INFRASTRUCTURE AND TRANSPORT MINISTERS

Australian Transport Assessment and Planning Guidelines

PV5 Environmental parameter values

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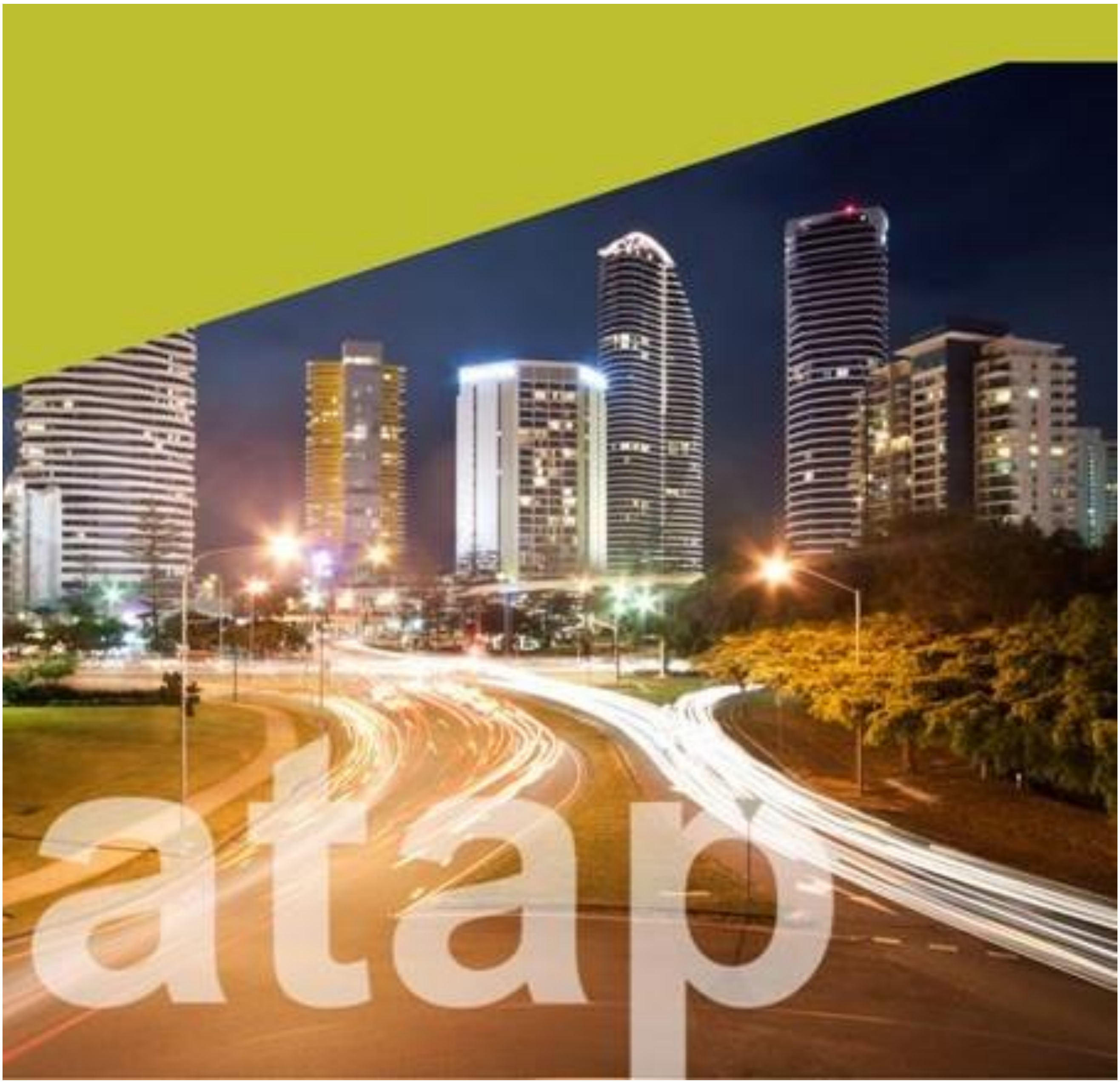

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At a glance

Environmental parameter values in the Australian Transport Assessment and Planning (ATAP) Guidelines are an important reference for facilitating consistency in monetising the environmental costs of transport in Australia, and the environmental benefits and disbenefits of transport projects and initiatives.

As with previous versions of these parameter values, the numbers are based on the latest international (predominantly European) values adapted to the Australian context, and indexed to current dollars. Values related to greenhouse gas (GHG) emissions align with new national emissions values endorsed at the Infrastructure and Transport Ministers Meeting (ITMM) in December 2023.[1]

The guide provides environmental parameter values for:

- Eight environmental impact categories
  - air pollution
  - GHG emissions
  - noise pollution
  - upstream and downstream costs (with 'well-to-tank' emissions being a major quantifiable component)
  - soil and water pollution
  - nature and landscape
  - additional costs in urban areas (barrier effects)
  - biodiversity.
- Urban and rural locations.
- Passenger and freight transport modes, including:

  Passenger transport
  - 2-wheelers: e-bikes, scooters/mopeds, motorcycles
  - passenger cars: mini, small, medium, large, 4WD/SUV
  - buses and coaches: minibus (light commercial vehicles), urban small bus (midi bus), urban standard bus, urban articulated bus, busway bus, coach
  - passenger rail: tram, metro single-deck train, metro double-deck train, regional trains, inter-city train
  - aviation: mid-sized aircraft (Airbus, Boeing) by distance
  - water transport: local ferry, large passenger and vehicle ferry

  Freight transport
  - light commercial vehicles (vans, utes)
  - heavy commercial vehicles: rigid by payload, articulated by payload
  - freight rail: short
  - road freight: light commercial vehicles (LCVs), heavy vehicles (HVs), by size
  - freight rail: short container and bulk goods, long container and bulk goods
  - aviation: mid-sized aircraft (Airbus, Boeing) by distance

[1] https://www.infrastructure.gov.au/sites/default/files/documents/itmm-communinque-6-december-2023.pdf

  - water transport: small vessels by distance, large vessels by distance.
- Different energy types (as they apply by mode):
  - petrol
  - diesel
  - liquid petroleum gas (LPG)
  - compressed natural gas (CNG)
  - electricity
  - other (including aircraft and maritime vessel fuels).

Some values may be substantially different to previously reported values due to updated baseline data, new assumptions and updated calculations or the recalibration of the underpinning European data. Caveats and assumptions are listed to provide a context for the use of the values.

The reported environmental unit costs should be used with a significant degree of caution, as a reflection of the uncertainties involved in the estimation of environmental unit costs, especially those related to climate change. They should be interpreted as indicative rather than definitive, and their impact on decision-making should be checked through sensitivity testing.

