions sources portal to portal and assuming best practice GHG abatement, is estimated to be 0.130 kg CO_2-e per PKT in 2026 and reducing to 0.055 kg CO_2-e per PKT after 20 years of opening (2046). The reduction in functional unit is a direct result of the carbon efficiency of the project in its operation as an Extended Program, with full implementation of Extended HCMTs in timetable running along the Sunbury – Cranbourne/Pakenham railway line. This allows for more efficient movement of passengers and therefore car users are likely to be encouraged to switch to public transport.

6.9.2 Alternative Design Options

Several alternative design options to the Concept Design have been proposed. For example, the Concept Design includes construction of the tunnels above the CityLink tunnels whereas a variation is to construct the tunnels below the CityLink tunnels. All variations are described in other chapters of the EES and are included in the technical studies, as relevant. It is considered that the variations would have an immaterial influence on the construction and operational GHG footprints determined for the Concept Design, and have therefore not been discussed further within this technical study.

7 Risk Assessment

Table 7-1 presents the greenhouse gas risks associated with the project. The environmental risk assessment methodology is outlined in Section 4.4.

Existing performance requirements were identified to inform the assessment of initial risk ratings. These existing performance requirements are based on standard requirements that are typically incorporated into contracts for rail projects.

The potential impacts of the identified risks have been assessed, the findings of which are summarised in the earlier chapters of this report. The impact assessment focusses on those risks that have been assessed as having a risk level of medium or above. As a result of the impact assessment, project-specific performance requirements (Environmental Performance Requirements) have been proposed to reduce risks and hence determine the Residual Risk Rating. The Environmental Performance Requirements are collated in Section 9 and Table 9-1. All Environmental Performance Requirements are incorporated into the Environmental Management Framework for the project (Chapter 23 of the EES).

The risk assessment determined there to be two (2) low residual risks related to GHG emissions: one during the construction phase (**Risk #GH001**) and one during the operational phase (**Risk #GH002**). No risks were identified having a residual risk higher than low risk. For both **Risk #GH001** and **Risk #GH002**, the initial risk was classed as a medium risk. There is a reduction in the likelihood from Possible to Unlikely as a result of implementation of the Environmental Performance Requirements, however it is considered that there would be no change in the consequence (i.e. GHG modelling predicts that annual Scope 1 and Scope 2 emissions would still be greater than 25 kt CO_2-e p.a. during construction and operation, even with the implementation of the Environmental Performance Requirements and under a best practice scenario).

For further details refer to the Technical Appendix B *Environmental Risk Assessment Report* of the EES which includes the full Risk Register, with existing performance requirements and recommended Environmental Performance Requirements assigned to each risk.

Table 7-1 Risk Register for Impact Assessment

Impact pathway		Precinct	Initial risk			Residual risk			Risk no.
Category	Event		Cons.	Like.	Risk level	Cons.	Like.	Risk level	
Design									
Design changes during detailed design (vertical/horizontal alignment, construction methods, scale of project)	Material changes from Concept Design during detailed design which materially affect (increase) the construction carbon footprint; i.e. detailed design does not capture the GHG abatement/sustainability initiatives from Concept Design for Melbourne Metro construction, leading to high energy consuming construction methods and high embodied carbon in construction materials.	All	Moderate	Possible	Medium	Moderate	Unlikely	Low	GH001
Design changes during detailed design (vertical/horizontal alignment, scale of project)	Material changes from Concept Design during detailed design which materially affect (increase) the operational carbon footprint; i.e. detailed design does not capture the GHG abatement/sustainability initiatives from Concept Design for Melbourne Metro operation, leading to proposed high energy consuming and/or BAU technologies and infrastructure.	All	Moderate	Possible	Medium	Moderate	Unlikely	Low	GH002

8 Best Practice GHG Abatement Initiatives

The GHG abatement and sustainability initiatives included as part of the Concept Design, and being further considered during the finalisation of the Concept Design, are summarised below in Table 8-1 for the ‘Energy’ and ‘Materials and Waste’ sustainability themes. These are considered to be best practice GHG abatement initiatives for both construction and operational phases of the project. Many aspects of the design and energy initiatives are based on internationally recognised best practice in terms of rail and tunnel infrastructure and the future of rolling stock in large cities.

The reduction in GHG emissions associated with further opportunities to be considered/investigated would be quantified during the Detailed Design. The quantification would be undertaken via the GHG modelling for the purposes of determining achievements under the IS rating (refer to Section 4.5.1), with all GHG monitoring/modelling and GHG abatement requirements being included in tender documentation for Detailed Design and construction.

This section should also be read in conjunction with the IS rating sustainability targets and requirements.

Table 8-1 GHG abatement initiatives – sustainability in design

Sustainability theme	Initiatives included in Concept Design	Further opportunities to be considered / investigated
Energy	*Construction* • Use of biofuels (e.g. biodiesel blends) for construction plant and equipment. • High efficacy Light Emitting Diode (LED) construction lighting for night-time works. • Intelligent controls/sensors for lighting. *Operation (Concept Design)* • Melbourne Metro traction power substations include regenerative braking line side energy storage provision (trackside energy recovery system). Achieves approximately 30 per cent reduction in traction energy consumption. • Gravity drainage of infiltrating water to low points in vertical alignment from where it is pumped to the surface. • Eliminated signalling (energy requirement) within tunnel. HCMTs utilise radio signalling from within the driver cabin. • Use ground heat sink for cooling by adopting geothermal piles in the structural design. Adopts geo-exchange systems within the station retaining walls and ground slab for base load cooling and heating. • Designed ventilation system to only be operational when temperatures are outside normal range or train has unexpectedly stopped within the tunnel. • Integrated photovoltaic (PV) roof top panels as power supply to station electrical at Domain, Parkville and Arden stations; and transparent PV film on entry canopies at CBD North and CBD South stations. • Daylight dimming controls for lighting. • Provide an effective mechanism for monitoring energy consumption data from sub-meters to Master Control System in real time (for major energy uses). • Provide time-controlled and occupancy/motion sensors lighting control systems in low traffic areas with flexibility to control individual space/zones. • LED lighting within the tunnel (at 10 m intervals) and at portals. • Locating electrical and mechanical plant rooms near the surface wherever practical to	• Use thermal mass of the exposed concrete structure for cooling. • Investigate opportunities to install PV on the vent shafts. • Fibre optic technology for daylighting. Daylight from the ground level could be introduced onto the concourse level or the platform level with the fibre optic technology (refer Figure 8-1). • Piezoelectric technology (kinetic energy harvesting) for energy generation at ticketing gates and turnstiles (refer Figure 8-2). • Future charging stations for electric vehicles at stations with car parks. • Precinct scale tri-generation – utilising the over site development (OSD). • Further expansion of temperature bands for transient spaces and potential to remove space heating. • Precinct energy systems through collaboration with adjoining technological users, e.g. RMIT University.

Sustainability theme	Initiatives included in Concept Design	Further opportunities to be considered / investigated
	improve ease of ventilation and cooling. • Provide power factor correction (PFC) units to keep the power factor as close as possible to unity. • Specified selective circuits to improve energy efficiency. • Install energy efficient vertical transport systems. – Use of ramps instead of escalators, where possible – Variable speed drive escalators that enable a "slow-mode" so that they oscillate at lower speeds or are 'off' when not in use and increase in speed when users step onto the foot panel at the entry to the escalator – Regenerative braking on escalators – Variable voltage variable frequency (VVVF)/regenerative braking control gear for lifts. • Transformer rooms to be mechanically cooled using energy efficient systems and solutions. • Thermal labyrinth utilising the ground energy within the CBD South under plenum space. • Air Handling Units (AHUs) to include bypass for reduced pressure drop opportunity. • Expanded temperature bands within transient spaces. • Modulation of outside (fresh) air supply provided based on station occupancy. • Use of Platform Screen Doors (PSDs) to reduce airflow from tunnel into/out of the station patron areas; enables improved control of airflow paths, supporting air-conditioning/tempering of platforms without excessive wastage. • Night purging capability in AHU control system. • Following the Urban Forestry Strategy ambition for 40 per cent canopy coverage to mitigate urban heat island (UHI).	
Materials	• Use of locally sourced bluestone paving which is durable and long lasting (low embodied energy). • Reduced the Portland Cement content in concrete works by 30 per cent, identifying appropriate options for use and specifying the inclusion of slag and fly ash or similar in concrete.	

Sustainability theme	Initiatives included in Concept Design	Further opportunities to be considered / investigated
	• Designed to use steel fibres instead of rebar (a steel bar or rod used to reinforce concrete) in the segmental lining where feasible thus reducing quantities of steel required (35 kg of steel fibre per m^3 of concrete versus 135 kg of steel reinforcement). • Specified the use of recycled steel as appropriate. • Replacement of virgin (coarse) aggregate with recycled concrete aggregate or crushed slag aggregate. • Use of Post Tensioned (PT) Beams and slabs to ground and concourse levels of stations (significantly reduces the quantity of the conventional steel reinforcement). • Use of sprayed concrete as a permanent lining for mined tunnels and adits in lieu of cast-in-situ concrete which would not require setup form work and therefore saving quantity of steel and construction equipment and labour cost. • Selection of waterproofing membrane for tunnels with consideration given to embodied carbon. • Avoidance of PVC in pipework, flooring and cable sheathing. PVC to be used must meet the Best Practice Guidelines for PVC. • Refrigerants with zero Ozone Depleting Potential (ODP). • Refrigerant leak detection systems. • All materials to have environmental certifications and be sourced from environmentally certified supplies and supply chains.	
Waste	• Twin tunnel design reduces spoil excavation, treatment and transport disposal as compared to a single bored tunnel. • Durability of design to ensure that materials do not need to be disposed of and replaced any sooner than is necessary. • Where feasible, designed cut-and-cover structure's depth as shallow and reduced excavation volume to achieve the expected clearance. • Quantities of spoil, contaminated soil calculated and given to construction team to enable spoil disposal strategy to be developed.	• Re-use of excavated clean spoil as fill where suitable (within the project or externally e.g. disused quarries). • Vacuum waste systems.

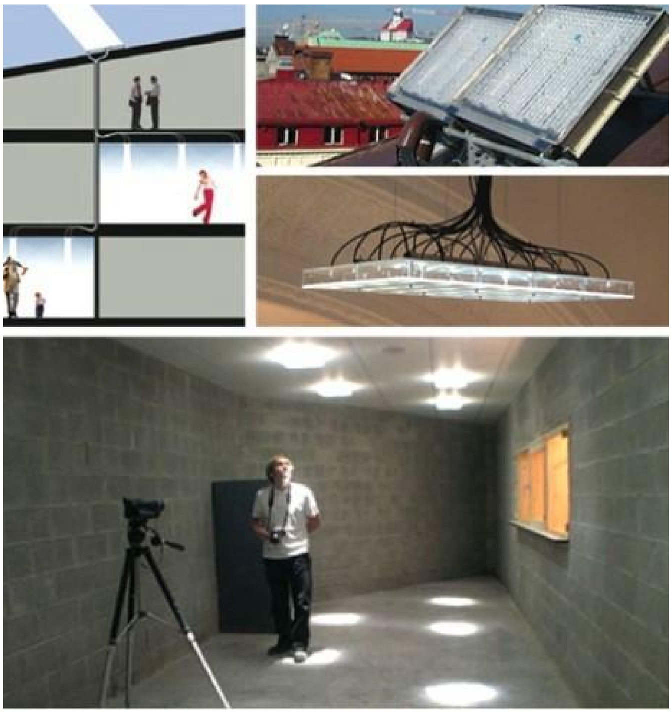

Figure 8-1 Harnessing daylight with fibre optics (to be further investigated in Detailed Design)

Figure 8-2 Kinetic energy harvesting could be used for the underground train stations to operate electric gates and turnstiles (to be further investigated in Detailed Design)

9 Environmental Performance Requirements

This section provides a comprehensive list of the Environmental Performance Requirements identified as a result of this impact assessment. Table 9-1 provides the performance requirements, which apply across the project, linked to the draft EES draft evaluation objective.

