



22 Greenhouse Gas

22.1 Overview

This chapter provides an assessment of the greenhouse gas (GHG) emissions associated with the construction and operation of Melbourne Metro. The chapter is based on the impact assessment presented in Technical Appendix V *Greenhouse Gas*. All relevant references are provided in Technical Appendix V.

Greenhouse gases such as carbon dioxide (CO₂) are emitted into the Earth's atmosphere as a result of human activities (such as burning of fossil fuels to generate electricity) and from natural processes (such as ocean-atmosphere exchange and forest fires).

Before the industrial revolution, CO₂ levels in the air remained steady for thousands of years. Although the current annual output of 26 gigatonnes (Gt) of CO₂ equivalent emissions (CO₂-e) generated by humans is small compared to the 680Gt moving through the carbon cycle each year, the land and ocean cannot absorb all of the extra CO₂. Only 40 per cent of this additional CO₂ is absorbed, while the rest increases the GHGs in the atmosphere. GHGs absorb and re-radiate heat from the sun, contributing to climate change, and there is a global scientific consensus that human activities are causing an escalation in these emissions, leading – in turn – to global warming.

CO₂ is considered to be the most important GHG produced or influenced by human activities contributing to climate change, representing approximately 77 per cent of total global GHG emissions (primarily from fossil fuel use). CO₂ is the most significant GHG associated with the construction and operation of Melbourne Metro, with major sources of CO₂ emissions being:

- Indirect CO₂ emissions associated with the consumption of purchased electricity during construction and operation
- Indirect CO₂ emissions associated with embodied carbon in construction materials.

If Melbourne Metro adopts a business as usual (BAU) approach* to reducing GHG emissions, construction GHG emissions would be approximately 642 kilotonnes (kt) of CO₂-e (of which 67 per cent would be associated with embodied GHG emissions in construction materials). With the adoption of best practice GHG abatement, CO₂-e emissions from construction would reduce to approximately 543kt CO₂-e (a reduction of about 15 per cent from the BAU scenario).

During Melbourne Metro's operations (portal to portal including traction energy), approximately 71kt CO₂-e/annum would be released in the first year of opening (2026), reducing to 58kt CO₂-e/annum after 20 years of opening (2046), assuming BAU GHG abatement and technologies. The reduction over time is due to the projected decline in the GHG intensity of electricity generation in Victoria as the state reduces its reliance on brown coal and moves to a more renewable electricity market.

The inclusion of best practice GHG abatement and sustainability initiatives in the design and operation of Melbourne Metro (such as regenerative braking on trains and the purchase of accredited GreenPower) would reduce annual operational emissions to approximately 48kt CO₂-e in 2026 and 38kt CO₂-e in 2046. This equates to a reduction of approximately 30 to 35 per cent from the BAU scenario.

GHG units of measurement

- Carbon dioxide equivalent emissions – The Organisation for Economic Co-operation and Development (OECD) defines carbon dioxide equivalent emissions (CO₂-e) as 'a measurement used to compare the emissions from various greenhouse gases based upon their global warming potential. For example, the global warming potential for methane over 100 years is 21. This means that emissions of one million metric tons of methane are equivalent to emissions of 21 million metric tons of carbon dioxide'.

When GHG emissions are calculated, these are reported as being equivalent to a given volume of carbon dioxide and expressed as CO₂-e. For example, 100 tonnes of methane emissions would be reported as 2,100 t CO₂-e.

- kt – 1 kilotonne = 1,000 tonnes
- Gt – 1 gigatonne = 1,000 kilotonnes
- Vehicle kilometres travelled (VKTs) – number of vehicles X distance travelled
- Passenger kilometres travelled (PKTs) – number of passengers X distance travelled

* The scopes of the BAU and best practice approaches are described in Section 22.5.

GHG emissions from traction power (portal to portal) represent 56 per cent of the overall carbon footprint for the infrastructure lifecycle of Melbourne Metro (covering construction and operation over a 100-year design life), largely due to the relatively high energy requirements (traction energy) for operation of the HCMTs.

Although modelling undertaken for the GHG impact assessment suggests there would be a net increase in transport GHG emissions over time as a result of the project (compared to a 'no Melbourne Metro' scenario), primarily due to the Extended HCMT Program (2031) being facilitated across the metropolitan rail network by the project, the reality is that GHG emissions would be likely to reduce as a result of the 'greening' of the electricity grid in Victoria over the next 30 to 100 years.

Best practice GHG avoidance, reduction and mitigation measures would be incorporated into the construction and operation phases of Melbourne Metro, including the use of building products with less embodied energy, the purchase of accredited GreenPower and the achievement of sustainability ratings (see Section 22.5.3).

To put the project's footprint in context, net CO₂-e emissions for Victoria reported in the National Greenhouse Gas Inventory for 2013 were 123,900kt CO₂-e. This means that annual operational emissions under the 'with Melbourne Metro' BAU scenario (including indirect 'Scope 3' emissions from the effects of the passenger/transport mode shift) would represent approximately 0.10 per cent of Victoria's net CO₂-e emissions. With the adoption of best practice sustainability initiatives, net annual operational emissions would represent 0.07 per cent of Victoria's net CO₂-e emissions. This is considered to be a negligible contribution to regional GHG emissions.