1. Introduction

This Part of the ATAP Guidelines (the Guidelines), Part PV5, provides environmental unit costs for use in the assessment of transport policies, plans and initiatives in Australia. The recommended values are set out in Look-Up tables.

In 2021, ATAP published an updated version of PV5 that adapted the then latest international (primarily European) environmental parameter values to the Australian context. It was also a multi-modal update, providing new parameter values for an extended list of transport modes, vehicle types and sizes, and fuel types.

In this 2024 update, the report and underlying methodology is largely unchanged from 2021. However, two changes have been made:

- The unit costs for greenhouse gas emissions and well-to-tank impacts, have been updated to align with new national emissions values endorsed at the ITMM.[2]
- All unit costs have been indexed to June 2023 dollars.

Like previous versions of PV5, the parameter values reported here are based on European data (CE Delft 2019a), which provides a detailed update of European values. Key impact categories covered by the European data and adapted to the Australian context include air pollution, greenhouse gas emissions (climate change), noise pollution, 'well-to-tank' (WTT) emissions (a major quantifiable component of upstream and downstream costs) and the impact on nature and landscape (habitat).

The latest European data did not include updates for other categories previously reported in Austroads (2012 & 2014), namely soil and water pollution, biodiversity, and urban barrier effects. As such, this report provides a mix of detailed values based on the new European data and indexed values based on Austroads (2012 & 2014) and reported in ATAP (2020) where new baseline data was unavailable. Some values reported here differ substantially from previously reported values. These differences can be accounted for by updated baseline data, new assumptions and updated calculations or the recalibration of the European data. Caveats and assumptions are listed to provide a context for the use on the parameter values.

1.1 Caveat

The estimation of environmental unit costs is a complex and challenging activity, involving significant uncertainty. This is especially the case with greenhouse gas emissions, which are influenced by actions not just in Australia, but also in other countries. The challenges include:

- The lack of Australian data
- Transferring and calibrating environmental cost valuations from other countries to Australia
- The existence of a number of different methodologies available to produce estimates, including based on damage costs, control/avoidance costs and social cost.

As a result, environmental unit costs, including those presented here, should be used with a significant degree of caution. They should be interpreted as indicative rather than definitive. The use of sensitivity testing to assess the robustness of transport system decisions to environmental unit costs is strongly encouraged. Recommended parameter values for sensitivity testing GHG emissions values are provided in Section 4.2.1.

[2] https://www.infrastructure.gov.au/sites/default/files/documents/itmm-communinque-6-december-2023.pdf

2. Context

2.1 Role of environmental parameter values

Environmental impacts such as air pollution, greenhouse gas (GHG) emissions and noise pollution and biodiversity loss are by-products of transport activities that can harm the wellbeing of the society and the quality of the natural environment. Consequently, these impacts (or externalities) should be accounted for when undertaking economic appraisals, such as cost-benefit analysis (CBA), of transport projects or policies.

Transport-related environmental impacts are not direct costs to individuals or businesses but are borne by broader communities, ecosystems and some impacts, such as GHG emissions, can occur across borders. Costs accrue to either prevent damage by mitigating the impact (determined using the avoidance cost approach), or costs caused by the damage such as health costs (determined using the damage costs approach) (Austroads 2014).

Due to the lack of explicit market prices, monetising the environmental impacts of transport activities for the purpose of economic appraisals is a challenging task and outcomes vary depending on the assumptions made by individual economic appraisal practitioners.

Environmental parameter values in the ATAP Guidelines are monetised values for a suite of environmental impacts that should be assigned to a unit of transport activities. The Guidelines provide a consistent set of inputs for economic appraisals of transport projects and initiatives thereby facilitating a consistent approach for economic appraisals following the ATAP framework.

Box 1 — Units of measurement

Values in this report are provided for three units of transport activity:

- Vehicle-kilometres travelled (vkt) is a unit of measurement representing the total distance (in kilometres) travelled by a vehicle. Vkt does not consider who or what is being transported and is a valid measure for both freight and passenger transport.
- Passenger-kilometres (pkm) is a unit of measurement for passenger transport which represents the movement of one person by a given transport mode (road, rail, air, water) over one kilometre. In this study, all occupants (including the driver) of passenger cars, buses and two-wheelers are considered passengers (regardless of whether the trips are for private or commercial purposes). For rail, ferry and air transport, drivers and crew are not included in the passenger assumptions. Passenger-kilometres are calculated by using the total vehicle-kilometres travelled by a vehicle type and the average occupancy of the vehicle type.
- Tonne-kilometres (tkm) is a unit of measurement of freight transport which represents the transport of one tonne of goods (including packaging and tare weights of containers) by a given transport mode (road, rail, air, water) over one kilometre. Tonne-kilometres are calculated using the laden distance travelled for work purposes and average load weight.

2.2 Background

From 2015 to 2019, the Guidelines referred users to the values in two Australian publications:

- NGTSM (2006), Volume 3, Appendix C
- Austroads (2012) — which reports indexed values from an Austroads (2003) study. It also took account of the NGTSM values, eliminating the need for the NGTSM values as a separate source.

In addition, in 2014, Austroads also released a set of environmental parameter values for use by practitioners. The Austroads (2014) work was essentially a review and major updating of Austroads (2012). It involved updated methodologies and data sources.

In 2020, ATAP released an interim update reflecting the combined (averaged) values provided in Austroads (2012 & 2014).

In 2021, an update was undertaken to reflect more recent data sources, new insights and updated methodologies (reported in CE Delft 2019a).

2.2.1 Austroads (2012)

Austroads (2012) reported indexed values from earlier studies published by Austroads (dating back to 2003). Values were provided for both passenger and freight transport and were reported in vehicle-kilometres (vkt), passenger-kilometres (pkm) and tonne-kilometres (tkm).

2.2.2 Austroads (2014)

Values reported in Austroads (2014) were a major update of the Austroads (2012) report and data set. It included a review and update of methodologies and data sources, predominantly based on a major European study (CE Delft et al. 2011). The update led to parameter values which were somewhat different to those reported in Austroads (2012), i.e. often substantially lower, with this ascribed to the different costing methodology applied as well as some changes in the evidence base.

2.2.3 ATAP (2020)

ATAP 2020 indexed values to December 2019 A$s and consolidated the values presented in Austroads (2012 & 2014). The values from the two studies were consolidated given the uncertainty around the estimation of the parameter values and different assumptions, data and methodologies used. ATAP (2020) listed low, mid and high values, with Austroads (2012) values adopted as high values, and Austroads (2014) values adopted as low values. Mid values were an average between the low and high values.