Table 9-1 Environmental Performance Requirements – GHG Emissions

Draft EES evaluation objective	Key impacts	Environmental Performance Requirements	Proposed mitigation measure	Precinct	Timing
Transport connectivity - To enable a significant increase in the capacity of the metropolitan rail network and provide multimodal connections, while adequately managing effects of the works on the broader transport network, both during and after the construction of the project	Potential for net increase in GHG emissions over the infrastructure lifecycle, contributing to the effects of climate change	Develop and implement a Sustainability Management Plan to meet, as a minimum, the Melbourne Metro sustainability targets, including achieving the specified ratings under the Infrastructure Sustainability Council of Australia's *Infrastructure Sustainability Rating Tool* and the *Green Star Design and As Built Melbourne Metro Rail Tool*.	Minimum monthly updates to GHG model during detailed design for calibration and testing of initiatives Contractor's monthly reporting to include planned versus actual analysis to gauge progress against GHG reduction targets Operator's monthly reporting to include planned versus actual analysis to gauge progress against GHG reduction targets The MMRA and operator could investigate renewable energy projects (such as wind farms) that tap into finance opportunities from the Clean Energy Finance Corporation (CEFC) and that provide for offset of operational GHG emissions.	All	Design / Construction / Operation
		Monitor and report on how each of the best practice GHG abatement measures and sustainability initiatives identified in the Concept Design is implemented in the detailed design of the project and whether any additional measures not included in the Concept Design are feasible.	Incorporate all actions that result from the application of the SEPP Protocol for Environmental Management (Greenhouse Gas Emissions and Energy Efficiency in Industry) for selection of best practice energy efficient electrical and mechanical design, technology and equipment Partial replacement of cement with fly ash and/or blast furnace slag Use of recycled steel.	All	Design

Additionally, the following sustainability Project Performance Requirements (PPRs) have been defined for the Concept Design (refer to Technical Appendix W *Sustainability and Climate Change Appraisal* of the EES), that are applicable to the reduction of GHG emissions:

- Melbourne Metro shall ensure energy-consuming equipment used during construction and/or supplied as part of the MM System shall meet the Minimum Energy Performance Standards (MEPS) of the Australian Greenhouse and Energy Minimum Standards Regulator
- Melbourne Metro shall ensure energy consuming equipment used during construction and/or supplied as part of the MM System that is rated by the Australian Greenhouse and Energy Minimum Standards Regulator shall have an energy star rating of at least 5 stars
- Melbourne Metro shall ensure information technology equipment used during construction and/or supplied as part of the MM System shall be Energy Star accredited to the most recent applicable specification of the US Government's Environmental Protection Agency
- Each underground station shall achieve a minimum 5 star Green Star standard as defined by the Green Building Council of Australia (GBCA)
- Melbourne Metro System shall achieve a minimum ‘Excellent’ (70 or above) certified rating for 'design' and 'as built' by the Infrastructure Sustainability Council of Australia (ISCA).

10 Conclusion

This GHG assessment has addressed the EES Scoping Requirements for Melbourne Metro which require that the EES provides details of all the project components including aspects of the operational phase of the project that could give rise to environmental effects, including greenhouse gas emissions.

10.1 Relevant EES Objectives

The following draft EES evaluation objectives and assessment criteria (and indicators where relevant) are relevant to this assessment. Additionally, MMRA has included assessment criteria against the Transport Connectivity EES Evaluation Objective that the project should 'identify best practice initiatives to reduce GHG emissions across the infrastructure lifecycle of the project.'

Draft EES evaluation objectives	Assessment criteria	Indicator
Transport Connectivity objective: To enable a significant increase in the capacity of the metropolitan rail network and provide multimodal connections, while adequately managing effects of the works on the broader transport network, both during and after the construction of the project. **Project description and context** Describe aspects of the operational phase of the project that could give rise to environmental effects, including with regard to greenhouse gas emissions:	Identification of best practice initiatives to reduce greenhouse gas (GHG) emissions across the construction and operational phases of the project, below a Business-As-Usual reference footprint.	• Predicted reduction in GHG emissions (as indicated by percentage reduction) of best practice greenhouse gas abatement construction and operational, compared to BAU GHG abatement scenario. • Predicted reduction in GHG emissions (as indicated by grams CO_2-e per passenger kilometre) of Melbourne's transport system with the Melbourne Metro (at opening and 20 years from opening) compared with the 'no Melbourne Metro' scenario.

The project is consistent with draft EES evaluation objectives as:

- Best practice GHG abatement initiatives have been included and proposed in the Concept Design, in accordance with SEPP Protocol for Environmental Management (Greenhouse Gas Emissions and Energy Efficiency in Industry) requirements
- MMRA has established clearly defined sustainability targets for the project (including PTV Project Requirements) which aim to achieve reductions in Scope 1 and 2 GHG emissions by minimum 20 per cent below a BAU reference footprint over the lifecycle of the project (including construction and operation), excluding the use of renewable energy; and the sourcing of a minimum of 20 per cent renewable energy over the infrastructure lifecycle.

10.2 Impact Assessment Summary

This assessment has calculated a GHG emissions footprint for a BAU approach to energy efficiency and GHG abatement in an attempt to determine a preliminary GHG reference footprint for the purposes above, for both construction and operational phases. Then, assuming the project achieves its sustainability targets/PTV project requirement, GHG reductions as a result of best practice GHG abatement included within the Melbourne Metro Concept Design were calculated.

With the consideration of the sustainability performance targets and requirements for the project, the following are applicable to the project's GHG emissions footprint:

- Concept Design to achieve reductions in Scope 1 and 2 GHG emissions by a minimum of 20 per cent below a reference footprint over the lifecycle of the project (including construction and operation), excluding the use of renewable energy.
- At least 20 per cent of energy to be sourced from renewable sources for the infrastructure lifecycle (construction and operation phases) through either:
  - Generation of onsite renewable energy; and/or
  - Use of alternative fuels; and/or
  - Purchase of renewable energy from an Australian Government accredited renewable energy supplier.

Total GHG emissions from construction under a best practice GHG abatement scenario would reduce to approximately 543 kt CO_2-e from the BAU scenario of 642 kt CO_2-e. This includes embodied energy in materials, representing 68 per cent of the construction GHG footprint (including construction of rolling stock).

Assuming that the PTV project requirement is met, the Scope 1 and Scope 2 GHG emissions associated with energy consumption during construction would reduce from 161 kt CO_2-e (BAU) to 128 kt CO_2-e (best practice); this assumes that 20 per cent of all energy requirements during construction would be sourced from renewable energy sources. Achieving this requirement and GHG abatement would, for example, require the Melbourne Metro to source approximately 15 GWh of electricity from accredited GreenPower over the duration of the construction.

Key best practice GHG abatement initiatives that have been incorporated into the Concept Design, or are still being investigated, for construction include:

- Reducing the Portland Cement content in concrete by 30 per cent across all concrete used in the project compared to the reference footprint, with partial replacement of cement with fly ash and/or blast furnace slag (captured in Concept Design)
- Replacement of virgin (coarse) aggregate with recycled concrete aggregate or crushed slag aggregate (captured in Concept Design)
- Use of Post Tensioned (PT) Beams and slabs to ground and concourse levels of stations; significantly reduces the quantity of the conventional steel reinforcement (captured in Concept Design)
- Reduce the mass of reinforcing steel used in construction, e.g. use of steel fibre reinforced concrete/shotcrete in segmental lining of tunnels wherever possible, optimal fabrication techniques such as reinforcing carpets, special mesh, prefabricated reinforcement cages
- Consideration of the use of biofuels for construction plant and equipment
- High efficacy LED construction lighting for night-time works
- Intelligent controls/sensors for lighting.

Total annual GHG emissions from operation of the project (portal to portal), assuming a best practice GHG abatement scenario, are estimated to be 47.6 kt CO_2-e per annum in 2026, 55.7 kt CO_2-e per annum in 2031 with commencement of the Extended Program, and reducing to 37.6 kt CO_2-e per annum in 2046 (due to the projected decline in GHG intensity for Victoria). The functional unit (GHG indicator) for the operation of the project, calculated for all operations portal to portal and using rail passenger movements provided by PTV (VITM), has been determined to be 0.130 kg CO_2-e per PKT in 2026 and reducing to 0.055 kg CO_2-e per PKT by 2046. This compares to 0.15 kg CO_2-e per PKT for cars (projected to 2030) and approximately 0.09 kg CO_2-e per PKT for the projected national average for passenger rail (projected to 2030).

The best practice GHG abatement measures that have been incorporated into the operational phase include:

- Energy efficient tunnel lighting. This includes designing the lighting system to use energy efficient lighting (e.g. LEDs, low light, lights off in tunnels, zoning and controls) while meeting lighting requirements and procurement requirements

- Regenerative braking on rolling stock (HCMTs) to provide energy back into the electrical supply (captured in Concept Design)
- Geothermal piling incorporates pipework for a geothermal heat exchange system (to be investigated further in Detailed Design)
- Regenerative power on vertical transportation at stations: elevators and escalators (to be further investigated in Detailed Design)
- Variable speed drive escalators that enable a 'slow-mode' when not in use
- Solar photovoltaics (PV) at Domain, Parkville and Arden stations, and transparent PV film for entry canopies at CBD North and CBD South; PV at ventilation shafts system-wide
- Optimisation of ventilation between stations and tunnels e.g. AHUs to include bypass for reduced pressure drop opportunity, expanded temperature bands within transient spaces, platform screen doors (captured in Concept Design)
- Zone areas of Heating, Ventilation and Air-Conditioning (HVAC) system to deal with separate areas that are known to have different occupancy periods and requirements (captured in Concept Design).

With the adoption of the final performance requirements outlined in Section 9, the residual rating for all risk issues identified during construction (**Risk #GH001**) and operation (**Risk #GH002**) is considered to be Low. As such, the impact of the project's GHG emissions are considered acceptable given the significant benefits and improvement the project makes to Melbourne's road and rail transport network. With consideration of the 'greening' of the electricity grid over the next few decades in line with international, Commonwealth and Victorian Government climate change policy, it is expected that the project would also contribute positively to Melbourne's future GHG inventory and carbon footprint.

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Appendices

Appendix A

Relevant Legislation and Policy

International Framework

Kyoto Protocol

The Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was adopted at the third session of the Conference of the Parties (COP 3) in Kyoto, Japan, on 11 December 1997, and entered into force on 16 February 2005. Australia signed to the Kyoto Protocol in April 1998, however did not ratify the Protocol until 12 December 2007. It came into force on 11 March 2008.

Australia has met its Kyoto Protocol target of limiting emissions to 108 per cent of 1990 levels, on average, over the Kyoto period 2008–2012. Over the five reporting years in the Kyoto period (2008 to 2012), Australia's net emissions averaged 104 per cent of the base year level (CCA: 2014). Australia had committed to reducing its GHG emissions by 5 per cent below 2000 levels by 2020, however more recently a 2030 target was announced.

In August 2015, the Commonwealth Government committed to a new target to reduce emissions by 26-28 per cent by 2030 below 2005 levels. This target represents a 50-52 per cent reduction in emissions per capita and a 64-65 per cent reduction in the emissions intensity of the economy between 2005 and 2030. This target is a step up from the current 2020 target, and has been in direct response to wide public consultation and consideration of Australia's national circumstances (DPMC, 2015). The Commonwealth Government's new target (announced in March 2015) was subject to further discussion as part of the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) in Paris held in late 2015 (refer below). The hope to reach a global deal to stabilise levels of CO_2 in the atmosphere at 450 ppm has now been superseded with recent agreements at the Paris COP, to set a goal to limit global warming to less than 2°C.

2015 UNFCCC

The 2015 UNFCCC, 'COP 21' or 'CMP 11' was held in Paris from 30 November to 12 December 2015, of which 196 countries attended. It was the 21st yearly session of the COP to the 1992 UNFCCC and the 11th session of the Meeting of the Parties (CMP) to the 1997 Kyoto Protocol.

The expected key result of the COP was an agreement to set a goal of limiting global warming to less than 2°C compared to pre-industrial levels. The agreement calls for zero net anthropogenic GHG emissions to be reached during the second half of the 21st century. In the adopted version of the Paris Agreement (UNFCCC, 2015), the parties would also 'pursue efforts to' limit the temperature increase to 1.5°C. The 1.5°C goal would require zero emissions sometime between 2030 and 2050, according to some scientists (Sutter et al., 2015).