In addition, PTV forecasts that Melbourne Metro would remove 281.8 million VKTs of cars per annum and nearly 4.4 million VKTs of trucks per annum from Melbourne roads in 2046.* This tangible benefit equates to a reduction of road transport GHG emissions of 74kt CO₂-e per annum (at 2046) compared to the 'no Melbourne Metro' scenario, as a result of people opting to travel by train rather than by road (vehicle).

* 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.

22.2 EES Objective

A key requirement of the EES Scoping Requirements is 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 with regard to noise, vibration, drainage and water management and greenhouse gas emissions.*

While there is no specific reference to construction phase greenhouse gas emissions in the EES Scoping Requirements, MMRA considers that an assessment of construction phase GHG impacts is important and that Melbourne Metro should seek to minimise GHG emissions to align with Commonwealth and Victorian Government policy.

To inform the EES, base case investigations were conducted to determine a GHG inventory for the project and provide a preliminary assessment of the potential GHG impacts and risks associated with construction and operation of Melbourne Metro. Using this information, best practice measures have been identified that would be implemented to reduce GHG emissions during construction and operation.

22.3 Legislation and Policy

GHG emissions from Melbourne Metro would be monitored, managed and mitigated in accordance with applicable international, Commonwealth and Victorian legislation, objectives and requirements. The main laws and policies relevant to Melbourne Metro are outlined in Table 22–1. Further details are provided in Technical Appendix V.

Table 22–1 GHG protocols, legislation and policy relevant to Melbourne Metro

Legislation	Policy/guideline	Comment
International		
	Protocol to the United Nations Framework Convention on Climate Change (Kyoto Protocol)	<p>The main driver for Commonwealth and State GHG laws and policies has been the Kyoto Protocol, adopted in December 1997. Under the Protocol, Australia committed to reducing its GHG emissions by 5 per cent below 2000 levels by 2020. In August 2015, Australia committed to a new target of reducing emissions by 26 to 28 per cent below 2005 levels by 2030.</p> <p>The aspiration of reaching a global deal to stabilise levels of CO₂ in the atmosphere at 450 ppm has been superseded by the recent agreement at the Paris Conference of the Parties (COP) to set a goal to limit global warming to less than 2°C.</p>

Legislation	Policy/guideline	Comment
	United Nations Framework Convention on Climate Change (UNFCCC) – Conference of the Parties (COP): Paris, 2015	See discussion box on page 22-8.
	Greenhouse Gas Protocol by the World Business Council for Sustainable Development and the World Resources Institute	The corporate accounting and reporting standards developed under this protocol include a suite of tools to assist companies in calculating their GHG emissions. These standards would be used as the basis for determining the GHG emissions associated with Melbourne Metro.
	ISO 14064-1:2006 Greenhouse gases	This standard provides guidance for quantifying and reporting GHG emissions and removals, and includes requirements that would be considered in the design, development, management, reporting and verification of Melbourne Metro's GHG inventory.
Commonwealth		
<i>National Greenhouse and Energy Reporting Act 2007</i>	National Greenhouse and Energy Reporting (Measurement) Determination 2008	The Act provides for the reporting and dissemination of information related to GHG emissions, GHG projects, energy production and energy consumption.
<i>Renewable Energy (Electricity) Act 2000 and regulations</i>	Renewable Energy Target (RET)	The Act would inform Melbourne Metro's sustainability requirements and decisions about energy consumption, such as a project requirement (and best practice GHG abatement initiative) to source a minimum 20 per cent of energy from renewable sources for the construction and operation phases.
<i>Clean Energy Legislation (Carbon Tax Repeal) Act 2014</i>	Emissions Reduction Fund (ERF), as part of the Direct Action Plan	Emission reduction technologies implemented for Melbourne Metro could be eligible for offsets credited through the ERF.

Legislation	Policy/guideline	Comment
State		
<i>Climate Change Act 2010</i>	Victorian Climate Change Adaptation Plan (March 2013)	Under this Act, Melbourne Metro would be required to demonstrate its alignment with Victorian Government strategies for responding to climate change.
<i>Environment Protection Act 1970</i>	SEPP (Air Quality Management) Protocol for Environmental Management (PEM): Greenhouse gas emissions and energy efficiency in industry (2002)	SEPP (AQM) establishes a framework for managing GHG emissions from projects, including using renewable energy sources and ongoing monitoring, assessment, data collection and reporting. The EPA states that the PEM is the overarching regulatory instrument for informing GHG assessment methodology and approach. The PEM defines best practice as 'the best combination of eco-efficient techniques, methods, processes 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'.
Local		
	GHG reduction plans and strategies	These documents provide guidance only. Best practice GHG mitigation measures adopted during the design, construction and operation of Melbourne Metro to reduce GHG emissions would complement local government strategies.
Other relevant documents		
	Green Star Design & As Built Melbourne Metro Rail Tool (Green Building Council of Australia)	Green Star ratings encourage a new approach to designing and constructing buildings by rewarding sustainability best practice and excellence. Melbourne Metro would aim to achieve a 5-star rating for the design and construction of all five stations.
	Infrastructure Sustainability Council of Australia (ISCA) – Infrastructure Sustainability (IS) rating system	Monitoring and modelling of Melbourne Metro's GHG emissions would be undertaken to identify the measures required to reduce Scope 1 and 2 emissions by a minimum 20 per cent below the BAU (base case) footprint.