2.2.4 ATAP (2021)

ATAP (2020) updated environmental parameter values to reflect more recent data sources, new insights and updated methodologies in Europe (CE Delft 2019a). It also provided more detailed values than reported previously — with values provided for more modes, vehicle types and sizes, and fuel types. Earlier European data (CE Delft et al. 2011) were also used as a reference to highlight key changes in baseline data.

The greenhouse gas emissions value used in the Australian studies above (Austroads 2012 and 2014; ATAP 2021) was around A$ 60 per tonne of CO2-e (in June 2020 dollars).

2.3 Caveats

As noted in Chapter 1, estimating environmental externality values is a complex and challenging activity involving significant uncertainty. This is because environmental impact costs, such those relating to air pollution, greenhouse gas emissions, noise or electricity generation/fuel production and distribution are not directly quantifiable. These effects can be quantified by measuring the costs of the damage they cause (*damage costs*, e.g. health costs), or by estimating the cost to prevent or reduce them (*avoidance costs*, e.g. GHG mitigation), or the cost for replacing or repairing adverse impacts (*replacement costs*, e.g. repairing habitat damage).

Australian data for estimating externalities is only sporadically available, and does not yet provide adequate coverage of all the relevant environmental impact categories. As such, the parameter values in previous ATAP Guidelines were based on European studies and data, which have used differing methodologies, data sets and new insights over the years. This makes the valuation of externalities and numerical comparison challenging (Austroads 2014).

Converting overseas (European) data into Australian values requires adjustments to be made to account for differences in exchange rates, inflation, consumer price level (or purchasing power), population density and the carbon intensity of power sources.

Although the parameter values presented in this report are based on more recent (European) data and reflect more recent knowledge, developments and methodologies compared to previous studies, the values need to be used with caution. In recognition of this caution, parameter values should be used as indicative values, and sensitivity testing should be performed when used in transport studies. To help account for this uncertainty, some typical value ranges are provided here, expressed as percentages which can be applied to mid values in order to obtain low and high values (see sections 4.2.1 and 5.3).

Future ATAP work may involve collection of Australian data for estimating the unit costs of environmental impacts more directly.

3. Scope

This report provides environmental parameter values for use in transport projects. Unit costs are provided for eight categories of environmental impacts. Where revised values based on new research were not available, previously reported values (in Austroads 2012 & 2014) have been indexed to current dollar values.

3.1 Environmental impact categories

Environmental parameter values are provided here for the impact categories, transport modes, and locations listed below.

- Eight impact categories
  - air pollution
  - greenhouse gas (GHG) emissions
  - upstream and downstream costs (WTT emissions)
  - noise pollution
  - nature and landscape
  - soil and water pollution
  - additional costs in urban areas (barrier effects)
  - biodiversity
- Two transport modes
  - passenger transport (road, rail, air and maritime)
  - freight transport (road, rail, air and maritime)
- Two locations
  - urban
  - rural.

Table 3-1 provides a brief description of the eight environmental cost elements.

Table 3-1: Environmental cost elements

Cost element	Description
Air pollution	Health costs, building and material damage, crop losses
Climate change	Long-term social and economic impacts of greenhouse gas emissions into the atmosphere
Upstream and downstream costs (well-to-tank emissions)	Indirect environmental (air pollution and greenhouse gas emissions) costs of energy generation and distribution
Noise pollution	Health, wellbeing and annoyance impacts
Nature and landscape	Impact of infrastructure on existing habitats
Soil and water pollution	Impact of run-off on water quality and soil quality
Additional costs in urban areas (barrier effects)	The barrier and separation effects of motorised traffic on pedestrians, cyclists, etc.
Biodiversity	Impact of air pollution on natural ecosystems

Source: Adapted from Austroads (2012 & 2014).

3.2 Transport modes and energy sources (vehicle classes and energy types)

Parameter values are provided for a range of vehicle types, differentiating between vehicle sizes, fuel types and other categories where applicable (e.g. transport distances).

The breakdown by vehicle and fuel type closely follows the structure of the key data source, CE Delft (2019a). Equivalence tables used to facilitate the conversion of European values into Australian values are shown in Section 4.3. These tables include vehicle sizes and kerb weights, emission classes, carbon intensity of electricity generation and fleet composition.

Transport modes and energy types are broken down as follows:

- Transport modes

  Passenger transport

  - 2-wheelers: e-bikes, scooters/mopeds, motorcycles
  - passenger cars: mini, small, medium, large, 4WD/SUV
  - buses and coaches: minibus (light commercial vehicles), urban small bus (midi bus), urban standard bus, urban articulated bus, busway bus, coach
  - passenger rail: tram, metro single-deck train, metro double-deck train, regional train, inter-city train
  - aviation: mid-sized aircraft (Airbus, Boeing) by distance
  - water transport: local ferry, large passenger and vehicle (RoPax) ferry

  Freight transport

  - light commercial vehicles (vans, utes)
  - heavy commercial vehicles: rigid by payload, articulated by payload
  - freight rail: short
  - road freight: light commercial vehicles (LCVs), heavy vehicles (HVs), by size
  - freight rail: short container and bulk goods, long container and bulk goods
  - aviation: mid-sized aircraft (Airbus, Boeing) by distance
  - water transport: small vessel by distance, large vessel by distance
- Energy types (as they apply by mode)
  - petrol
  - diesel
  - liquid petroleum gas (LPG)
  - compressed natural gas (CNG)
  - electricity
  - other (including aircraft and maritime vessel fuels).

3.3 Exclusions and scope limits

The values presented here are limited by the available baseline European data. For example, hydrogen is an emerging transport energy source but there was no baseline data to support the development of Australian parameter values for hydrogen-powered vehicles.

4. Methodology

The ideal approach for estimating Australian environmental parameter values would be to base them completely on direct Australian environmental impact data — however, such data either does not currently exist or has only limited availability. In its absence, past Australian guidance, and this report, provide Australian estimates inferred predominantly from European data, adjusted to Australian dollar values.

4.1 High-level methodology

The parameter values published in Austroads (2014) were based on European data published in CE Delft et al. (2011) which were adjusted to Australian conditions using a set of adjustment factors and methodologies (top-down approach).

This current report applied a consistent top-down methodology using the later European data in CE Delft (2019a). Minor adjustments were made where required to adapt the methodology to the more detailed outputs.

As in Austroads (2014), the parameter values here are provided in vehicle-kilometres as well as person-kilometres (for passenger transport) and tonne-kilometres (for freight transport). Where possible, mid-level estimates as well as plausible minimum and maximum estimates (% of mid values) are provided for sensitivity analyses.