The agreement establishes a 'global stocktake' which revisits the national goals to 'update and enhance' them every five years beginning 2023. However no detailed timetable or country-specific goals for emissions were incorporated into the Paris Agreement, as opposed to the previous Kyoto Protocol.

At the time of this EES being prepared, it is not known to what extent the positive agreement reached at the Paris COP will affect the Commonwealth Government's current targets, and how such targets will become legislated.

Greenhouse Gas Protocol

The international Greenhouse Gas Protocol is a collaboration between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The first edition of the Greenhouse Gas Protocol: *A Corporate Accounting and Reporting Standard* (Corporate Standard) was published in 2001. Since then the GHG Protocol has built upon the Corporate Standard by developing a suite of calculation tools to assist companies in calculating and reporting their greenhouse gas emissions.

The Protocol would be used as the basis for the determination of GHG emissions associated with the Melbourne Metro. According to the GHG Protocol, GHG emissions are split into three categories, known as 'Scopes'. Refer to Section 4.1.

International Standard ISO 14064-1

In 2006, the International Organization for Standardisation (ISO) adopted the Corporate Standard of the GHG Protocol as the basis for its ISO 14064 *Greenhouse gases – Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*. This milestone highlighted the role of the GHG Protocol's Corporate Standard as the international standard for corporate and organisational GHG accounting and reporting. ISO 14064-1 details principles and requirements for designing, developing, managing and reporting organisation or company-level GHG inventories. It includes requirements for determining GHG emission boundaries, quantifying an organisation's GHG emissions and removals, and identifying specific company actions or activities aimed at improving GHG management. It also includes requirements and guidance on inventory quality management, reporting, internal auditing and the organisation's responsibilities for verification activities.

ISO 14064-1 sets the framework for the identification and management of GHG emissions across the construction and operational phases of the Melbourne Metro.

Commonwealth

Australia is meeting its 2020 emissions reduction target (refer Kyoto Protocol above) through the Commonwealth Government's Direct Action Plan policies that reduce emissions, increase energy productivity and improve the health of soils and the environment. DoE (2015a) claims these policies will also enable Australia to meet its 2030 target.

The Government will further consider Australia's emissions reduction policies in detail in 2017–2018, in close consultation with businesses and the community (DoE, 2015a).

National Greenhouse and Energy Reporting Act 2007

The *National Greenhouse and Energy Reporting Act* 2007 (*NGER Act*) provides for the reporting and dissemination of information related to GHG emissions, GHG projects, energy production and energy consumption.

Under the *NGER Act*, corporations in Australia that exceed thresholds for GHG emissions or energy production or consumption are required to measure and report data to the Clean Energy Regulator on an annual basis (NGER Scheme). The *National Greenhouse and Energy Reporting (Measurement) Determination 2008* identifies a number of methodologies to account for GHGs from specific sources relevant to Melbourne Metro. This includes emissions of GHGs from direct fuel combustion (fuels for transport energy purposes), emissions associated with consumption of power from direct combustion of fuel (e.g. diesel generators used during construction) and from consumption of electricity from the grid.

The current operator of the rail network in Melbourne, Metro Trains Melbourne Pty Ltd (MTM), at an organisational level exceeds the threshold for reporting under the *NGER Act*, and as such annually reports the GHG emissions from its rail operations to the Commonwealth Government. GHG emissions associated with operation of the Melbourne Metro would need to be reported under the NGER scheme, along with GHG emissions from the existing network, by the operator in place at the time. For the scenario where a different operator is appointed to operate Melbourne Metro, GHG emissions may require reporting, should operational GHG emissions trigger the reporting threshold(s).

Commonwealth Renewable Energy Target

The Commonwealth Renewable Energy Target (RET) commits Australia to generating 33,000 GWh of additional renewable electricity generation by 2020 (Large-scale RET) in order to achieve the goal of a 20 percent share of renewable energy in Australia's electricity supply by 2020.

Amending legislation to implement the Commonwealth Government's reforms to the RET was agreed to by the Australian Parliament on 23 June 2015, which involved reducing the RET from 41,000 GWh to 33,000 GWh of additional renewable electricity generation by 2020. According to the Commonwealth Government, 'the new target for large-scale generation of 33,000 GWh in 2020 will double the amount of large-scale renewable energy being delivered by the scheme compared to current levels and means that about 23.5 per cent of Australia's electricity generation in 2020 will be from renewable sources' (DoE, 2015).

The Clean Energy Regulator oversees the operation of the RET, and the Commonwealth Department of the Environment provides policy advice and implementation support for the scheme.

The RET is designed to encourage investment in new large-scale renewable power stations and the installation of new small-scale systems, such as solar photovoltaic (PV) and hot water systems in households. The RET has two core components: the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). Together, these schemes create a financial incentive for investment in renewable energy.

The principles of the RET have been incorporated into the project's sustainability requirements. In particular, the project must commit to PTV's performance requirement of 20 per cent of energy consumption being sourced from renewable sources for the infrastructure lifecycle (construction and operation phases), generated by a Victorian Government accredited GreenPower renewable energy source.

Carbon Pricing Mechanism

The Commonwealth Government had enacted the *Clean Energy Act 2011* to reduce carbon emissions. This legislation established an Emissions Trading Scheme (ETS) or carbon price. Under this ETS, corporations were required to purchase a permit for every tonne of carbon equivalent they emit, and find ways to reduce their emissions.

The *Clean Energy Legislation (Carbon Tax Repeal) Act 2014* repealed the *Clean Energy Act 2011*. This abolished the carbon pricing mechanism from 1 July 2014, and was replaced with the Direct Action Plan, which aims to focus on sourcing low cost emission reductions. The Direct Action Plan included an Emissions Reduction Fund (ERF); legislation to implement the ERF came into effect on 13 December 2014, and is now considered to be the centrepiece of the Commonwealth Government's policy suite to reduce emissions. Emission reduction technologies implemented on Melbourne Metro could be eligible for offsets credited through the ERF (e,g. PTV upgrade to wider network to capture the full capability of regenerative braking and significantly reducing traction energy consumption).

Victoria

Climate Change Act 2010

Victoria's primary policy driver for GHG emission reduction is the *Climate Change Act 2010* (CC Act) which came into effect on 1 July 2011.

The *CC Act* contains measures that support the management of and adaptation to climate risks and increase the ability of individuals, businesses and communities to capitalise on opportunities. It includes requiring the Victorian Government to develop a Climate Change Adaptation Plan every four years to outline the potential impacts and risks associated with a changing climate. The first Victorian Climate Change Adaptation Plan was released in March 2013.

The *CC Act* originally mandated a 20 per cent GHG emission reduction target for Victoria by 2020 compared to 2000 levels and provided the framework to achieve this. The Act gives powers to decision makers and regulators to take climate change into account when making specified decisions under the *Catchment and Land Protection Act 1994*, *Coastal Management Act 1995*, *Environment Protection Act 1970*, *Flora and Fauna Guarantee Act 1988*, *Public Health and Wellbeing Act 2008* and *Water Act 1989*.

A review of the *CC Act* was undertaken in response to the implementation of the Commonwealth Government's *Clean Energy Act 2011*. The previous Victorian Coalition Government made a number of changes to the Act as a result of the review's recommendations, including:

- Removing elements deemed redundant with a national emissions trading scheme in place
- Removal of the stated 20 per cent emission reduction target
- Amendment of the Environment Protection Authority (EPA Vic) mandate to recommend regulations for the purpose of contributing to the target
- Removal of the need for biannual reporting of progress towards the target.

The current State Government is now considering whether a Victorian emissions reduction target might be re-introduced, and is currently reviewing legislation and programs to determine whether a state carbon emissions reduction target would be effective. The Minister for Environment, Climate Change and Water has appointed an Independent Review Committee to undertake an independent review of the *CC Act*. The Department of Environment, Land, Water and Planning (DELWP) is supporting the independent review. The independent review committee would conduct the review and propose options to strengthen the Act, so it can provide a strong foundation for Victorian action on climate change. The review report would be delivered to the Government before 31 December 2015. It would then be tabled in Parliament early in 2016, to be followed by a Government response.

It is unlikely that the reintroduction of a state emissions reduction target would have any material implications on current sustainability and GHG abatement targets proposed for Melbourne Metro. The current targets proposed are based on best practice GHG abatement initiatives, largely driven by the Commonwealth Government's RET and policies on GHG emissions reduction, and the project's requirement to satisfy sustainability targets under the Infrastructure Sustainability (IS) rating scheme.

Victorian Renewable Energy Action Plan

The Victorian Government is in the process of the development of the Victorian Renewable Energy Action Plan, which would set long-term actions to drive renewable energy investment in Victoria. As a first step, the Government is currently[32] unveiling its *Renewable Energy Roadmap*, which sets out the Government's plan to attract Victoria's share of renewable energy investment and jobs in Australia by 2020. The Roadmap identifies the establishment of a renewable energy target for Victoria of at least 20 per cent by 2020.

The Government has also launched an initiative to source renewable energy certificates from new projects in Victoria, bringing forward around $200 million of new investment in at least 100 MW of renewable energy projects. This supports the projections of declining GHG intensity emission factors that have been used to estimate GHG emissions from the operation of Melbourne Metro, as identified in Section 4.7.4.1, which have relied upon the prediction of shifts to more renewable energy as a percentage of stationary power generation.

Environment Protection Act 1970

The *Environment Protection Act 1970* governs pollution prevention and environmental protection for Victoria. EPA Vic is responsible for administering the Act, issuing any regulations, recommending statutory policies, issuing works approvals, licences, permits, pollution abatement notices and writing policy to implement select National Environment Protection Measures (NEPMs).

[32] September 2015

State Environment Protection Policy (Air Quality Management) 2001

The State Environment Protection Policy (Air Quality management) establishes the framework for managing air emissions from all sources of pollution. One of the aims of SEPP AQM is to support Victorian and national measures to address the enhanced greenhouse effect and depletion of the ozone layer.

SEPP AQM provides requirements for the inclusion of a greenhouse gas assessment for development proposals, as part of the regulatory approvals process in Victoria. The requirements for management of GHGs are set out in clause 33 of SEPP (AQM), which requires that generators of GHG emissions:

- Avoid and minimise emissions in accordance with the principles of the waste hierarchy
- Pursue continuous improvement
- Apply best practice to the management of their emissions.

Protocol for Environmental Management: Greenhouse gas emissions and energy efficiency in industry (2002)

The *Protocol for Environmental Management (PEM) – Greenhouse gas emissions and energy efficiency in industry* (EPA Vic Publication 824) is an incorporated document of the SEPP (AQM). The PEM sets out requirements for the management of GHG emissions and energy consumption, and provides guidance to industry on the steps that must be taken to demonstrate compliance with the policy principles and provisions of SEPP (AQM). The main objectives of the PEM are:

i) To support businesses to take-up cost-effective opportunities for GHG mitigation

ii) Integrate consideration of GHG and energy issues within existing environmental management procedures and programs.

Requirements outlined in the PEM include:

i) estimate expected energy consumption and GHG emissions

ii) estimate expected direct GHG emissions

iii) identify and evaluate opportunities to reduce GHG emissions (i.e. by proposing best practice energy efficiency and GHG emissions management).

The requirements of the PEM would be satisfied by addressing each of the items above. It is noted that evaluation processes such as the IS rating system may be usefully applied in helping to ensure that best practice is achieved in construction and through continuous improvement of operation.

Local Government

The Melbourne Metro would respond to local government policies for GHG emissions reduction indirectly, rather than through direct implementation of each council policy. Whilst the local government strategies presented in the following sections focus on activities that Council can influence, consideration of GHG mitigation measures adopted during the design, construction and operation of Melbourne Metro would complement each council’s position in actively managing their GHG emissions targets. The same holds true for all local government areas (LGAs) of the larger metropolitan area affected by the mode shift and reducing road based transport emissions within LGAs.