22.4 Sustainability Performance Targets

MMRA has determined that the following sustainability performance rating schemes and targets would apply to Melbourne Metro:

- Achieve a minimum 'Excellent' certified rating for 'design' and 'as built' under the ISCA IS rating system. MMRA's sustainability performance targets and requirements applicable to the IS rating scheme include:
 - Concept Design to achieve reductions in Scope 1 and Scope 2 GHG emissions (see Section 22.5.3 for definitions) by a minimum 20 per cent below a reference (BAU) footprint over the lifecycle of the project (including construction and operation), excluding the use of renewable energy
 - 20 per cent of energy to be sourced from renewable sources over the lifecycle of the project (construction and operation phases) through either generation of onsite renewable energy, use of alternative fuels 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 the base case
- Achieve a minimum 5-star Green Star standard as defined by the Green Building Council of Australia (GBCA) for each underground station.

The Melbourne Metro contractor would be required to develop and implement a plan to meet these targets, which would ensure best practice GHG abatement across the project's construction and operation phases.

22.5 Methodology

The overall objective of the GHG impact assessment was to calculate GHG emissions associated with the construction and operation of Melbourne Metro, compared with the 'no Melbourne Metro' scenario, and to model GHG reductions (from a BAU GHG abatement scenario) assuming the implementation of best practice GHG abatement mitigation measures.

22.5.1 Assessment Approach

The approach adopted to assess the potential impacts of GHG emissions from Melbourne Metro involved:

- Consultation with stakeholders, including the EPA and local government
- Quantification of GHG emissions by Scope 1 (direct) and Scope 2 and 3 (indirect) emissions, as defined by the international GHG Protocol (see Section 22.5.3)

- Determining whether 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
- Modelling of GHG emissions associated with the construction of Melbourne Metro, considering both a BAU and best practice GHG abatement carbon footprint
- Identifying mitigation measures that could be implemented to reduce Melbourne Metro’s GHG emissions
- Modelling of GHG emissions associated with the operation of Melbourne Metro, considering both a BAU and best practice GHG abatement carbon footprint

Global action on reducing GHG emissions

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’.

The Paris COP reached an agreement ‘to achieve a balance between anthropogenic [influenced by human activities] emissions by sources and removals by sinks of greenhouse gases [that is, achieve net zero GHG emissions] in the second half of this century’.

At the time of the EES being prepared, the effect of this agreement on the Australian Government’s current targets was unknown. It was also not known how such targets would be legislated.

- Inclusion of passenger mode shift as indirect (Scope 3) operational GHG emissions, comparing Melbourne’s transport GHG emissions for the ‘with Melbourne Metro’ scenario against the ‘no Melbourne Metro’ scenario using outputs from the Victorian Integrated Transport Model (VITM)* provided by PTV.

The following operational scenarios were assessed:

- ‘Existing case’ using latest VITM reference year (2011)
 - ‘Day one’ of opening (2026)
 - Five years after opening (2031): PTV ‘Extended Program’†

* The VITM includes road and public transport modes and takes into account projected population increases.

† 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, 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.

- 20 years after opening (2046)
- Calculation of the functional unit to present findings as 'kilograms (or grams) CO₂-e emissions per passenger kilometre travelled (PKT)' for the 'with Melbourne Metro' and 'no Melbourne Metro' scenarios.

The assessment was prepared in accordance with the requirements of the PEM: Greenhouse Gas Emissions and Energy Efficiency in Industry, which includes consideration of best practice GHG abatement.

22.5.2 GHG Footprint

For the construction phase of Melbourne Metro, an overall GHG footprint was determined using the construction methods proposed in the Concept Design and adopting a BAU approach to GHG abatement. An additional GHG footprint for construction was also determined that adopts further best practice GHG abatement initiatives and assumes that key PTV and MMRA sustainability targets would be achieved (see discussion box on the following page).

For the operational phase of Melbourne Metro, the GHG inventory was determined for both the 'with Melbourne Metro' and 'no Melbourne Metro' scenarios in 2011, 2026, 2031 and 2046. As with the construction phase, an additional best practice GHG footprint was also calculated for the operational phase.

Business as usual carbon footprint

The impact assessment calculated a GHG emissions footprint for Melbourne Metro based on a 'business as usual' (BAU) approach to energy efficiency and GHG abatement – meaning the use of technologies that are readily available and considered standard practice with BAU GHG abatement initiatives.