Austroads (2014) provided **average** values in output data tables, separating urban and rural as well as passenger and freight transport. This report maintains a similar structure for the output data tables. However, considering the addition of transport modes and the refinement of the parameter values (e.g. by energy source), additional, more comprehensive tables are provided for all parameters where more detailed data (**marginal** parameter values) are available. For an overview of data availability and the difference between the average and marginal values, refer to Section 4.4 and Appendix A.

4.2 Methodological steps

The method used **average** and detailed **marginal** parameter values from CE Delft (2019a), using aggregated values for all 28 countries of the European Union (EU28). Values from individual countries are not used as detailed (marginal) values are only provided for EU28. Austroads (2014) also established that there was no single European country that was representative of Australia and EU28 data was a preferred basis to adapt for the Australian context.

Based on average and marginal values, the following steps were taken to adjust values, applying a refined methodology compared to that which was used in Austroads (2014):

1. Aggregation of road types: CE Delft (2019a) provides values for different types of metropolitan, urban and rural roads. These types of roads were consolidated into urban and rural road types based on the vkt on each road type. This replicates the output structure used in Austroads (2014). Refer to Table 4-3 for details.
2. Conversion to costs per 1000 km: CE Delft (2019a) reports parameter values in Euros per vkt, pkm or tkm. However, previous Australia values were reported in Australian dollars per 1000 vkt, pkm or tkm. For consistency, the European values were converted into Euros per 1000 km as a basis for step 3.
3. Currency conversion: CE Delft (2019a) reports values in 2016 Euros which were converted to 2016 Australian dollars using exchange rates according to RBA (2020). One Australian dollar equals 0.6741 Euros (average 2016).

4. Indexation: CE Delft (2019a) reported values for a 2016 price level (2016 Euros) which were converted into a 2023 price level (June 2023 Australian dollars) to account for inflation using the Australian Bureau of Statistics (2020b) CPI index.

5. Adjustment for purchasing power: The parameter values were adjusted to reflect purchasing power parity between countries using data according to World Bank (2019). The price level in Australia is 14.7% above the European average (EU28).

6. Adjustment for population density: The population density in European cities is generally much higher compared to Australian cities. Population density data from 92 European cities and Australia's six largest cities (Demographia 2020) was compared and used to adjust for population density. The population density in Australian cities is about 42% compared to European cities. The study acknowledges that the population density differential is likely to be even greater in rural (inhabited) populations, however in the absence of comparable rural population density data, the population density adjustment is assumed to be equal for urban and (inhabited) rural areas.

   Where environmental impacts affect local populations, population density is an important factor in determining environmental costs. For example, more people are exposed to the impacts of air noise pollution in higher population density areas than in less dense areas. As such the environmental impact costs should be higher in more densely populated areas. Conversely, where environmental impacts are dispersed (e.g. greenhouse gases), population density is less important. Austroads (2014) applied a population density adjustment factor to every environmental impact to account for the different population densities of Australian and European cities.

   This report applies the population density adjustment to only those environmental impacts that population density is a driver of environmental costs (i.e. air pollution, the air pollution component of the WTT emissions[3] and noise). For impacts where population density does not drive costs (i.e. climate change, the greenhouse gas emissions component of WTT emissions, nature and landscape), no adjustment was made.

   As noted in Section 1, this report reflects the latest figures where new European baseline data was available (in CE Delft 2019a). New baseline data were not available for the soil and water, biodiversity and urban barrier effect impacts as the (average) values presented in this report replicate the mid-point values from Austroads (2012 & 2014) as published in ATAP (2020). It would be reasonable to remove the population adjustment for soil and water and biodiversity impacts as they are unaffected by the presence or density of human populations. Future updates could consider removing or amending the population density adjustment for urban barrier effects where the impact of population density is uncertain.

   Adjustments for population density significantly reduce the parameter values due to the comparatively low average population density in Australian cities. ATAP continues to investigate whether the population adjustment factors are appropriate.

7. Aggregation of emission classes (for road vehicles only): CE Delft (2019a) states (marginal) values by vehicle emission classes (Euro 0 to Euro 6 for light vehicles and 0 to VI for heavy vehicles) for most road vehicle types. This update was unable to identify any data that precisely specified the Australian vehicle population by emissions class. In the absence of specific vehicle population data by emissions class, the age of a vehicle (i.e. when it was first registered) is a reasonable indicator of its emissions class. Marginal values have been grouped using age brackets of Australian vehicles according to Australian Bureau of Statistics (2020a) and by matching vehicle ages to the introduction of the relevant vehicle emissions standards in Australia.

[3] CE Delft et al. (2019a) reports that 'The costs due to greenhouse gas emissions from WTT contribute to about 60–65% of the WTT costs. For road transport, for example, the share of climate change costs is 62%, the share of air pollution costs 38%'. This report has assumed a 62:38 climate change and air pollution cost split across all modes.

8. Adjustment for vehicle occupancy and payload: As a point of difference to Austroads (2014) where an adjustment for vehicle occupancy was performed, the same vehicle occupancy or average payload was assumed in this report for the different vehicle types and sizes. This approach is considered more suitable due to the more detailed data and the difficulty of matching vehicle occupancy and payload for similar Australian vehicles (for heavy vehicles). An equivalence table is provided matching European and Australian vehicle categories (Table 4-4). Occupancy and payload figures for every vehicle type can be found in Appendix A.

In addition to the above adjustments, the carbon intensity of Australian energy production was accounted for in vehicles using electricity, i.e. electric (road) vehicles and electric trams and trains. This affects the GHG emissions component of the WTT parameter values[4]. On average, emissions from electricity generation and use in Australia are 2.83 times higher than the average of EU28 (Department of Industry, Science, Energy and Resources 2020, European Environment Agency 2020). Refer to Table 4-7 for details. The values provided in this update are adjusted to the Australian average electricity mix. However, values for individual states and territories with lower or higher carbon intensity of electricity production can also be calculated using the other conversion factors listed in Table 4-7.

4.2.1 Unit cost of greenhouse gas emissions

A final step in the methodology was to apply suitable unit cost of greenhouse gas emissions (noting caveats in sections 1.1 and 2.3).

The unit cost of greenhouse gas emissions is expressed internationally in the units of $ per tonne of CO2-e (carbon dioxide equivalent), also referred to as the $ per tonne of carbon. It is a key variable in estimating the environmental costs of greenhouse gas emissions.