The GHG emissions reduction targets set by each council typically focus on council’s own carbon footprint (of their operations and services) that they have responsibility and accountability for, rather than State projects being constructed within their LGA. However where the reduction targets may have an external focus (i.e. not just internal operations), the GHG mitigation measures and sustainability targets of the Melbourne Metro would complement the emissions reduction targets of Councils, as mentioned above.

City of Melbourne

The City of Melbourne, through its *Zero Net Emissions by 2020 – update 2014* strategy, is working to reduce GHG emissions across the municipality to zero by 2020 and is leading the way in future sustainability and averting the consequences of climate change. The strategy aims to set the City of Melbourne as a carbon neutral city by the year 2020.

City of Port Phillip

In 2007, the City of Port Phillip (CoPP) released *Climate Change in the City of Port Phillip – An Initial Perspective* (CoPP, 2007a). This inaugural Climate Change Discussion Paper and Report provided an initial overview of the effects and consequences of climate change and rising GHG emissions on the City of Port Phillip and globally.

As a result of this discussion paper, the CoPP has committed to achieving and sustaining zero GHG emissions in council operations and services by 2020, through its *Toward Zero – Sustainable Environment Strategy 2007* (CoPP, 2007b), which represents the overall strategy for what guides Council's actions with respect to meeting the challenges of climate change and management of GHG emissions reduction.

The City is also committed to achieving and sustaining a 50 per cent reduction in per capita community GHG emissions by 2020 (based on 2006 levels), in collaboration with regional, state and federal partners.

With respect to sustainable transport, the CoPP's ultimate aim is a sustainable transport strategy that delivers low-emissions and healthy vehicles and transport modes, in collaboration with regional, state and federal partners (CoPP, 2007b).

City of Stonnington

The City of Stonnington has implemented *Sustainable Environment Strategy 2013-2017* which contains a goal to 'support the community to reduce energy consumption and corresponding greenhouse gas emissions' (CoS, 2014).

The City of Stonnington has committed to reduce its GHG emissions by 20 per cent by 2015, and 30 per cent by 2020, compared to 2005 levels of 17,941 tonnes CO_2-e (City of Stonnington, 2009). The City of Stonnington joined the Cities for Climate Protection (CCP) program in 2005. CCP is a global local government program aimed at reducing energy consumption and associated GHG emissions, and consists of five Milestones. The GHG reduction target set by Council helps it to meet Milestones 4 and 5 of the CCP program.

City of Maribyrnong

The Concept Design includes the Western Turnback within the City of Maribyrnong ('West Footscray Concept Design').

In 2008, the City of Maribyrnong set a target to become a carbon neutral council by 2015. Maribyrnong City Council achieved its target of zero carbon corporate emissions in June 2015, through the implementation of its *Carbon Neutral Action Plan* (City of Maribyrnong, 2008), which includes several strategies to reduce GHG emissions at a corporate level. These included avoidance and behaviour change initiatives (including the purchasing of energy efficient appliances, recycling), a Green Travel Plan including investigation of alternative fuels within Council's vehicle fleet, and installation of the co-generation system at the Maribyrnong Aquatic Centre, among many others.

With the City of Maribyrnong becoming a carbon neutral LGA, the Council supports the GHG abatement initiatives that Melbourne Metro are intended to be included within the Concept Design (which included capture of the Western Turnback).

Appendix B

GHG Emissions Factors

Table B-1 GHG emissions factors for liquid fuels – stationary combustion (DoE, 2015a), kg CO_2-e/L

Fuel	Scope 1	Scope 3	Full Fuel Cycle (1 + 3)
Diesel oil	2.7097	0.1390	2.8487
Biodiesel	0.0093	NE	NE
Ethanol for use in internal combustion engines	0.0063	NE	NE

NE = Not estimated. Scope 3 factors for biofuels such as biodiesels and ethanol are highly dependent on individual plant and project characteristics, and therefore have not been estimated (DoE, 2015a)

Table B-2 GHG emissions factors for transport fuel combustion (DoE, 2015a), kg CO_2-e/L

Fuel	Scope 1	Scope 3	Full Fuel Cycle (1 + 3)
Post 2004 vehicles			
Gasoline (other than for use as fuel in an aircraft)	2.3126	0.1231	2.4357
Diesel oil	2.7217	0.1390	2.8606
LPG	1.5956	0.0943	1.6899
Ethanol for use as fuel in an internal combustion engine	0.0094	NE	NE
General transport			
Biodiesel	0.0900	NE	NE

Table B-3 Fuel combustion emissions factor for natural gas (DoE, 2015a), kg CO_2-e/kL

Scope 1	Scope 3 (Vic)	Full Fuel Cycle (1 + 3)
2.35	0.15	2.50

Table B-4 Projected Victorian GHG intensity (GGI) factors – electricity

Year / projection	GHG intensity (kgCO_2-e/kWh)			Source/notes
	Scope 2	Scope 3	Full Fuel Cycle	
2006	1.23	0.10	1.33	Australian Greenhouse Office (2006).
2008	1.22	0.14	1.36	Department Climate Change (2008).
2015	1.13	0.13	1.26	NGA Factors (DoE, 2015a).
Construction (2018-2022)	1.08	0.13	1.21	Australia's emissions projections 2014–15 (DoE, 2015b).
Construction / fit out (2023-2026)	1.07	0.13	1.20	Australia's emissions projections 2014–15 (DoE, 2015b).
2026	1.05	0.13	1.18	Australia's emissions projections 2014–15 (DoE, 2015b).

Year / projection	GHG intensity (kgCO_2-e/kWh)			Source/notes
	Scope 2	Scope 3	Full Fuel Cycle	
2031	1.03	0.13	1.16	Australia's emissions projections 2014–15 (DoE, 2015b).
2046	0.6	0.13	0.73	AJM JV projection from 2034-35, using 2034-35 GGI as per DoE (2015b).
Beyond 2046	0.6	0.13	0.73	No GHG intensity projection beyond 2046; assumes GHG intensities do not decline (conservative assumption).

Table B-5 IS Materials Calculator emissions factors

Material / activity	GHG emission factor	Units
Concrete Strength Grade 40 MPa, 0% SCM[#] [&]	0.188	t CO_2-e / tonne concrete
Concrete Strength Grade 40 MPa, 30% SCM	0.144	t CO_2-e / tonne concrete
Concrete Strength Grade 40 MPa, 60% SCM	0.100	t CO_2-e / tonne concrete
Concrete Strength Grade 50 MPa, 0% SCM	0.239	t CO_2-e / tonne concrete
Concrete Strength Grade 50 MPa, 30% SCM	0.182	t CO_2-e / tonne concrete
Concrete Strength Grade 50 MPa, 60% SCM	0.125	t CO_2-e / tonne concrete
Grout ('Recycled Crushed Concrete/Masonry')	0.000210	t CO_2-e / tonne grout
Steel Reinforcing Bar	1.591	t CO_2-e / tonne steel
Steel, rail lines	1.185	t CO_2-e / tonne steel
Steel rock bolts and tunnel fit out ('Steel Angle')	1.186	t CO_2-e / tonne steel
Aluminium	21.34	t CO_2-e / tonne Aluminium
Articulated Truck Freight	0.106	kg CO_2-e / tonne.km [##]
Rigid Truck	0.396	kg CO_2-e / tonne.km

[#] SCM = Supplementary Cementitious Materials
[&] Concrete block fill (pump mix) and 40 MPa Shot Crete also assumed as Concrete Strength Grade 40 MPa 0% SCM
[##] To calculate total CO_2-e emissions for materials delivery this emission factor is multiplied by the total tonnes of material delivered to site and then multiplied by the one-way distance assumed (e.g. 30 km). This process is repeated for each material type.

Table B-6 Land clearing emissions factors (RMS & VicRoads, 2013)

vegetation Class	Name	Scope 1 emission	Unit	Notes
D	Open Woodlands	209	t CO_2-e/ha	Based on Maximum Potential Biomass Class of 2. Assumed applicable for clearing of planted native vegetation within the project area.
I	Grassland	110	t CO_2-e/ha	Based on Maximum Potential Biomass Class of 2. Assumed applicable for clearing of exotic vegetation within the project area.

Appendix C

Victorian Integrated Transport Model (VITM) table outputs

TRAIN Vehicle Kilometres Travelled (VKTs) (AFFECTED LINES ONLY)

VKT by Train Vehicle Type		4	10	16	22	28	34	40	46	52	58	64	70	76	82	88	94
Scenario		2011 Base				2021 Base				2021 Project				2031 Base			
Run Number		*00b*				*01a*				*110a*				*02a*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
	1	5208.331	10973.1	7824.509	10973.1	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	6868.877	11555.1	10590.57	7468.2	6956.367	11160.72	10434.59	6223.86	5370.015	10946.52	8342.072	7757.64
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	18	0	0	0	0	3513.854	3920.76	5270.782	2694.96	4916.625	5591.16	7374.937	5591.16	5299.84	5108.22	7949.97	2694.96
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vehicle Type	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	41	201.72	0	302.58	0	0	0	0	0	0	0	0	0	0	0	0	0
	42	601.8	1444.32	902.7	1444.32	0	0	0	0	0	0	0	0	0	0	0	0
	43	644.34	966.54	966.57	966.54	1457.55	3084.84	2186.52	3084.84	1457.55	3084.84	2186.52	3084.84	3365.183	7594.56	5048.08	7030.8
	44	1210.62	2193.72	1815.93	2193.72	152.95	367.08	229.425	367.08	152.95	367.08	229.425	367.08	112.75	270.6	169.125	270.6
	45	91.14	0	136.71	0	0	0	0	0	0	0	0	0	0	0	0	0
	46	1539.68	2800.38	2309.55	2800.38	0	0	0	0	0	0	0	0	0	0	0	0
	47	0	0	0	0	3565.934	8339.063	5349.091	8098.3325	3565.934	8339.063	5349.091	8098.333	2048.513	4392.623	3072.851	4151.893
	48	0	0	0	0	671.7895	2015.369	1007.684	1054.5	671.7895	2015.369	1007.684	1054.5	671.7362	2015.209	1007.604	1054.42
	49	0	0	0	0	145.2	435.6	217.8	217.8	145.2	435.6	217.8	217.8	145.2	435.6	217.8	217.8
Total VKT		9497.631	18378.06	14258.55	18378.06	16376.15	29717.81	24851.88	22985.7125	17866.41	30993.83	26800.04	24637.57	17013.24	30763.33	25807.5	23178.11
CHECK Metro		9,241	16,364	13,564	16,364	16,279	25,340	24,709	18,243	17,769	26,616	26,657	19,895	17,059	25,823	25,878	18,436
CHECK V/Line		4,289	7,405	6,434	7,405	5,840	13,875	8,761	12,455	5,840	13,875	8,761	12,455	6,231	14,438	9,346	12,455
CHECK TOTAL		13,530	23,769	19,998	23,769	22,119	39,215	33,470	30,698	23,609	40,491	35,418	32,350	23,290	40,261	35,224	30,891
Difference		4,032	5,391	5,739	5,391	5,743	9,497	8,618	7,712	5,743	9,497	8,618	7,712	6,277	9,498	9,416	7,713