Best practice carbon footprint

The assessment also calculated Melbourne Metro's best practice GHG emissions footprint based on the following best practice GHG abatement initiatives:

- Achieving at least 20 per cent reduction in Scope 1 and Scope 2 GHG emissions (compared to the BAU reference footprint) over the infrastructure lifecycle of the project, excluding the use of renewable energy (MM Sustainability Performance Target)
- Sourcing a minimum 20 per cent of energy from renewable sources during the construction and operation phases (PTV Project Requirement for construction), through either generation of onsite renewable energy, use of alternative fuels or purchase of renewable energy from an Australian Government accredited renewable energy supplier (Melbourne Metro Sustainability Performance Target)
- Use of biofuels for construction plant and equipment
- Using high efficacy LED construction lighting for night time works and intelligent controls/sensors for lighting
- Using energy efficient tunnel lighting
- Using regenerative braking on trains to provide energy back to the electrical supply
- Using renewable energy sources (such as PV solar, geothermal piling) at train stations
- Reducing Portland cement content in concrete used across the project by 30 per cent, compared to the BAU reference (base) case (Melbourne Metro Sustainability Performance Target). Note that embodied GHG emissions from concrete used in construction would represent approximately 40 per cent of the BAU embodied GHG emissions footprint
- Sourcing local construction materials and using low-embodied emissions materials for asphalt, concrete and steel, where feasible
- Adopting all planned best practice GHG abatement measures
- Integrating sustainable design practices into the detailed design process that would reduce overall GHG emissions
- Including mandatory actions under the PEM Greenhouse Gas Emissions and Energy Efficiency in Industry to select best practice energy efficient electrical and mechanical equipment design, technology and equipment.

22.5.3 GHG Inventories

The GHG inventories for the assessment were calculated in line with the principles of the internationally accepted Greenhouse Gas Protocol, which splits GHG emissions into three categories, known as ‘scopes’:

- Scope 1 – Direct emissions of GHGs from sources that are owned or operated by a reporting organisation (such as combustion of diesel in company-owned vehicles or used in onsite generators)
- Scope 2 – Indirect emissions associated with the import of energy from another source (such as the import of electricity from the grid)
- Scope 3 – Other indirect emissions that are a direct result of the operations of the organisation, but arise from sources not owned or operated by the organisation (such as building materials, business travel and waste).

GHG emission sources included in the assessment and their scope are shown in Table 22–2.

Table 22–2 Sources of direct and indirect GHG emissions from Melbourne Metro included in GHG assessment

Source of GHG emissions	Activity	Direct	Indirect	
		Scope 1	Scope 2	Scope 3
Construction				
Stationary fuel	Fuel consumed by construction plant/equipment	●		●
Transport fuel	Fuel consumed for construction materials delivery and spoil/rock removal	●		●
	Fuel consumed by project vehicles	●		●
	Change in road traffic use (fuel consumption) due to traffic impacts around construction zones (2021 VITM outputs)			●
Construction materials	Embodied emissions of materials used in construction, including materials used in construction of rolling stock			●
Purchased electricity	Electricity consumed in project offices		●	●
	Electricity consumed in construction plant/equipment (such as TBMs, lighting)		●	●
	Change in tram network (and electricity consumption) around construction zones (2021 VITM outputs)		●	●

Source of GHG emissions	Activity	Direct	Indirect	
		Scope 1	Scope 2	Scope 3
Carbon sinks	Land clearing/soil disturbance	●		
Liming/ Stationary fuel	Offsite treatment of WASS* (application and mixing of calcic limestone)			●
Operation				
Stationary fuel	Fuel consumption in plant/equipment used in permanent ancillary operations (such as station boilers assumed for BAU heating, ventilation and air conditioning (HVAC))	●		●
Purchased electricity	Electricity consumed to operate rolling stock (traction energy, portal-to-portal)		●	●
	Electricity consumption at train stations/tunnels		●	●
	Traction energy (wider rail network, as included in VITM)			●
	Electricity consumed to operate trams (trams included in VITM)			●
Transport fuel	Diesel consumed to operate V/Line services (V/Line included in VITM)			●
Vehicle emissions	Road based vehicles (as included in VITM)			●

The main emission sources excluded from the GHG inventory are:

- Fuel consumed by construction workers travelling to and from the site in privately owned vehicles or by public transport – as the GHG emissions associated with this would be a small percentage of the total project emissions and Melbourne Metro would have limited control over how workers travel to and from the site
- Emissions associated with the transportation, placement and decomposition of construction waste in landfill (not including spoil) – these emissions would be negligible as it is anticipated most construction waste would be inert (neither chemically nor biologically reactive) and is unlikely to decompose in landfill
- Fuel consumed in operations and permanent ancillary areas outside the Melbourne Metro footprint where the project has limited operational control.

* Waste Acid Sulfate Soil: corresponds to disturbed potential acid sulfate soil (PASS), actual acid sulfate soil (AASS) and acid sulfate rock (ASR).