This 2024 version of PV5 uses the national emissions values endorsed by ITMM, reported in Infrastructure Australia (2024). The national emissions values have been estimated using a target consistent approach, meaning they are based on the estimated future costs of abatement necessary for the Australian economy to meet national emissions reduction targets and international commitments. The methodology supporting these parameters is provided in Centre for International Economics and WSP Australia (2024).

The $ per tonne CO2-e values out to 2050 are shown in Table 4-1 below. These values:

- Provide the minimum values that should be used in the analysis of transport and infrastructure projects
- Provide a low, medium and high range of values, reflecting the uncertainty forecasting
- Are in real terms, that is, excluding inflation. The central value goes from A$56 in 2024 to $377 in 2050, based on modelling to align with Australia's legislated emissions reduction targets.

For future years from 2024 to 2050, adjustment factors for Climate Change and WTT emissions are provided in Table 4-2 that practitioners can apply to reflect the increasing unit costs shown in Table 4-1.

[4] CE Delft et al. (2019a) reported that 'The costs due to greenhouse gas emissions from WTT contribute to about 60–65% of the WTT costs. For road transport, for example, the share of climate change costs is 62%, the share of air pollution costs 38%'. With limited details provided on the background data, this report assumes a 62:38 climate change and air pollution cost split across all modes. This assumption is made acknowledging that this proportion may not hold for all vehicle or fuel types (especially for electricity generation) and therefore introduces a level of uncertainty into some of the resulting estimates.

Table 4-1 $ per tonne CO2-e values

	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	FY2030	FY2031	FY2032
Low	44	56	62	69	76	87	107	124	144
Central	56	66	76	88	104	123	148	171	192
High	66	77	95	107	132	152	180	210	227

	FY2033	FY2034	FY2035	FY2036	FY2037	FY2038	FY2039	FY2040	FY2041
Low	159	166	172	184	191	193	206	210	212
Central	209	222	234	244	254	264	273	282	291
High	258	262	280	293	308	319	329	340	351

	FY2042	FY2043	FY2044	FY2045	FY2046	FY2047	FY2048	FY2049	FY2050
Low	215	228	246	267	272	274	276	284	287
Central	300	309	318	326	335	344	354	363	377
High	361	370	375	380	403	421	429	437	469

Source: Infrastructure Australia (2024)

Table 4-2 Climate change and WTT adjustment factors for GHG emissions $per tonne CO2-e

	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	FY2030	FY2031	FY2032
Low	0.786	1.000	1.107	1.232	1.357	1.554	1.911	2.214	2.571
Central	1.000	1.179	1.357	1.571	1.857	2.196	2.643	3.054	3.429
High	1.179	1.375	1.696	1.911	2.357	2.714	3.214	3.750	4.054

	FY2033	FY2034	FY2035	FY2036	FY2037	FY2038	FY2039	FY2040	FY2041
Low	2.839	2.964	3.071	3.286	3.411	3.446	3.679	3.750	3.786
Central	3.732	3.964	4.179	4.357	4.536	4.714	4.875	5.036	5.196
High	4.607	4.679	5.000	5.232	5.500	5.696	5.875	6.071	6.268

	FY2042	FY2043	FY2044	FY2045	FY2046	FY2047	FY2048	FY2049	FY2050
Low	3.839	4.071	4.393	4.768	4.857	4.893	4.929	5.071	5.125
Central	5.357	5.518	5.679	5.821	5.982	6.143	6.321	6.482	6.732
High	6.446	6.607	6.696	6.786	7.196	7.518	7.661	7.804	8.375

Source: Calculated from Table 4-1.

The environmental impacts that are influenced by the $ per tonne of CO2-e are greenhouse gas emissions and well-to-tank impacts. The unit costs for these components provided here — in Tables 5-1 to 5-16 — are based on the central $ per tonne value in Table 4-1 of A$ 56 for FY2024.

For these two environmental impacts, the procedure for calculating the unit cost ($ per unit of travel) for any future year out to 2050 is:

- Select the unit cost from Tables 5-1 to 5-16 relevant to the appraisal
- For each year of the appraisal period, multiply the unit cost by the relevant factor in Table 4-2
- Apply the resulting unit costs in calculating benefits (disbenefits) for each year of the appraisal period.

Som examples calculations are provided below.

Example calculations

Greenhouse gas unit cost for passenger cars:

- Table 5-1 gives a unit cost A$ 10.2 per vkt
- Multiplying by the factors in Table 4-2 gives: for 2024, $10.2 x 1.000 = $10.20 per vkt; for 2025 $10.2 x 1.179 = $12.02 per vkt, etc … for 2050, $10.2 x 6.732 = $68.67
- Then apply these year-by-year numbers to changes in vkt between Base Case and Project Case for each appraisal year to yield annual greenhouse gas emissions benefits across the appraisal period.

Well-to-tank unit cost for passenger cars:

- Table 5-1 gives a unit cost A$ 2.6 per vkt
- Multiplying by the factors in Table 4-2 gives: for 2024, $2.6 x 1.000 = $2.60 per vkt; for 2025 $2.6 x 1.179 = $3.06 per vkt, etc … for 2050, $2.6 x 6.732 = $17.50
- Then apply these year-by-year numbers to changes in vkt between Base Case and Project Case for each appraisal year to yield annual greenhouse gas emissions benefits across the appraisal period.

Given the uncertainty involved in forecasting, ***the ATAP Guidelines recommend that practitioners use a range of values for the $ per tonne of CO2-e via sensitivity testing*****.** Parameter values for sensitivity testing were also endorsed at ITMM and are reflected in the low and high values in Table 4-1 and Table 4-2. Such testing will allow practitioners to assess whether the value used for the $ per tonne of greenhouse gas emissions is a critical input to any given appraisal. That is, are the final results of the appraisal sensitive to the $ per tonne of CO2-e value used, and hence will use of the appraisal results lead to a robust decision.

Sensitivity testing can be undertaken by using the low and high adjustment factors in Table 4-2.

Practitioners may wish to include additional sensitivity testing on alternative values, or this may be required under jurisdictional guidelines, however, the central values provided are the minimum values that should be used for transport and infrastructure proposals and analysis.

4.3 Equivalence tables

The tables in this section summarise information and data that was used to convert European to Australian parameter values or adjust values to Australian conditions.

4.3.1 Road types

Weighting factors (WFs) based on vkt on different roads in Australia were used to aggregate European road types (motorways, urban/rural roads and other roads) to Australian urban and rural categories only. These are shown in Table 4-3.