VKT by Train Vehicle Type		172	178	184	190	100	106	112	118	124	130	136	142	148	154	160	166
Scenario		2031 'day1'				2031 Project				2046 Base				2046 Project			
Run Number		*111a*				*21a*				*03a*				*25b*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	5824.9	9908.64	8737.326	6513.3	5824.9	9908.64	8737.326	6513.3	4827.405	10946.52	7528.067	4700.52	2187.329	5103.36	3281.001	2658.78
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	18	6743.645	7422.12	10115.5	5591.16	2468.13	1830.96	3702.225	0	6563.314	5703.66	9780.172	5623.92	5883.453	7155.72	8825.209	4225.68
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	5108.155	6441.84	7662.232	6441.84	0	0	0	0	6008.965	6666.12	9013.447	6666.12
Vehicle Type	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	43	3632.393	7594.56	5448.85	7030.8	3820.417	7823.52	5730.81	5708.34	4894.147	8569.82	7341.375	7059.04	5117.427	7247.36	7676.235	6177.4
	44	112.75	270.6	169.125	270.6	112.75	270.6	169.125	270.6	112.75	270.6	169.125	270.6	112.75	270.6	169.125	270.6
	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	47	2048.513	4392.623	3072.851	4151.893	2048.513	4392.623	3072.851	4151.893	3668.91	7550.611	5503.506	7303.23	3668.91	7550.611	5503.506	7303.23
	48	671.7362	2015.209	1007.604	1054.42	671.7362	2015.209	1007.604	1054.42	526.5895	1579.769	789.8843	836.7	526.5895	1579.769	789.8843	836.7
	49	145.2	435.6	217.8	217.8	145.2	435.6	217.8	217.8	145.2	435.6	217.8	217.8	145.2	435.6	217.8	217.8
Total VKT		19179.14	32039.35	28769.05	24829.97	20199.8	33118.99	30299.97	24358.19	20738.32	35056.58	31329.93	26011.81	23650.62	36009.14	35476.21	28356.31
CHECK Metro						19,790	27,949	29,687	20,938	18,188	26,893	27,507	19,031	20,877	29,168	31,318	21,534
CHECK V/Line						6,686	14,667	10,029	11,132	9,235	18,136	13,853	15,417	9,458	16,813	14,187	14,535
CHECK TOTAL		-	-	-	-	26,476	42,616	39,716	32,070	27,423	45,029	41,360	34,448	30,335	45,981	45,505	36,069
Difference		(19,179)	(32,039)	(28,769)	(24,830)	6,276	9,497	9,416	7,712	6,685	9,972	10,030	8,436	6,684	9,972	10,029	7,713

Table Reports VKT by Vehicle Type for Trains

Source: VITM Ptlink Files

*Source for Checks: MM Summary Sheet

Train Lines affected by MM project. (Lines through South Yarra and North Melbourne)

VEHICLETYPE NUMBER=1 LONGNAME="Metro_Refurb" NAME="Metro_Refurb" SEATCAP=456 CRUSHCAP=1280 LOADDISTFAC=70
VEHICLETYPE NUMBER=2 LONGNAME="COMENG (REFURB)" NAME="COMENG (REFURB)" SEATCAP=456 CRUSHCAP=1280 LOADDISTFAC=70
VEHICLETYPE NUMBER=10 LONGNAME="Sun_Dan_Trains" NAME="Sun_Dan_Trains" SEATCAP=643 CRUSHCAP=2070 LOADDISTFAC=70
VEHICLETYPE NUMBER=11 LONGNAME="Fish_Bend_Trains" NAME="Fish_Bend_Trains" SEATCAP=400 CRUSHCAP=1450 LOADDISTFAC=70
VEHICLETYPE NUMBER=16 LONGNAME="Metro6Car" NAME="Metro6Car" SEATCAP=450 CRUSHCAP=1400 LOADDISTFAC=70
VEHICLETYPE NUMBER=17 LONGNAME="Metro7Car" NAME="Metro7Car" SEATCAP=450 CRUSHCAP=1450 LOADDISTFAC=70
VEHICLETYPE NUMBER=18 LONGNAME="HCMT" NAME="HCMT" SEATCAP=550 CRUSHCAP=1420 LOADDISTFAC=70
VEHICLETYPE NUMBER=19 LONGNAME="HCMT9car" NAME="HCMT9car" SEATCAP=710 CRUSHCAP=1830 LOADDISTFAC=70
VEHICLETYPE NUMBER=20 LONGNAME="Extended HCMT" NAME="Extended HCMT" SEATCAP=785 CRUSHCAP=2025 LOADDISTFAC=70

VEHICLETYPE NUMBER=41 LONGNAME="Vline_VL6" NAME="Vline_VL6" SEATCAP=444 CRUSHCAP=686 LOADDISTFAC=70
VEHICLETYPE NUMBER=42 LONGNAME="Vline_Ballarat" NAME="Vline_Ballarat" SEATCAP=444 CRUSHCAP=489 LOADDISTFAC=70
VEHICLETYPE NUMBER=43 LONGNAME="HCDMU" NAME="HCDMU" SEATCAP=855 CRUSHCAP=1450 LOADDISTFAC=70
VEHICLETYPE NUMBER=44 LONGNAME="SP2" NAME="SP2" SEATCAP=178 CRUSHCAP=224 LOADDISTFAC=70
VEHICLETYPE NUMBER=45 LONGNAME="SP4" NAME="SP4" SEATCAP=358 CRUSHCAP=448 LOADDISTFAC=70
VEHICLETYPE NUMBER=46 LONGNAME="Vline_NZ5_SG" NAME="Vline_NZ5_SG" SEATCAP=358 CRUSHCAP=409 LOADDISTFAC=70
VEHICLETYPE NUMBER=47 LONGNAME="VL6" NAME="VL6" SEATCAP=444 CRUSHCAP=686 LOADDISTFAC=70
VEHICLETYPE NUMBER=48 LONGNAME="NZ5 (BG)" NAME="NZ5 (BG)" SEATCAP=370 CRUSHCAP=407 LOADDISTFAC=70
VEHICLETYPE NUMBER=49 LONGNAME="NZ5 (SG)" NAME="NZ5 (SG)" SEATCAP=358 CRUSHCAP=409 LOADDISTFAC=70

TRAIN SERVICES (AFFECTED LINES ONLY)

Number of Services by Train Vehicle Typ		4	10	16	22	28	34	40	46	52	58	64	70	76	82	88	94
Scenario		2011 Base				2021 Base				2021 Project				2031 Base			
Run Number		*00b*				*01a*				*110a*				*02a*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	1	162	348	236	348	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	186	324	279	216	209	324	313	180	159	288	239	216
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	18	0	0	0	0	68	72	102	72	65	72	98	72	95	108	142	72
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	41	4	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
	42	5	12	8	12	0	0	0	0	0	0	0	0	0	0	0	0
	43	8	12	12	12	19	36	29	36	19	36	29	36	46	108	69	96
	44	12	18	18	18	5	12	8	12	5	12	8	12	5	12	8	12
	45	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	46	14	24	21	24	0	0	0	0	0	0	0	0	0	0	0	0
	47	0	0	0	0	33	89	50	87	33	89	50	87	14	29	20	27
	48	0	0	0	0	5	15	8	8	5	15	8	8	5	15	8	8
	49	0	0	0	0	1	4	2	2	1	4	2	2	1	4	2	2
Total Services		206	414	302	414	318	552	477	433	338	552	507	397	325	564	487	433
Change on Base										20	0	30	-36				

Number of Services by Train Vehicle Typ		172	178	184	190	100	106	112	118	124	130	136	142	148	154	160	166
Scenario		2031 Day 1				2031 Project				2046 Base				2046 Project			
Run Number		*111a*				*21a*				*03a*				*25b*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	178	288	267	180	178	288	267	180	150	288	225	180	91	180	136	108
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	18	102	108	153	72	50	36	75	0	111	108	165	72	126	144	189	72
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	58	72	87	72	0	0	0	0	73	72	110	72
	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	43	49	108	73	96	52	108	78	60	68	136	102	92	72	100	108	68
	44	5	12	8	12	5	12	8	12	5	12	8	12	5	12	8	12
	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	47	14	29	20	27	14	29	20	27	26	53	38	50	26	53	38	50
	48	5	15	8	8	5	15	8	8	4	11	6	6	4	11	6	6
	49	1	4	2	2	1	4	2	2	1	4	2	2	1	4	2	2
Total Services		354	564	531	397	363	564	544	361	364	612	545	414	397	576	596	390
Change on Base		29	0	44	-36	38	0	57	-72					33	-36	51	-24

Table Reports VKT by Vehicle Type for Trains
Source: VITM Ptline Files
Train Lines affected by MM project. (Lines through South Yarra and North Melbourne)
VEHICLETYPE NUMBER=1 LONGNAME="Metro_Refurb" NAME="Metro_Refurb" SEATCAP=456 CRUSHCAP=1280 LOADDISTFAC=70
VEHICLETYPE NUMBER=2 LONGNAME="COMENG (REFURB)" NAME="COMENG (REFURB)" SEATCAP=456 CRUSHCAP=1280 LOADDISTFAC=70
VEHICLETYPE NUMBER=10 LONGNAME="Sun_Dan_Trains" NAME="Sun_Dan_Trains" SEATCAP=643 CRUSHCAP=2070 LOADDISTFAC=70
VEHICLETYPE NUMBER=11 LONGNAME="Fish_Bend_Trains" NAME="Fish_Bend_Trains" SEATCAP=400 CRUSHCAP=1450 LOADDISTFAC=70
VEHICLETYPE NUMBER=16 LONGNAME="Metro6Car" NAME="Metro6Car" SEATCAP=450 CRUSHCAP=1400 LOADDISTFAC=70
VEHICLETYPE NUMBER=17 LONGNAME="Metro7Car" NAME="Metro7Car" SEATCAP=450 CRUSHCAP=1450 LOADDISTFAC=70
VEHICLETYPE NUMBER=18 LONGNAME="HCMT" NAME="HCMT" SEATCAP=550 CRUSHCAP=1420 LOADDISTFAC=70
VEHICLETYPE NUMBER=19 LONGNAME="HCMT9car" NAME="HCMT9car" SEATCAP=710 CRUSHCAP=1830 LOADDISTFAC=70
VEHICLETYPE NUMBER=20 LONGNAME="Extended HCMT" NAME="Extended HCMT" SEATCAP=785 CRUSHCAP=2025 LOADDISTFAC=70

VEHICLETYPE NUMBER=41 LONGNAME="Vline_VL6" NAME="Vline_VL6" SEATCAP=444 CRUSHCAP=686 LOADDISTFAC=70
VEHICLETYPE NUMBER=42 LONGNAME="Vline_Ballarat" NAME="Vline_Ballarat" SEATCAP=444 CRUSHCAP=489 LOADDISTFAC=70
VEHICLETYPE NUMBER=43 LONGNAME="HCDMU" NAME="HCDMU" SEATCAP=855 CRUSHCAP=1450 LOADDISTFAC=70
VEHICLETYPE NUMBER=44 LONGNAME="SP2" NAME="SP2" SEATCAP=178 CRUSHCAP=224 LOADDISTFAC=70
VEHICLETYPE NUMBER=45 LONGNAME="SP4" NAME="SP4" SEATCAP=358 CRUSHCAP=448 LOADDISTFAC=70
VEHICLETYPE NUMBER=46 LONGNAME="Vline_NZ5_SG" NAME="Vline_NZ5_SG" SEATCAP=358 CRUSHCAP=409 LOADDISTFAC=70
VEHICLETYPE NUMBER=47 LONGNAME="VL6" NAME="VL6" SEATCAP=444 CRUSHCAP=686 LOADDISTFAC=70
VEHICLETYPE NUMBER=48 LONGNAME="NZ5 (BG)" NAME="NZ5 (BG)" SEATCAP=370 CRUSHCAP=407 LOADDISTFAC=70
VEHICLETYPE NUMBER=49 LONGNAME="NZ5 (SG)" NAME="NZ5 (SG)" SEATCAP=358 CRUSHCAP=409 LOADDISTFAC=70

ANNUALISATION FACTORS

Time Period	Number of Periods Annually
AM	250
PM	250
IP	349
OP	349

*Factors for Annualisation of Time Periods
eg: 250 AM Peaks per year

CARS VKTs

	Car VKT							
	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Number	*00*	*01*	*110*	*02*	*111*	*21*	*03*	*25*
AM	13,074,073	14,596,272	14,567,230	16,421,552	16,369,734	16,310,884	18,642,459	18,446,957
IP	26,998,071	31,641,680	31,609,078	36,592,468	36,532,445	36,495,214	42,654,923	42,457,780
PM	21,706,612	25,033,120	24,997,452	28,761,337	28,686,836	28,626,216	33,251,098	32,993,293
OP	18,571,319	20,883,956	20,838,386	23,588,126	23,511,912	23,435,734	27,041,421	26,755,975
Table reports VKT for period, source: model summary sheets								

TRUCKS VKTs

	Total Truck VKT							
	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numl	00	01	110	02	111	21	03	25
AM	863,992	1,011,493	1,011,473	1,419,240	1,418,766	1,418,314	2,085,251	2,081,788
IP	2,829,082	3,331,212	3,330,794	4,644,776	4,642,957	4,643,658	6,775,398	6,770,474
PM	1,053,369	1,255,034	1,255,034	1,750,401	1,749,192	1,748,732	2,550,498	2,546,209
OP	1,405,810	1,754,595	1,754,376	2,509,444	2,510,171	2,509,782	3,846,879	3,844,787