22.6 Risk Assessment

An Environmental Risk Assessment has been completed for the impacts of Melbourne Metro in relation to GHG emissions. Further information about the risk assessment approach adopted for Melbourne Metro is included in Chapter 4 *EES Assessment Framework and Approach*.

Impact assessment must be informed by risk assessment so that the level of mitigation action relates to the likelihood of an adverse impact occurring.

Potential GHG emission impacts from the construction and operation of Melbourne Metro would be expected at a regional or whole-of-project level, rather than at a local or ‘precinct’ level. No significant adverse impacts due to GHG emissions are anticipated.

Two GHG emission risks have been identified. These were initially assigned medium risk ratings. As a result of the impact assessment, project-specific Environmental Performance Requirements – combined with identified mitigation measures – have been recommended to reduce the identified impacts. Effective implementation of these requirements would result in low residual risk ratings for GHG emission risks.

GHG risks associated with Melbourne Metro are shown in Table 22–3. Further details showing the initial and residual risk rating of each risk is provided in Technical Appendix B *Environmental Risk Assessment Report* and Technical Appendix V *Greenhouse Gas*.

The recommended Environmental Performance Requirements are listed in Section 22.8.

Table 22–3 GHG emissions risks

Impact pathway		Project phase	Precincts	Residual risk rating
Category	Potential event			
Design changes during detailed design (vertical/horizontal alignment, construction methods, scale of project)	Material changes from the Concept Design during detailed design which materially affect (increase) the construction carbon footprint – that is, detailed design does not capture the GHG abatement/ sustainability initiatives from the Concept Design for Melbourne Metro’s construction, leading to high energy consuming construction methods and high embodied carbon in construction materials	Design	All	Low

Impact pathway		Project phase	Precincts	Residual risk rating
Category	Potential event			
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 – that is, detailed design does not capture the GHG abatement/ sustainability initiatives from the Concept Design for Melbourne Metro’s operation, leading to proposed high energy consuming and/or BAU technologies and infrastructure	Design	All	Low

22.7 Impact Assessment

22.7.1 Construction

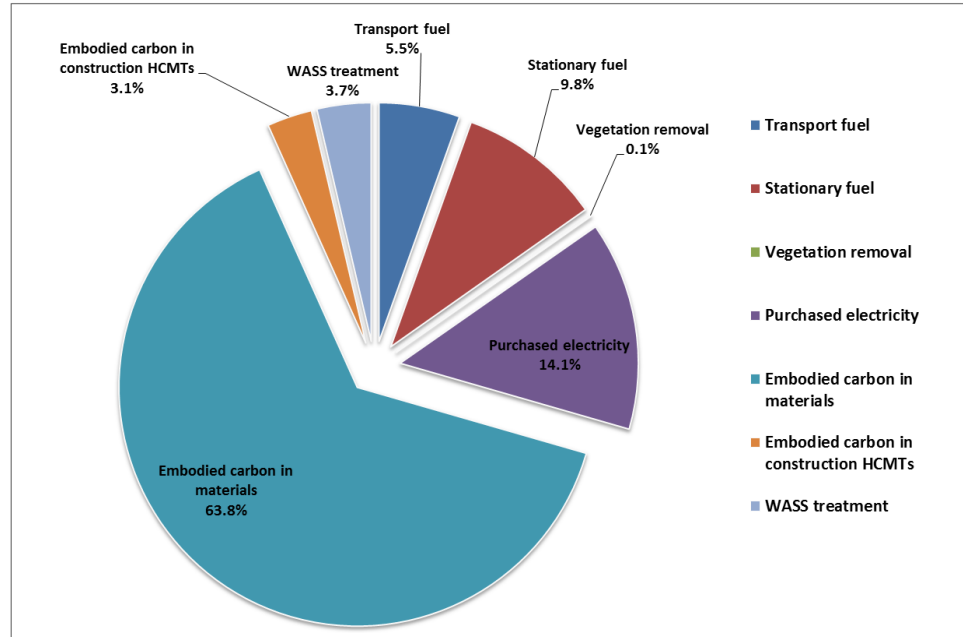
Although much of the focus of the GHG impact assessment is on whole-of-project effects – that is, a 100-year design life, which therefore focuses on the operational phase of Melbourne Metro – a construction GHG impact assessment was also undertaken due to the significance of emissions during this phase.

- It is estimated that total GHG emissions from construction of Melbourne Metro would be approximately 642kt CO₂-e, assuming BAU construction techniques and methods. The bulk of these emissions would be:
 - Indirect emissions associated with embodied carbon in materials used to construct Melbourne Metro stations, tunnels, portals and rolling stock*
 - Indirect emissions associated with the consumption of purchased electricity during construction.

A summary of the sources of construction GHG emissions by activity type (BAU scenario) is provided in Figure 22-1.

* Includes only the difference in HCMT rolling stock between the ‘with Melbourne Metro’ and ‘no Melbourne Metro’ scenarios (that is, does not include construction of all HCMT rolling stock being implemented as part of the Victorian Government’s Rolling Stock Strategy 2015-2025).