Table 4-3: Road types based on vkt

European road types and subcategories			Australian road types			
			Urban		Rural	
			Arterial roads	Local roads	National highways and arterial roads	Local roads
Metropolitan area	Motorway	A	X			
	Urban road	B		X		
	Other road	C		X		
Urban area	Motorway	D	X			
	Urban road	E		X		
Rural area	Motorway	F			X	
	Rural road	G				X
Vkt-based WF (1)			0.72	0.28	0.83	0.17
Calculation for conversion of parameter values for EU road types into parameter values for Australian urban & rural road types			= avg(A, D) * WF(Urban Arterial) + avg(B, C, E) * WF(Urban Local)		= F*WF(Rural Arterial) + G*WF (Rural Local)	

(1) Vkt-based weighting factors (WFs) are calculated based on Austroads (2015), Table C.3.1.

Source: European road types and subcategories according to CE Delft (2019a); Australian road types based on matching of urban and rural categories to road types reported in Austroads (2015).

4.3.2 European vs Australian vehicle categories

The European vehicle categories reported in CE Delft (2019a) can be matched with Australian vehicle categories according to Table 4-4. Two different Australian classifications are reported:

- vehicle classification according to Austroads 12 categories (Austroads 2019a)
- vehicle classification according to the ATAP 20 vehicle categories (Australian Transport Assessment and Planning 2016).

Table 4-4 also shows whether a vehicle type is a light or heavy vehicle and whether its function is for passenger (P) or freight (F) transport.

Table 4-4: Vehicle categories

Vehicle classes and types		Gross vehicle mass	Austroads		ATAP PV2		Vehicle type	Passenger (P) / freight transport (F)
2-wheelers	Moped/ scooter		n/a	n/a	n/a	n/a	Light	P
	Motorcycle		n/a	n/a	n/a	n/a	Light	P
Passenger cars	Mini		n/a	n/a	n/a	n/a	Light	P
	Small		1	Short vehicle	01	Small car	Light	P
	Medium		1	Short vehicle	02, 05	Medium car	Light	P
	Large		1	Short vehicle	03	Large car	Light	P

Vehicle classes and types		Gross vehicle mass	Austroads		ATAP PV2		Vehicle type	Passenger (P) / freight transport (F)
Urban bus	Midi	<15 t	3	Two axle truck	06, 07	Light/medium rigid	Light	P
	Standard	15-18 t	3, 4	Two/three axle truck	08, 09	Medium rigid/heavy bus	Heavy	P
	Artic.	>18 t	6	Three axle articulated vehicle	09	Heavy bus	Heavy	P
Coach	Standard	≤18 t	3, 4	Two/three axle truck	08, 09	Medium rigid/heavy bus	Heavy	P
	Artic.	>18 t	6	Three axle articulated vehicle	09	Heavy bus	Heavy	P
LCV	Van/ute		1, 3	Short vehicle/two axle truck	04, 06	Light/medium rigid	Light	P, F
Heavy vehicles	Rigid	<7.5 t	3	Two axle truck	06	Light rigid	Light/ heavy	F
	Rigid	7.5-12 t	3, 4	Two/three axle truck	07, 08	Medium/heavy rigid	Heavy	F
	Rigid	12-14 t	3, 4	Two/three axle truck	07, 08	Heavy rigid	Heavy	F
	Rigid	14-20 t	4	Three axle truck	08	Heavy rigid	Heavy	F
	Rigid	20-26 t	4	Three axle truck	08	Heavy rigid	Heavy	F
	Rigid	26-28 t	4	Three axle truck	08	Heavy rigid	Heavy	F
	Rigid	28-32 t	4	Three axle truck	08	Heavy rigid	Heavy	F
	Rigid	>32 t	4	Three axle truck	08	Heavy rigid	Heavy	F
	Artic.	14-20 t	7, 8	Four/five axle articulated vehicle	10,11	Four/five axle articulated	Heavy	F
	Artic.	20-28 t	7, 8	Four/five axle articulated vehicle	10,11	Four/five axle articulated	Heavy	F
	Artic.	28-34 t	9, 10	Six axle articulated vehicle/B-double	12,13	Six axle articulated/ rigid + five axle dog	Heavy	F
	Artic.	34-40 t	9, 10	Six axle articulated vehicle/B-double	12,13	Six axle articulated/ rigid + five axle dog	Heavy	F
	Artic.	40-50 t	10-12	Double/triple road train	14-20	B-double/twin steer + five axle dog/A-double/B-triple, A-B combination/ A-triple/double B-double	Heavy	F

Vehicle classes and types		Gross vehicle mass	Austroads		ATAP PV2		Vehicle type	Passenger (P) / freight transport (F)
	Artic.	50-60 t	10-12	Double/triple road train	14-20	B-double/twin steer + five axle dog/A-double/B-triple, A-B combination/ A-triple/double B-double	Heavy	F

Source: Description of vehicle classes, vehicle types and gross vehicle masses (GVMs) according to CE Delft (2019a); Austroads vehicle descriptions according to Austroads (2019a); ATAP PV2 vehicle descriptions from ATAP (2016).

4.3.3 Vehicle ages and emission classes

CE Delft (2019a) reports values for European vehicle emission classes Euro 0 to 6 (light vehicles) and Euro 0 to VI (heavy vehicles). This report was unable to identify data that precisely specified the Australian vehicle population by emissions class. In the absence of specific vehicle population data by emissions class, the age of a vehicle (i.e. when it was first registered) is a reasonable indicator of its emissions class.

An approximate matching of Australian vehicles was undertaken based on the timing of the introduction of the relevant vehicle emissions standards in Australia and the age categories and number of vehicles registered in each age category.

Australia has adopted vehicle emissions standards through the Australian Design Rules (ADR79 for light vehicles and ADR80 for heavy vehicles) progressively between 1995 and November 2016. Table 4-5 identifies when the vehicle emissions standards were introduced in Australia.

Table 4-5: Introduction of emission standards in Australia

Standard	Phase-in periods (after which emission standard is mandatory for all new vehicles)[5]		
	Light petrol and LPG vehicles	Light diesel vehicles	Heavy vehicles
Euro (I)	n/a	n/a	1 Jan 1995 to 1 Jan 1996 (ADR70/00)
Euro 2 (II)	1 Jan 2003 to 1 Jan 2004 (ADR79/00)	1 Jan 2002 to 1 Jan 2003 (ADR79/00)	n/a
Euro 3 (III)	1 Jan 2005 to 1 Jan 2006 (ADR79/01)	n/a	1 Jan 2002 to 1 Jan 2003 (ADR80/00)
Euro 4 (IV)	A July 2008 to 1 July 2010 (ADR79/02)	1 Jan 2006 to Jan 2007 (ADR79/02)	1 Jan 2007 to 1 Jan 2008 (ADR80/02)
Euro 5 (V)	1 Nov 2013 to 1 Nov 2016 (ADR79/03)	1 Nov 2013 to 1 Nov 2016 (ADR79/03)	1 Jan 2010 to Jan 2011 (ADR80/03)
Euro 6 (VI)[6]	n/a	n/a	n/a

Source: Department of Infrastructure, Transport, Cities and Regional Development (2020a & 2020b).