Table reports trips for period, source: model summary sheets

	Approximate Rigid Truck VKT							
	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numl	*00*	*01*	*110*	*02*	111	*21*	*03*	*25*
AM	526,127	530,613	530,603	711,433	711,195	710,969	1,025,976	1,024,272
IP	1,694,802	1,722,236	1,722,020	2,290,772	2,289,875	2,290,221	3,272,575	3,270,196
PM	632,445	652,982	652,982	868,632	868,032	867,804	1,244,438	1,242,346
OP	525,465	526,636	526,571	706,510	706,715	706,606	1,040,576	1,040,010

	Approximate Articulated Truck VKT							
	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numl	*00*	*01*	*110*	*02*	111	*21*	*03*	*25*
AM	337,678	480,379	480,370	707,057	706,821	706,596	1,058,086	1,056,329
IP	1,133,647	1,607,169	1,606,968	2,351,297	2,350,376	2,350,731	3,498,600	3,496,057
PM	420,430	600,727	600,727	879,739	879,131	878,900	1,302,904	1,300,713
OP	878,706	1,223,410	1,223,257	1,796,154	1,796,674	1,796,396	2,678,203	2,676,746

	Approximate B-Double Truck VKT							
	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numl	*00*	*01*	*110*	*02*	111	*21*	*03*	*25*
AM	187	501	501	750	750	750	1,189	1,187
IP	634	1,807	1,807	2,707	2,706	2,706	4,223	4,220
PM	494	1,326	1,326	2,030	2,028	2,028	3,156	3,151
OP	1,639	4,549	4,549	6,780	6,782	6,781	10,782	10,776

	Approximate HPFV Truck VKT							
	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numl	*00*	*01*	*110*	*02*	111	*21*	*03*	*25*
AM	-	-	-	-	-	-	-	-
IP	-	-	-	-	-	-	-	-
PM	-	-	-	-	-	-	-	-
OP	-	-	-	-	-	-	117,318	117,254

Breakdown of Truck Types by TRIPS
Source: Freight Demand from VITM.
Note: Base and Project matrices identical

Number of Trips

		Rigid	Articulate	B-Double	HPFV
2011	AM	22469	14421	8	0
	IP	24068	16099	9	0
	PM	17919	11912	14	0
	OP	3527	5898	11	0
2021	AM	22256	20149	21	0
	IP	23828	22236	25	0
	PM	17732	16313	36	0
	OP	3473	8068	30	0
2031	AM	28454	28279	30	0
	IP	30468	31273	36	0
	PM	22680	22970	53	0
	OP	4481	11392	43	0
2046	AM	40547	41816	47	0
	IP	43393	46390	56	0
	PM	32332	33851	82	0
	OP	6466	16642	67	729

Approximate Percentage of VKT Modes

		Rigid	Articulate	B-Double	HPFV
2011	AM	61%	39%	0%	0%
	IP	60%	40%	0%	0%
	PM	60%	40%	0%	0%
	OP	37%	63%	0%	0%
2021	AM	52%	47%	0%	0%
	IP	52%	48%	0%	0%
	PM	52%	48%	0%	0%
	OP	30%	70%	0%	0%
2031	AM	50%	50%	0%	0%
	IP	49%	51%	0%	0%
	PM	50%	50%	0%	0%
	OP	28%	72%	0%	0%
2046	AM	49%	51%	0%	0%
	IP	48%	52%	0%	0%
	PM	49%	51%	0%	0%
	OP	27%	70%	0%	3%

TRAM VKTs

VKT by Tram Vehicle Type		4	9	14	19	24	29	34	39	44	49	54	59	64	69	74	79
Scenario		2011 Base				2021 Base				2021 Project				2031 Base			
Run Number		*00*				*01*				*110*				*02*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	21	2266.823	6241.023	3294.899	5893.358	5653.92	12703.68	8480.88	12703.68	5508.64	12466.8	8262.96	12466.8	3639.68	7424.64	5459.52	7424.64
	22	2435.056	5940.807	3514.444	5940.807	0	0	0	0	0	0	0	0	0	0	0	0
	23	2349.674	6617.58	3425.005	6617.58	4601.68	8279.28	6902.52	8279.28	4683.68	8426.88	7025.52	8426.88	7320.56	11998.8	10980.84	12698.64
	24	775.2	1744.2	1162.8	1744.2	1152.64	3039.12	1728.96	3039.12	1152.64	3039.12	1728.96	3039.12	0	0	0	0
	25	526.3143	1366.393	728.7429	1366.393	351.12	1053.36	526.68	1053.36	351.12	1053.36	526.68	1053.36	0	0	0	0
	26	2138.266	3327.644	2914.7	3288.464	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0	1475.76	2678.4	2213.64	2678.4
	29	0	0	0	0	0	0	0	0	0	0	0	0	1492.32	2238.48	2238.48	2238.48
Total		10491.33	25237.65	15040.59	24850.8	11759.36	25075.44	17639.04	25075.44	11696.08	24986.16	17544.12	24986.16	13928.32	24340.32	20892.48	25040.16

VKT by Tram Vehicle Type		144	149	154	159	84	89	94	99	104	109	114	119	124	129	134	139
Scenario		2031 Day 1				2031 Project				2046 Base				2046 Project			
Run Number		*111*				*21*				*03*				*25*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	21	3639.68	7424.64	5459.52	7424.64	3639.68	7424.64	5459.52	7424.64	5635.28	11183.04	8452.92	11183.04	5567.36	11121.84	8351.04	11121.84
	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23	7418.96	12846.24	11128.44	12846.24	7418.96	12846.24	11128.44	12846.24	7656.48	13271.04	11484.72	13271.04	7754.88	13418.64	11632.32	13418.64
	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	1492.32	2238.48	2238.48	2238.48	1465.92	2198.88	2198.88	2198.88
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	1407.84	2617.2	2111.76	2617.2	1407.84	2617.2	2111.76	2617.2	0	0	0	0	0	0	0	0
	29	1465.92	2198.88	2198.88	2198.88	1465.92	2198.88	2198.88	2198.88	0	0	0	0	0	0	0	0
Total		13932.4	25086.96	20898.6	25086.96	13932.4	25086.96	20898.6	25086.96	14784.08	26692.56	22176.12	26692.56	14788.16	26739.36	22182.24	26739.36

Table Reports VKT by Vehicle Type for Trams

Source: VITM Ptlink Files

VEHICLETYPE NUMBER=21 LONGNAME="Tram_type1" NAME="Tram_type1" SEATCAP=60 CRUSHCAP=230 LOADDISTFAC=70
VEHICLETYPE NUMBER=22 LONGNAME="Tram_type2" NAME="Tram_type2" SEATCAP=60 CRUSHCAP=180 LOADDISTFAC=70
VEHICLETYPE NUMBER=23 LONGNAME="Tram_type3" NAME="Tram_type3" SEATCAP=64 CRUSHCAP=290 LOADDISTFAC=70
VEHICLETYPE NUMBER=24 LONGNAME="Tram_type4" NAME="Tram_type4" SEATCAP=40 CRUSHCAP=130 LOADDISTFAC=70
VEHICLETYPE NUMBER=25 LONGNAME="Tram_type5" NAME="Tram_type5" SEATCAP=50 CRUSHCAP=180 LOADDISTFAC=70
VEHICLETYPE NUMBER=26 LONGNAME="Tram_type6" NAME="Tram_type6" SEATCAP=62 CRUSHCAP=260 LOADDISTFAC=70
VEHICLETYPE NUMBER=27 LONGNAME="Tram_type7" NAME="Tram_type7" SEATCAP=40 CRUSHCAP=290 LOADDISTFAC=70
VEHICLETYPE NUMBER=28 LONGNAME="Tram_type8" NAME="Tram_type8" SEATCAP=60 CRUSHCAP=290 LOADDISTFAC=70
VEHICLETYPE NUMBER=29 LONGNAME="Tram_type9" NAME="Tram_type9" SEATCAP=62 CRUSHCAP=290 LOADDISTFAC=70
VEHICLETYPE NUMBER=30 LONGNAME="Tram_type10" NAME="Tram_type10" SEATCAP=62 CRUSHCAP=250 LOADDISTFAC=70

BUS VKTs

VKT by Bus Vehicle Type		4	9	14	19	24	29	34	39	44	49	54	59	64	69	74	79
Scenario		2011 Base				2021 Base				2021 Project				2031 Base			
Run Number		*00*				*01*				*110*				*02*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	3	44803.26	110118.7	65887.02	77705.74	60449.19	153653.1	90673.79	103663.2	60069.99	153226.5	90104.99	103663.2	80847.94	170939.2	121271.9	129710.5
	4	316	618.2609	474	176.0571	1086.72	3260.16	1630.08	3260.16	1086.72	3260.16	1630.08	3260.16	1788.8	5366.4	2683.2	5366.4
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	804.6	1107.72	1206.9	482.76

VKT by Bus Vehicle Type		144	149	154	159	84	89	94	99	104	109	114	119	124	129	134	139
Scenario		2031 Day 1				2031 Project				2046 Base				2046 Project			
Run Number		*111*				*21*				*03*				*25*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	3	80847.94	170939.2	121271.9	129710.5	80847.94	170939.2	121271.9	129710.5	104851.8	196421.6	157277.7	170158.9	104851.8	196421.6	157277.7	170158.9
	4	1788.8	5366.4	2683.2	5366.4	1788.8	5366.4	2683.2	5366.4	1788.8	5366.4	2683.2	5366.4	1788.8	5366.4	2683.2	5366.4
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	425.4	681.12	638.1	482.76	425.4	681.12	638.1	482.76	1139.76	1709.64	1709.64	783.72	760.56	1283.04	1140.84	783.72

Table Reports VKT by Vehicle Type for Bus

Source: VITM Ptlink Files

VEHICLETYPE NUMBER=3 LONGNAME="Bus" NAME="Bus" SEATCAP=50 CRUSHCAP=75 LOADDISTFAC=70

VEHICLETYPE NUMBER=4 LONGNAME="SkyBus" NAME="SkyBus" SEATCAP=100 CRUSHCAP=150 LOADDISTFAC=70

VEHICLETYPE NUMBER=5 LONGNAME="Bus401PROJ" NAME="Bus401PROJ" SEATCAP=50 CRUSHCAP=140 LOADDISTFAC=70

VEHICLETYPE NUMBER=6 LONGNAME="articulated bus" NAME="articulated bus" SEATCAP=70 CRUSHCAP=110 LOADDISTFAC=70

TRAIN Passenger Kilometres Travelled (PKT) (AFFECTED LINES ONLY)

PKT by Train Vehicle Type		4	10	16	22	28	34	40	46
Scenario		2011 Base				2021 Base			
Run Number		*00b*				*01a*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	1	1829488.271	2071089.504	2226525.296	1403249.413	0	0	0	0
	2	0	0	0	0	2133521.283	2446987.152	2740811.846	1572664.457
	10	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0
	18	0	0	0	0	1022594.549	1165964.058	1320226.622	802997.5242
	19	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0
	40	0	0	0	0	0	0	0	0
	41	86825.3845	0	103519.6386	0	0	0	0	0
	42	121174.1297	212900.9139	194571.0152	122979.9801	0	0	0	0
	43	202702.5369	172692.9564	282466.2219	82632.9429	560068.8709	549952.245	717269.1704	329339.043
	44	101187.0427	253436.3595	171863.8883	149744.0883	7918.5071	12874.7535	11838.72	4987.7022
	45	29946.978	0	26512.4628	0	0	0	0	0
	46	122323.5019	285077.4171	270946.0617	116603.7171	0	0	0	0
	47	0	0	0	0	727367.9407	1104674.761	1137679.673	589694.4207
	48	0	0	0	0	93767.774	267466.8594	164321.2793	87171.4302
	49	0	0	0	0	5866.2784	54139.527	22670.2014	21160.4484
Total PKT		2,493,648	2,995,197	3,276,405	1,875,210	4,551,105	5,602,059	6,114,818	3,408,015
Average Occupancy		263	163	230	102	278	189	246	148