Figure 22-1 Summary of construction GHG emissions by activity type



When Melbourne Metro adopts a best practice approach to GHG abatement and meets the PTV and MMRA sustainability targets, the GHG emissions associated with energy consumption (Scope 1 and 2 emissions) during construction would reduce from 161kt CO₂-e to 128kt CO₂-e. This assumes that 20 per cent of all energy requirements during construction would be sourced from renewable energy sources. For example, this would require the contractor to source approximately 15 GWh of electricity from renewable sources over the duration of the construction phase, due to electricity consumed onsite (for TBMs, roadheaders and other uses).

The best practice scenario also assumes that a 30 per cent reduction in the use of Portland cement in concrete is achievable by substituting 30 per cent of Portland cement content with supplementary cementitious material (SCM), such as fly ash and/or blast furnace slag. 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. Whilst partial replacement with SCM reduces the embodied energy content of concrete, the use of SCM in concrete needs to consider strength and durability requirements of the proposed concrete structures and workability requirements (for example, the incorporation of fly ash and/or slag in concrete mixes would typically require an additional two days of curing). Reductions in GHG emissions are estimated to be 23 to 24 per cent (221.2kt CO₂-e to 168.1kt CO₂-e) from the incorporation of 30 per cent SCM in concrete across the project.

Table 22–4 summarises the construction GHG emission sources for both BAU and best practice approaches to GHG abatement. The best practice scenario assumes that the contractor would achieve (as a minimum) the Melbourne Metro sustainability performance targets defined in Section 22.4.

Table 22–4 Construction emission sources: BAU vs best practice

Emission source	Project activity	GHG emissions (kt CO ₂ -e)		% Reduction
		BAU base case	Best practice	
Transport fuel	Fuel consumption for spoil removal	15.1	12.1	20%
	Fuel consumption for materials delivery	14.3	11.4	20%
	Fuel consumption for site vehicles	5.8	4.6	20%
Stationary fuel	Diesel consumption in 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	Electricity use in construction plant and equipment	87.0	69.6	20%
	Electricity use in construction site offices	3.8	3.1	20%
Embodied carbon in materials	Stations	298.2	264.5	11%
	Tunnels and portals	111.5	84.4	24%

* 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.

† Waste Acid Sulfate Soil: corresponds to disturbed potential acid sulfate soil (PASS), actual acid sulfate soil (AASS) and acid sulfate rock (ASR).

‡ 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. While direct disposal without treatment would significantly reduce GHG emissions associated with this activity, this is not considered to be an optimal sustainability initiative for the project, and is typically 'last' on the waste hierarchy.

Emission source	Project activity	GHG emissions (kt CO ₂ -e)		% Reduction
		BAU base case	Best practice	
<i>SUB TOTAL (within MMRA scope)</i>		622.4	523.8	16%
Embodied carbon in materials (<i>outside of MMRA's scope</i>)	Rolling stock HCMTs (Melbourne Metro contribution)	19.6	19.6	0%
TOTAL		642.0	543.4	15%

Key best practice GHG abatement initiatives during construction include:

- Reducing the Portland cement content in concrete by 30 per cent across all concrete used in the project compared to the Concept Design footprint, with partial replacement of cement with fly ash and/or blast furnace slag (as captured in the Concept Design)
- Replacement of virgin (coarse) aggregate with recycled concrete aggregate or crushed slag aggregate (as captured in the Concept Design)
- Use of Post Tensioned (PT) Beams and slabs at ground and concourse levels of stations, which significantly reduces the quantity of conventional steel reinforcement required (as captured in the Concept Design)
- Reducing the mass of reinforcing steel used in construction; for example, by using optimal fabrication techniques such as reinforcing carpets, special mesh and prefabricated reinforcement cages (as captured in the Concept Design)
- Use of biofuels for construction plant and equipment
- Consideration of using hybrid or electric plant and equipment for construction
- Using high efficacy LED construction lighting for night-time works
- Using intelligent controls/sensors for lighting
- Commitment to the sourcing of 20 per cent of energy from renewable sources (Melbourne Metro sustainability performance target and PTV Project Performance Requirement).

Under a best practice GHG abatement scenario, total GHG emissions from the construction phase of Melbourne Metro would reduce to approximately 543kt CO₂-e, representing a 15 per cent reduction from the BAU scenario.

22.7.2 Operation

The operational phase GHG inventory has been determined on an annual basis from 'Day 1' of opening (2026) to 2046 (for both the 'with Melbourne Metro' and 'no Melbourne Metro' scenarios) using transport modelling (VITM) outputs provided by PTV.

Rolling stock and passenger mode shift

'Day one' of operation of Melbourne Metro would involve 59 HCMTs in timetable running (a total of 62 HCMTs in the rolling stock fleet). HCMT are trains with significantly more capacity than those currently in use on the network. The trains are planned to be able to carry 1,100 passengers (7-car), with the ability to be lengthened to 10-cars carrying 1,570 passengers.