[5] In each case, the first date applies to vehicle models first produced on or after that date, with all new vehicles required to comply by the second date.

[6] The Australian Government's Ministerial Forum on Vehicle Emissions is currently undertaking a review to consider whether Australia should adopt the Euro 6 standards for light vehicles and Euro VI standards for heavy vehicles (https://www.infrastructure.gov.au/vehicles/environment/emission/index.aspx).

Table 4-6 shows the approximate matching of vehicle emission classes to vehicle age brackets and the estimated vehicle populations within each class.

It is worth noting that some new imported vehicles sold in Australia may meet and comply with higher emission standards than defined by the applicable Australian standard (beyond-compliant vehicles). For example, some Euro 6 (VI) vehicles are being sold in Australia, despite it not yet being a national standard. Users should note that this could lead to an overestimation of the externality costs in this report, in particular for air pollution, whereas climate change and WTT emissions parameter values are rather similar for the Euro 4 (IV), 5 (V), and 6 (VI) emission classes.

Table 4-6: Emission classes and vehicle age brackets

Vehicle distributions based on ABS data (1)	Light vehicles (2)	Heavy vehicles (2)	2-wheelers	Passenger cars	LCVs	HVs	Buses & coaches
Pre-2004	Euro 1-2	Euro I-II	22.98%	21.27%	24.13%	35.94%	28.75%
2005-2009	Euro 3	Euro III	23.48%	21.82%	20.00%	20.20%	22.35%
2010-2014	Euro 4	Euro IV	25.78%	27.56%	25.36%	19.37%	25.33%
2015-2019	Euro 5	Euro V	27.76%	29.35%	30.50%	24.49%	23.57%
Total			100%	100%	100%	100%	100%

(1) Vehicles on register obtained from Australian Bureau of Statistics (2020a).

(2) Approximate matching

Source: Estimation based on Australian Bureau of Statistics (2020a).

The vehicle matching did not include Euro 0 light and heavy vehicles as these older vehicles represent a very small proportion of the current vehicle fleet (around 1-1.5% by some estimates (Cosgrove, D, 5 November 2020, email, personal communications)) and represent an even smaller proportion of vkt. This omission, while relatively insignificant, would partially offset the potential overestimation of externality costs from beyond-compliant vehicles.

4.3.4 Electricity emissions factors for end users

The carbon intensity of electricity in Australia is higher on average and in most states and territories compared to the EU28 average. This is an important distinction for the conversion of WTT parameter values for electric passenger cars and rail vehicles. Table 4-7 provides conversion factors as ratios between the EU28 and Australian states and territories.

Table 4-7 shows the carbon intensity of electricity in Europe (EU28), Australia and each state and territory. It also provides the Australian average conversion factors and those for each state and territory. The WTT parameter values for electric road and rail vehicles as provided in CE Delft (2019a) are adjusted using the conversion factor ratio between the average Australian vs EU28 ratio (i.e. 2.83 in column 5 of Table 4-7).

In estimating parameter values for individual states and territories, the respective values should be multiplied by the ratio between the Australian average and individual states and territories (i.e. the factor in the right column of Table 4-7). A graphic representation of European and Australian emissions from electricity generation is shown in Figure 4-1.

Table 4-7: Carbon intensity of electricity for EU28 and Australia, in $kgCO_2/kWh$ (2020)

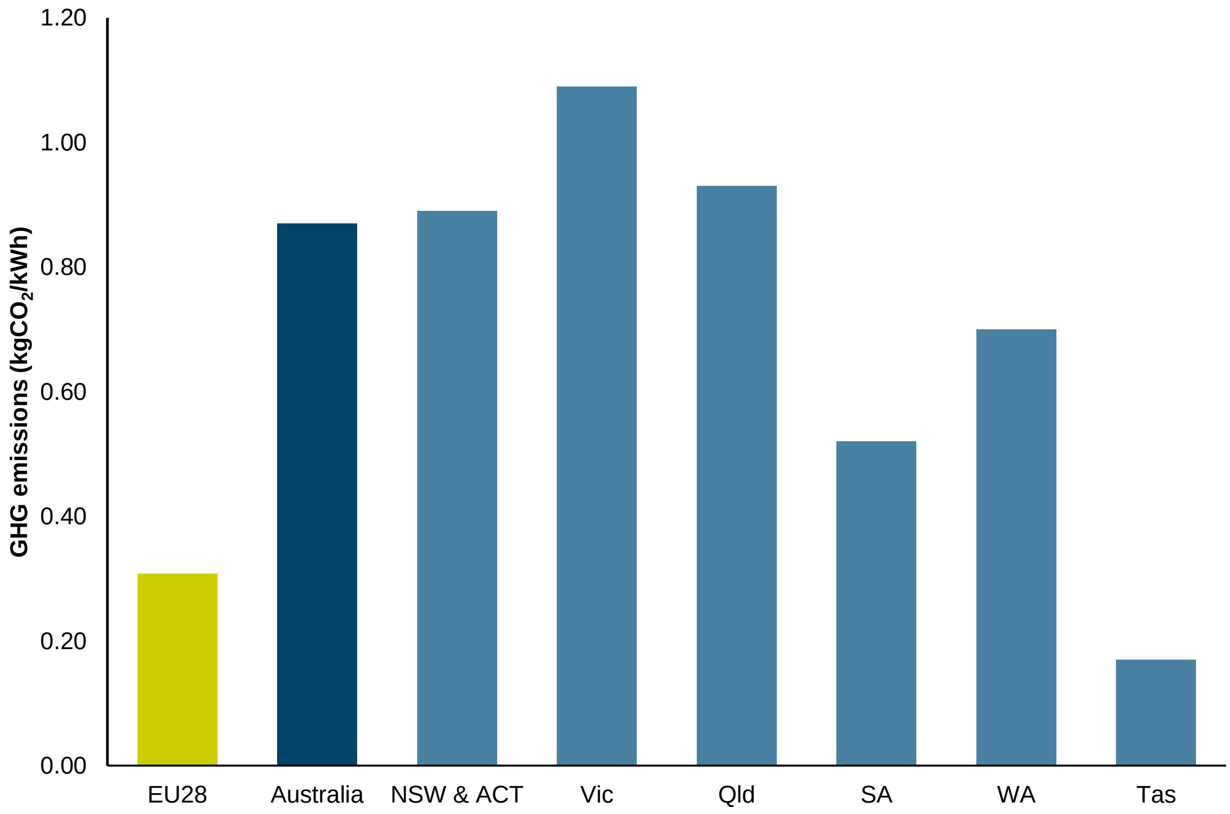
State or territory	Scope 2: electricity generation	Scope 3: electricity distribution	Full cycle	Conversion to EU28	Conversion to Australian average
EU28 (1)	0.28	0.03	0.31	1.00	n/a
Australia	0.78	0.09	0.87	2.83	1.00
NSW & ACT	0.81	0.09	0.89	2.89	1.02
Vic	0.98	0.11	1.09	3.54	1.25
Qld	0.81	0.12	0.93	3.02	1.07
SA	0.43	0.09	0.52	1.69	0.60
WA (2)	0.68	0.02	0.70	2.27	0.80
Tas	0.15	0.02	0.17	0.55	0.20
NT	0.62	0.07	0.70	2.27	0.80