PKT by Train Vehicle Type		52	58	64	70	76	82	88	94	172	178	184	190
Scenario		2021 Project				2031 Base				2031 Day 1			
Run Number		*110a*				*02a*				*111a*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	1	0	0	0	0	0	0	0	0	0	0	0	0
	2	1806358.216	2069967.224	2336707.996	1302791.024	1894114.121	2757760.383	2535923.912	2082935.848	1672787.799	2078390.9	2293142.406	1716439.245
	10	0	0	0	0	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	0	0	0
	18	1476420.135	1677633.779	1874807.717	1176178.964	2291674.489	2173490.977	3002063.769	1107408.119	2721913.017	3060004.923	3508103.172	1644654.318
	19	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0
	40	0	0	0	0	0	0	0	0	0	0	0	0
	41	0	0	0	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0	0	0	0
	43	556161.0561	554345.0226	713194.6497	327279.7872	1827864.504	2183205.026	2468277.815	1297206.944	1805502.114	2184709.388	2436128.836	1280773.499
	44	8045.4792	13151.6238	12048.8064	5127.4299	5466.7461	8447.5305	7924.1427	3352.9638	5592.5493	8687.7228	8114.1627	3467.4969
	45	0	0	0	0	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	0	0	0	0	0
	47	723519.7593	1106791.075	1142678.152	586538.7654	335870.9227	646237.4748	563962.6325	308007.4776	335699.4965	657347.4585	576520.6641	303318.7848
	48	93980.7187	270308.7039	166261.2464	87050.2125	109922.9828	333331.4316	190267.3857	110345.1942	105609.8806	335494.9392	184560.3599	109315.0275
	49	5868.2346	54248.5512	22643.4162	21172.7364	7919.7572	72101.646	30684.768	26691.3444	7922.7544	72027.198	30724.4499	26512.41
Total PKT		4,670,354	5,746,446	6,268,342	3,506,139	6,472,834	8,174,574	8,799,104	4,935,948	6,655,028	8,396,663	9,037,294	5,084,481
Average Occupancy		261	185	234	142	380	266	341	213	347	262	314	205

PKT by Train Vehicle Type		100	106	112	118	124	130	136	142	148	154	160	166
Scenario		2031 Project				2046 Base				2046 Project			
Run Number		*21a*				*03a*				*25b*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	1	0	0	0	0	0	0	0	0	0	0	0	0
	2	1635297.639	2051509.449	2241931.494	1691337.253	2249679.565	3732080.533	2990003.277	1476172.902	838735.7953	1419827.76	1126079.661	691841.502
	10	0	0	0	0	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	0	0	0
	18	875232.3966	658083.8031	1143855.695	0	3189060.686	3063968.775	4218795.905	2837078.929	2227307.484	2479950.428	2975303.121	1727248.579
	19	0	0	0	0	0	0	0	0	0	0	0	0
	20	2401212.87	3062661.754	3102873.697	2143718.306	0	0	0	0	3707906.335	4500874.813	4737560.893	3175587.638
	40	0	0	0	0	0	0	0	0	0	0	0	0
	41	0	0	0	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0	0	0	0
	43	1543992.078	1793289.644	2046340.403	968409.0717	2466168.081	3434622.05	3521806.867	2065999.19	2230391.597	2721517.019	2965966.957	1576159.346
	44	5542.2884	8593.4583	8043.774	3433.9521	6395.4543	9681.1701	9211.11105	3950.3994	6545.2343	9958.4901	9456.2715	4068.4524
	45	0	0	0	0	0	0	0	0	0	0	0	0
	46	0	0	0	0	0	0	0	0	0	0	0	0
	47	324682.3519	653071.4184	562710.4076	301168.4604	599967.1168	1391436.629	1012764.596	618515.7474	589119.6772	1403460.444	987608.8409	583253.7771
	48	104299.6675	333887.6304	182641.8444	108579.3894	72917.3989	264065.4996	143718.9993	76073.6553	74302.8739	261569.0994	138568.737	71852.3022
	49	7859.9484	72026.7066	30639.1212	26541.813	9438.2276	98651.4768	33027.471	24072.6306	9369.8996	98584.026	33116.52	24091.2786
Total PKT		6,898,119	8,633,124	9,319,036	5,243,188	8,593,627	11,994,506	11,929,328	7,101,863	9,683,679	12,895,742	12,973,661	7,854,103
Average Occupancy		341	261	308	215	414	342	381	273	409	358	366	277

Table Reports PKT by Vehicle Type for Trains
Source: VITM Ptlink Files
Train Lines affected by MM project. (Lines through South Yarra and North Melbourne)
VEHICLETYPE NUMBER=1 LONGNAME="Metro Refurb" NAME="Metro Refurb" SEATCAP=456 CRUSHCAP=1280 LOADDISTFAC=70
VEHICLETYPE NUMBER=2 LONGNAME="COMENG (REFURB)" NAME="COMENG (REFURB)" SEATCAP=456 CRUSHCAP=1280 LOADDISTFAC=70
VEHICLETYPE NUMBER=10 LONGNAME="Sun Dan Trains" NAME="Sun Dan Trains" SEATCAP=643 CRUSHCAP=2070 LOADDISTFAC=70
VEHICLETYPE NUMBER=11 LONGNAME="Fish_Bend_Trains" NAME="Fish_Bend_Trains" SEATCAP=400 CRUSHCAP=1450 LOADDISTFAC=70
VEHICLETYPE NUMBER=16 LONGNAME="Metro6Car" NAME="Metro6Car" SEATCAP=450 CRUSHCAP=1400 LOADDISTFAC=70
VEHICLETYPE NUMBER=17 LONGNAME="Metro7Car" NAME="Metro7Car" SEATCAP=450 CRUSHCAP=1450 LOADDISTFAC=70
VEHICLETYPE NUMBER=18 LONGNAME="HCMT" NAME="HCMT" SEATCAP=550 CRUSHCAP=1420 LOADDISTFAC=70
VEHICLETYPE NUMBER=19 LONGNAME="HCMT9car" NAME="HCMT9car" SEATCAP=710 CRUSHCAP=1830 LOADDISTFAC=70
VEHICLETYPE NUMBER=20 LONGNAME="Extended HCMT" NAME="Extended HCMT" SEATCAP=785 CRUSHCAP=2025 LOADDISTFAC=70

VEHICLETYPE NUMBER=41 LONGNAME="Vline VL6" NAME="Vline VL6" SEATCAP=444 CRUSHCAP=686 LOADDISTFAC=70
VEHICLETYPE NUMBER=42 LONGNAME="Vline Ballarat" NAME="Vline Ballarat" SEATCAP=444 CRUSHCAP=489 LOADDISTFAC=70
VEHICLETYPE NUMBER=43 LONGNAME="HCDMU" NAME="HCDMU" SEATCAP=855 CRUSHCAP=1450 LOADDISTFAC=70
VEHICLETYPE NUMBER=44 LONGNAME="SP2" NAME="SP2" SEATCAP=178 CRUSHCAP=224 LOADDISTFAC=70
VEHICLETYPE NUMBER=45 LONGNAME="SP4" NAME="SP4" SEATCAP=358 CRUSHCAP=448 LOADDISTFAC=70
VEHICLETYPE NUMBER=46 LONGNAME="Vline_NZ5_SG" NAME="Vline_NZ5_SG" SEATCAP=358 CRUSHCAP=409 LOADDISTFAC=70
VEHICLETYPE NUMBER=47 LONGNAME="VL6" NAME="VL6" SEATCAP=444 CRUSHCAP=686 LOADDISTFAC=70
VEHICLETYPE NUMBER=48 LONGNAME="NZ5 (BG)" NAME="NZ5 (BG)" SEATCAP=370 CRUSHCAP=407 LOADDISTFAC=70
VEHICLETYPE NUMBER=49 LONGNAME="NZ5 (SG)" NAME="NZ5 (SG)" SEATCAP=358 CRUSHCAP=409 LOADDISTFAC=70

CARS PKT

*** Car Occupancy Factors derived from VITM Occupancy Factors by Purpose averaged across all periods
*** Trips has been used as a proxy for Vehicle Kilometres to average across purposes to get a single average occupancy factor
*** This has been applied to car vehicle kilometres travelled

	Car VKT							
	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Number	*00*	*01*	*110*	*02*	*111*	*21*	*03*	*25*
AM	19,074,734	21,473,952	21,435,299	24,240,454	24,168,275	24,086,833	27,397,500	27,129,216
IP	39,389,486	46,551,058	46,511,934	54,015,482	53,936,502	53,893,715	62,686,916	62,440,992
PM	31,669,385	36,828,582	36,783,099	42,455,663	42,353,245	42,273,300	48,866,781	48,521,942
OP	27,095,073	30,724,356	30,663,142	34,819,297	34,712,987	34,608,340	39,740,859	39,348,963

Table reports PKT for period, source: model summary sheets

Car Occupancy Factors (Source VITM Model Inputs)

	AM	IP	PM	OP	Average
HBW_WC	1.07037	1.07319	1.0869	1.0869	1.07934
HBW_BC	1.07037	1.07319	1.0869	1.0869	1.07934
HBE-P	2.59583	1.52849	2.7783	2.7783	2.42023
HBE-S	2.40801	1.45389	2.2187	2.2187	2.074825
HBE-T	1.26586	1.19281	1.207	1.207	1.2181675
HBSh	1.27729	1.35897	1.3699	1.3699	1.344015
HBSoc	1.58272	1.46594	1.6836	1.6836	1.603965
HBO	1.4875	1.46305	1.4775	1.4775	1.4763875
EB	1.0597	1.07622	1.1208	1.1208	1.09438
NHBO	1.36902	1.33192	1.4278	1.4278	1.389135

Modeled Trips - Only Readily Available by Purpose for 24 Hours
(Source Model Summary Sheets)

	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
	00	*01*	*110*	*02*	*111*	*21*	*03*	*25*
HBWWC	1,563,316	1,745,906	1,739,404	2,010,463		1,993,888	2,401,349	2,366,442
HBWBC	678,549	713,458	711,735	775,434		769,845	884,294	871,883
HBEP	1,048,260	1,349,245	1,349,242	1,608,852		1,608,849	1,812,849	1,812,846
HBES	437,891	485,228	484,791	579,679		576,631	644,760	638,662
HBET	150,179	136,542	135,293	141,091		138,260	154,276	148,706
HBSH	1,592,685	1,953,469	1,952,891	2,296,062		2,294,542	2,836,115	2,832,121
HBSOC	978,660	1,150,410	1,147,882	1,342,298		1,337,033	1,620,702	1,607,464
HBO	2,172,076	2,596,242	2,593,274	3,034,154		3,027,414	3,665,432	3,650,080
NHBEB	592,564	679,370	678,095	786,675		783,211	945,031	937,735
NHBO	2,443,472	2,887,012	2,882,757	3,365,335		3,354,532	4,024,764	4,000,758
Average Occu	1.46	1.47	1.47	1.48	1.48	1.48	1.47	1.47

TRUCKS PKT

***Assuming Freight occupancy of 1, this is the same as VKT

Total Truck PKT

	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numb	00	01	110	02	111	21	03	25
AM	863,992	1,011,493	1,011,473	1,419,240	1,418,766	1,418,314	2,085,251	2,081,788
IP	2,829,082	3,331,212	3,330,794	4,644,776	4,642,957	4,643,658	6,775,398	6,770,474
PM	1,053,369	1,255,034	1,255,034	1,750,401	1,749,192	1,748,732	2,550,498	2,546,209
OP	1,405,810	1,754,595	1,754,376	2,509,444	2,510,171	2,509,782	3,846,879	3,844,787

Table reports trips for period, source: model summary sheets

Approximate Rigid Truck PKT

	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numb	*00*	*01*	*110*	*02*	111	*21*	*03*	*25*
AM	526,127	530,613	530,603	711,433	711,195	710,969	1,025,976	1,024,272
IP	1,694,802	1,722,236	1,722,020	2,290,772	2,289,875	2,290,221	3,272,575	3,270,196
PM	632,445	652,982	652,982	868,632	868,032	867,804	1,244,438	1,242,346
OP	525,465	526,636	526,571	706,510	706,715	706,606	1,040,576	1,040,010