The daily VKTs for the HCMTs running under the 'with Melbourne Metro' scenario have been directly compared to the 'no Melbourne Metro' scenario (which assumes 37 HCMTs would be operating on the Cranbourne/Pakenham rail corridor). The effects of the passenger mode shift due to operation of Melbourne Metro are that it would remove 281.8 million VKTs of cars and nearly 4.4 million VKTs of trucks from Melbourne roads in the first 20 years of operation (based on PTV forecasts).^{*} This equates to a reduction of road transport GHG emissions of 74kt CO₂-e per annum (at 2046), compared to the 'no Melbourne Metro' scenario.

Stations and Tunnels

Electricity usage considered in assessing station and tunnel operations includes sources such as heating, ventilation and air-conditioning (HVAC), lighting, use of equipment (such as ticket machines), vertical transportation (escalators and lifts), fire systems and station hydraulics for all five Melbourne Metro train stations.

BAU versus Best Practice Operations

Total GHG emissions from the operation of Melbourne Metro portal to portal, adopting BAU GHG abatement, are estimated to be approximately 70.9kt CO₂-e per annum in 2026, reducing to 58.0kt CO₂-e per annum in 2046. Note that the BAU scenario assumes no renewable energy initiatives (including purchase of accredited GreenPower) are implemented.

* The reduction in truck VKTs is attributable to more direct routes being made available to trucks as a result of cars being removed from previously congested (direct) routes (VITM analysis provided by PTV).

By adopting best practice GHG abatement, total GHG emissions from the operation of Melbourne Metro would be expected to reduce to approximately 47.6kt CO₂-e in 2026 and 37.6kt CO₂-e in 2046 – a reduction of approximately 33 per cent and 35 per cent, respectively. This is summarised in Table 22–5 for each of the 2026, 2031 and 2046 operational scenarios.

The best practice scenario for traction energy assumes best practice regenerative braking on trains (25 to 27 per cent reduction in energy consumption compared to the BAU case) plus a 20 per cent reduction from the purchase of accredited GreenPower.

Table 22–5 Annual operational GHG emissions (2026, 2031 and 2046) (kt CO₂-e p.a.)

Operation by scope	BAU total			Best practice total		
	2026	2031	2046	2026	2031	2046
Traction energy (portal to portal)	45.5	60.2	40.9	27.3	35.4	23.9
Stations and tunnel electrical	19.1	18.7	11.8	15.3	15.0	9.4
Stations HVAC	2.2	2.2	1.4	1.8	1.7	1.1
Tunnels ventilation	4.1	4.6	3.9	3.3	3.6	3.1
Melbourne Metro subtotal	70.9	85.7	58.0	47.6	55.7	37.6
Passenger mode shift (Net)	27.2	35.1	39.7	27.2	35.1	39.7
TOTAL Operation	98.0	120.8	97.7	74.7	90.8	77.3

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

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

Key best practice GHG abatement initiatives that have been incorporated into the Concept Design, or that would be considered further in the detailed design, include:

- Commitment to the sourcing of a minimum 20 per cent of energy from renewable sources (Melbourne Metro sustainability performance target and PTV Project Performance Requirement)
- Traction energy – regenerative braking on rolling stock (HCMTs) to provide energy back into the electrical supply
- Energy efficient tunnel lighting – including designing the lighting system to use energy efficient lighting (such as LEDs, low light, lights off in tunnels, zoning and controls) while meeting lighting requirements and procurement requirements
- Geothermal piling – incorporating pipework for a geothermal heat exchange system (to be further investigated during the Detailed Design)
- Regenerative power on vertical transportation (elevators and escalators) at stations
- Solar photovoltaics (PV) at Domain, Parkville and Arden stations, and transparent PV film for entry canopies at CBD North and CBD South stations
- Optimise energy requirements for ventilation and temperature control between stations and tunnels, such as the use of platform screen doors
- Zone areas of HVAC system to deal with separate areas that are known to have different occupancy periods and requirements
- Investigate (with PTV) options of purchasing a higher percentage of energy from renewable sources to align with the Victorian Government's GHG reduction policies.

Functional Unit

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 assessment, the functional unit is expressed as grams CO₂-e per passenger-kilometre-travelled (PKT), and can be provided for the 'with' and 'without' Melbourne Metro scenarios.

The functional unit (GHG indicator) for the operation of the project, for all sources (portal to portal) and assuming best practice operational GHG emissions, is 130 grams CO₂-e per passenger kilometre travelled (PKT) in 2026, 117 grams CO₂-e per PKT in 2031, and reducing to 55 grams CO₂-e per PKT by 2046 with the operation of Extended HCMT rolling stock only.