Approximate Articulated Truck PKT

	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numb	*00*	*01*	*110*	*02*	111	*21*	*03*	*25*
AM	337,678	480,379	480,370	707,057	706,821	706,596	1,058,086	1,056,329
IP	1,133,647	1,607,169	1,606,968	2,351,297	2,350,376	2,350,731	3,498,600	3,496,057
PM	420,430	600,727	600,727	879,739	879,131	878,900	1,302,904	1,300,713
OP	878,706	1,223,410	1,223,257	1,796,154	1,796,674	1,796,396	2,678,203	2,676,746

Approximate B-Double Truck PKT

	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numb	*00*	*01*	*110*	*02*	111	*21*	*03*	*25*
AM	187	501	501	750	750	750	1,189	1,187
IP	634	1,807	1,807	2,707	2,706	2,706	4,223	4,220
PM	494	1,326	1,326	2,030	2,028	2,028	3,156	3,151
OP	1,639	4,549	4,549	6,780	6,782	6,781	10,782	10,776

Approximate HPFV Truck PKT

	2011 Base	2021 Base	2021 Project	2031 Base	2031 Day 1	2031 Project	2046 Base	2046 Project
Run Numb	*00*	*01*	*110*	*02*	111	*21*	*03*	*25*
AM	-	-	-	-	-	-	-	-
IP	-	-	-	-	-	-	-	-
PM	-	-	-	-	-	-	-	-
OP	-	-	-	-	-	-	117,318	117,254

Breakdown of Truck Types by TRIPS
Source: Freight Demand from VITM.
Note: Base and Project matrices identical

Number of Trips

		Rigid	Articulate	B-Double	HPFV
2011	AM	22469	14421	8	0
	IP	24068	16099	9	0
	PM	17919	11912	14	0
	OP	3527	5898	11	0
2021	AM	22256	20149	21	0
	IP	23828	22236	25	0
	PM	17732	16313	36	0
	OP	3473	8068	30	0
2031	AM	28454	28279	30	0
	IP	30468	31273	36	0
	PM	22680	22970	53	0
	OP	4481	11392	43	0
2046	AM	40547	41816	47	0
	IP	43393	46390	56	0
	PM	32332	33851	82	0
	OP	6466	16642	67	729

Approximate Percentage of VKT Modes

		Rigid	Articulate	B-Double	HPFV
2011	AM	61%	39%	0%	0%
	IP	60%	40%	0%	0%
	PM	60%	40%	0%	0%
	OP	37%	63%	0%	0%
2021	AM	52%	47%	0%	0%
	IP	52%	48%	0%	0%
	PM	52%	48%	0%	0%
	OP	30%	70%	0%	0%
2031	AM	50%	50%	0%	0%
	IP	49%	51%	0%	0%
	PM	50%	50%	0%	0%
	OP	28%	72%	0%	0%
2046	AM	49%	51%	0%	0%
	IP	48%	52%	0%	0%
	PM	49%	51%	0%	0%
	OP	27%	70%	0%	3%

TRAM PKT

PKT by Tram Vehicle Type		4	10	16	22	28	34	40	46	52	58	64	70
Scenario		2011 Base				2021 Base				2021 Project			
Run Number		00				01				110			
Time Period		AM	IP	PM	OP	AM	IP	PM	OP	AM	IP	PM	OP
	21	60387.9992	100715.498	81107.1674	63781.2579	218037.028	350776.514	306251.65	247655.327	207337.5	342894.707	285759.356	239695.392
	22	73132.7142	106672.266	99261.627	66439.4838	0	0	0	0	0	0	0	0
	23	78365.6338	153857.894	106763.561	97452.5031	205798.777	316385.717	281239.607	219725.083	200851.688	315239.099	277402.72	220231.98
	24	25195.2192	37896.2238	37265.964	24500.7558	28024.1439	52749.5694	38271.5693	39612.7104	26401.757	48388.7916	35815.4907	36502.6419
Vehicle Type	25	17552.4812	30923.5998	23578.3575	21098.7369	9457.6161	16878.4386	13084.1046	11224.7721	8246.4726	15927.3066	12032.2107	10418.5275
	26	66703.816	93260.6862	93304.5186	59155.6284	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	0	0	0	0	0	0
Total		321,338	523,326	441,281	332,428	461,318	736,790	638,847	518,218	442,837	722,450	611,010	506,849
Tram PKT Check		321,338	523,326	441,281	332,428	461,318	736,790	638,847	518,218	442,837	722,450	611,010	506,849
Difference		0	(0)	(0)	(0)	0	(0)	0	0	(0)	0	0	0

PKT by Tram Vehicle Type		76	82	88	94	172	178	184	190	100	106	112	118
Scenario		2031 Base				2031 Day 1				2031 Project			
Run Number		02				111				21			
Time Period		AM	IP	PM	OP	AM	IP	PM	OP	AM	IP	PM	OP
	21	141058.945	235188.262	192913.316	171723.776	136241.024	224429.959	183913.394	163401.042	136675.094	224835.691	184720.81	164143.762
	22	0	0	0	0	0	0	0	0	0	0	0	0
	23	334247.505	496139.33	460565.701	348283.753	321632.998	500373.375	443391.91	341605.574	321126.115	499241.89	444242.101	340802.679
	24	0	0	0	0	0	0	0	0	0	0	0	0
Vehicle Type	25	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0
	28	52762.2299	88404.8988	74320.7279	60190.0041	56572.7971	98129.1846	76446.9789	73709.3172	56622.5272	97810.7244	76166.3373	73312.9104
	29	78012.4786	116541.471	107962.437	85509.9627	66728.7742	98161.5216	94579.7853	74466.7752	66660.2235	97715.9985	95025.563	74249.2341
Total		606,081	936,274	835,762	665,707	581,176	921,094	798,332	653,183	581,084	919,604	800,155	652,509
Tram PKT Check		606,081	936,274	835,762	665,708					581,084	919,604	800,155	652,509
Difference		(0)	0	(0)	1	(581,176)	(921,094)	(798,332)	(653,183)	0	(0)	0	0

PKT by Tram Vehicle Type		124	130	136	142	148	154	160	166
Scenario		2046 Base				2046 Project			
Run Number		03				25			
Time Period		AM	IP	PM	OP	AM	IP	PM	OP
	21	274829.26	445819.557	376302.2552	345978.719	268712.514	453406.1265	366318.6164	353177.648
	22	0	0	0	0	0	0	0	0
	23	454179.957	710580.2781	636586.2002	489725.18	437218.71	694849.0092	608813.8896	475205.356
	24	0	0	0	0	0	0	0	0
Vehicle Type	25	0	0	0	0	0	0	0	0
	26	98754.7142	149927.1369	139469.1909	113783.941	82631.6216	124836.264	119218.5587	97445.0367
	27	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	0	0
Total		827,764	1,306,327	1,152,358	949,488	788,563	1,273,091	1,094,351	925,828
Tram PKT Check		827,764	1,306,327	1,152,358	949,488	788,563	1,273,091	1,094,351	925,828
Difference		0	0	0	0	0	(0)	(0)	(0)

Table Reports PKT by Vehicle Type for Trams

Source: VITM Ptlink Files

VEHICLETYPE NUMBER=21 LONGNAME="Tram_type1" NAME="Tram_type1" SEATCAP=60 CRUSHCAP=230 LOADDISTFAC=70
VEHICLETYPE NUMBER=22 LONGNAME="Tram_type2" NAME="Tram_type2" SEATCAP=60 CRUSHCAP=180 LOADDISTFAC=70
VEHICLETYPE NUMBER=23 LONGNAME="Tram_type3" NAME="Tram_type3" SEATCAP=64 CRUSHCAP=290 LOADDISTFAC=70
VEHICLETYPE NUMBER=24 LONGNAME="Tram_type4" NAME="Tram_type4" SEATCAP=40 CRUSHCAP=130 LOADDISTFAC=70
VEHICLETYPE NUMBER=25 LONGNAME="Tram_type5" NAME="Tram_type5" SEATCAP=50 CRUSHCAP=180 LOADDISTFAC=70
VEHICLETYPE NUMBER=26 LONGNAME="Tram_type6" NAME="Tram_type6" SEATCAP=62 CRUSHCAP=260 LOADDISTFAC=70
VEHICLETYPE NUMBER=27 LONGNAME="Tram_type7" NAME="Tram_type7" SEATCAP=40 CRUSHCAP=290 LOADDISTFAC=70
VEHICLETYPE NUMBER=28 LONGNAME="Tram_type8" NAME="Tram_type8" SEATCAP=60 CRUSHCAP=290 LOADDISTFAC=70
VEHICLETYPE NUMBER=29 LONGNAME="Tram_type9" NAME="Tram_type9" SEATCAP=62 CRUSHCAP=290 LOADDISTFAC=70
VEHICLETYPE NUMBER=30 LONGNAME="Tram_type10" NAME="Tram_type10" SEATCAP=62 CRUSHCAP=250 LOADDISTFAC=70

BUS PKT

PKT by Bus Vehicle Type		4	10	16	22	28	34	40	46	52	58	64	70	76	82	88	94
Scenario		2011 Base				2021 Base				2021 Project				2031 Base			
Run Number		*00*				*01*				*110*				*02*			
Time Period		*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
Vehicle Type	3	410463.4677	598266.7071	596178.2706	335025.0468	636675.6838	854218.3326	907646.8626	458462.0145	638608.9236	855101.1291	907209.4383	459821.1705	844618.6015	1126663.852	1192209.762	631247.265
	4	3742.9949	4753.1844	7010.34135	2156.3358	41671.5097	93641.4801	50685.21465	116797.164	41662.9519	94251.0096	50959.85295	117653.4588	55740.8048	129002.9988	68434.69695	161429.7648
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	24790.9696	31448.3901	34543.2492	17603.6049
Total		414206.4626	603019.8915	603188.612	337181.3826	678347.1935	947859.8127	958332.0773	575259.1785	680271.8755	949352.1387	958169.2913	577474.6293	925150.3759	1287115.241	1295187.708	810280.6347

Table Reports PKT by Vehicle Type for Bus

Source: VITM Ptlink Files

VEHICLETYPE NUMBER=3 LONGNAME="Bus" NAME="Bus" SEATCAP=50 CRUSHCAP=75 LOADDISTFAC=70
VEHICLETYPE NUMBER=4 LONGNAME="SkyBus" NAME="SkyBus" SEATCAP=100 CRUSHCAP=150 LOADDISTFAC=70
VEHICLETYPE NUMBER=5 LONGNAME="Bus401PROJ" NAME="Bus401PROJ" SEATCAP=50 CRUSHCAP=140 LOADDISTFAC=70
VEHICLETYPE NUMBER=6 LONGNAME="articulated bus" NAME="articulated bus" SEATCAP=70 CRUSHCAP=110 LOADDISTFAC=70

172	178	184	190	100	106	112	118	124	130	136	142	148	154	160	166
2031 Day 1				2031 Project				2046 Base				2046 Project			
111				*21*				*03*				*25*			
AM	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*	*AM*	*IP*	*PM*	*OP*
858286.7233	1139834.71	1207045.286	635077.0878	866110.2933	1148590.078	1214797.76	641874.6813	1179550.92	1631660.744	1647372.028	960283.5234	1221115.273	1677210.488	1698346.263	986236.2969
53641.63	130667.013	67574.8014	163733.3718	56551.3308	134910.0177	70881.0591	169151.8872	67917.9987	202720.3584	104281.8359	256407.7377	73644.8396	207948.8442	102313.2374	263320.1211
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15263.6722	19434.7728	20505.70155	14035.0473	15337.1821	19321.5864	20572.1673	14009.4207	34467.5447	46729.0767	48811.4364	26271.8613	25115.5462	32877.7875	34304.6259	22049.5401
927192.0255	1289936.495	1295125.789	812845.5069	937998.8062	1302821.682	1306250.987	825035.9892	1281936.463	1881110.18	1800465.301	1242963.122	1319875.659	1918037.12	1834964.126	1271605.958

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