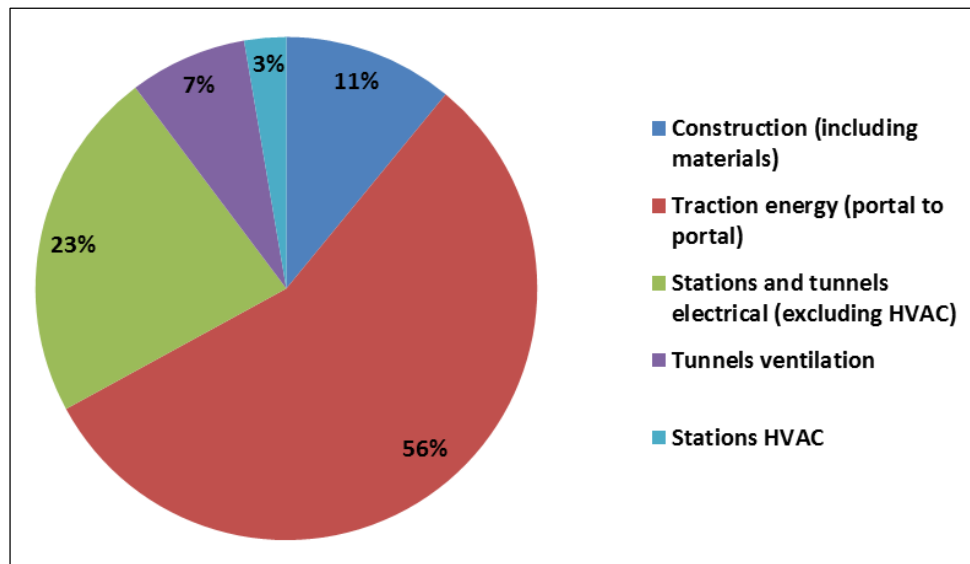
This compares to 150 grams CO₂-e per PKT for cars (projected to 2030), based on a recent study undertaken by Transport for NSW. This also compares to the projected national average for passenger rail in 2030 of approximately 90 grams CO₂-e per PKT (as calculated by Transport for NSW), although it should be noted that Victoria has the highest GHG emissions intensity (from electricity generation) of all the states and territories so it is expected that the project's calculated functional unit would be higher than the national average.

Considering CO₂-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 of the project on other transport modes. This provides a net GHG indicator across the entire transport network, for the 'with' and 'without' Melbourne Metro scenarios. When considering the movement of people across all transport modes, the project would provide a net reduction of 1.2 grams CO₂-e per PKT compared to the 'without Melbourne Metro' scenario after 20 years of operation (2046); that is, there is a greater carbon efficiency as the project moves toward operating as a fully Extended Program, making full use of the Extended HCMTs in timetable running along the new Sunshine – Dandenong Line.

22.7.3 Whole of Project

The Basis of Design for Melbourne Metro consists of a 100-year project design life (that is, 100 years of operation). Considering the infrastructure lifecycle of the project (construction and operation), Figure 22-2 provides a summary of the project's total GHG emissions.

Figure 22-2 Split of GHG emissions over the infrastructure lifecycle



Traction energy associated with operation of the HCMTs represents by far the largest source of GHG emissions (56 per cent) associated with the infrastructure lifecycle of the project due to the higher energy requirements of these trains compared with existing rolling stock.

22.7.4 Alternative Design Options

Several alternative design options to the Concept Design have been proposed. These options are considered to have an immaterial influence on the GHG footprint determined for the Concept Design for both construction and/or operation, and have therefore not been discussed further within the GHG impact assessment.

22.8 Environmental Performance Requirements

Table 22–6 shows the recommended Environmental Performance Requirements for Melbourne Metro in relation to GHG emissions.

The risk numbers listed in the final column align with the list of GHG risks provided in Technical Appendix B *Environmental Risk Assessment Report*.

Table 22–6 Environmental Performance Requirements for GHG emissions

Draft EES evaluation objective	Environmental performance requirements	Proposed mitigation measure	Precinct	Timing	Risk No.
<p>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</p>	<p>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.</p>	<p>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 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</p>	All	Design/ Construction/ Operation	GH001 GH002
	<p>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.</p>	<p>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</p>	All	Design	

22.9 Conclusion

The GHG impact assessment has addressed the EES Scoping Requirements for Melbourne Metro, which 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, MMRA has included assessment criteria against the draft EES evaluation objective for Transport Connectivity that the project should 'identify best practice initiatives to reduce GHG emissions across the infrastructure lifecycle of the project'. The Concept Design and all alternative design options are consistent with the draft EES evaluation objective as:

- Best practice GHG abatement initiatives have been included and proposed in the Concept Design (see Sections 22.7.1 and 22.7.2), in accordance with PEM 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
- The functional unit for the operation of the project, for all sources (portal to portal) and assuming best practice operational GHG emissions is estimated to be 55 grams CO₂-e per PKT in 2046, with the operation of Extended HCMT rolling stock only. This compares to the projected national average for passenger rail (in 2030) of approximately 90 grams CO₂-e per PKT
- When considering the movement of people across all transport modes, the project would provide a net reduction of 1.2 grams CO₂-e per PKT compared to the 'without Melbourne Metro' scenario after 20 years of operation (2046).

The recommended Environmental Performance Requirements would aim to ensure that sustainability and GHG reduction targets are achieved across the construction and operational phases of the project. Achieving these requirements would result in low residual risk ratings for GHG emission risks. As such, the impact of the project's GHG emissions is considered acceptable.

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.