(1) Scope 2 values for 2020 are extrapolated based on 1990 to 2017 values for EU28 electricity generation. The 2017 value is 294.21 gCO_2/kWh. The scope 3 value for Europe is estimated based on the average Australian scope 2/scope 3 ratio.

(2) South-west interconnected system only.

Source: Australian data sourced from the Department of Industry, Science, Energy and Resources (2020), Table 44. EU28 data sourced from European Environment Agency (2020).

Figure 4-1: Carbon intensity of electricity for EU28 and Australia



Source: Australian data sourced from the Department of Industry, Science, Energy and Resources (2020), Table 44. EU28 data sourced from European Environment Agency (2020).

Box 2 — A note of caution on the WTT parameter values for electric vehicles

Upstream (WTT) parameter values for electric vehicles, derived by direct scaling of the values provided in CE Delft (2019a), using the average conversion factor in Table 4-5, are higher than expected (based on what is known regarding average modal efficiencies for Australia) – for both electric passenger road vehicles and electric passenger trains. Some reasons for this discrepancy could include the CE Delft 2019a results possibly having:

- European power stations generally sited relatively close to population centres meaning higher air pollution costs
- different sources and methods used to calculate the baseline rail and road vehicle emission factors, and upstream emission costs, that are key inputs to the WTT parameter values
- differences in rail vehicle types – there is insufficient information available to fully explore the underlying data used to generate electric rail vehicle emission factors
- somewhat overestimated WTT air pollution costs even for the more highly populated European conditions, let alone the more sparsely populated Australian situation.

This, combined with further approximations introduced by the carbon cost scaling discussed in section 4.2.1, makes the baseline WTT parameter values (as presented in Tables 5-5 to 5-16) very approximate and likely to be generally less reliable than the Climate Change parameter values (e.g. will tend to overestimate Australian WTT impacts for electric vehicles). For reference, some alternative WTT parameter evaluations are provided (based on Australian data) in Tables 5-21 and 5-22.

A vehicle's well-to-wheel (WTW) GHG emissions are a combination of upstream (WTT) and exhaust emissions or tank-to-wheel (TTW) emissions as captured by the climate change impact parameter value.

For example, for a medium-sized petrol-power passenger car, the resulting WTW parameter values for aggregate emission output (across the air pollution, climate change and WTT emissions categories based on CE Delft 2019a) would be:

$9.6/1000 km (from the TTW climate change parameter estimate, see Table 5-2), plus

$2.8/1000 km (from the WTT parameter estimate), plus $3.00/1000 km (for the air pollution parameter value); giving a total of

$15.4/1000 km (with $12.4/1000 km for the climate change plus WTT parameters).

For an electric vehicle (based on CE Delft 2019a, again referring to Table 5-2), the total for aggregate emission output would be $14.41/1000 km (with $13.6/1000 km from the WTT cost parameter only). As there are no exhaust emissions from electric vehicles the 'climate change' category costs (from direct energy use) are zero.

In this example from Table 5-2, the WTW aggregate emissions parameter values are similar for the electric vehicle when compared with the petrol vehicle.

Research conducted by the University of Queensland suggested that electric vehicles should generate around 40% fewer lifecycle emissions compared with a similar size internal-combustion-engine vehicle (based on the Australian average emissions intensity of electricity generation) (Whitehead 2019). It should therefore be expected that the relevant unit costs would be of a similar relative magnitude to this.

Further complicating the situation is that CE Delft (2019a) bases its electric vehicle unit costs on a very efficient vehicle type (i.e. using 11.4 kWh/100 km according to CE Delft 2019b). This is below most electric vehicles available for sale in Australia (which tend to range from around 12 to 22 kWh/100 km according to Electric Vehicle Council 2020). If unit values were based on an electric vehicle within this range, the CE Delft 2019a methodology would generate even higher WTT unit costs for electric vehicles.

While electric vehicles only currently represent a very small proportion of Australia's road passenger vehicle fleet, this is likely to grow over time, and since most urban passenger rail is already electric, this WTT anomaly could cause some externality estimation issues.

For comparison, using the Table 5-22 values (derived from Australian data) for a medium-sized passenger car, the resulting WTW parameter estimate for aggregate emission output from the petrol-powered vehicle totals $31.0/1000 km (with $16.5/1000 km for the climate change plus WTT parameters).

When compared with the electric car estimates therein (Table 5-22), the WTW total is 12.5/1000 km (with $11.3/1000 km for the climate change plus WTT parameters). These values (with the EV at around 30% lower than the petrol-powered result for climate change plus WTT parameters, and over 50% lower for aggregate emission output) are more consistent with the Australian results of Whitehead 2019 and Smit 2020).

The ATAP Steering Committee will further consider options to re-adjust the WTT parameter values for electric road and rail vehicles.

4.4 Overview of 2019 European data sets used

Detailed EU28 data that can be used to estimate Australian values to the new level of detail (i.e. for different vehicles types, sizes and fuel types) were only available for a selection of impact categories as shown in Table 4-8. Specifically, detailed values for air pollution, greenhouse gas emissions, and WTT emissions were available. Noise pollution is also available but to a more detailed level. Values for the nature and landscape category were also available, although only at a high (average) level. Other values were not updated. This level of detail is reflected in the new Australian values in this report.

Detailed values were only available as marginal values opposed to average values (which were reported in Austroads 2014). Marginal costs represent the external costs caused by an additional transport activity (CE Delft 2019a), such as the noise costs of adding an additional vehicle to an already busy road. A fuller discussion of average vs marginal costs is provided in Appendix A.

For air pollution, greenhouse gas emissions and WTT emissions, marginal and average values are usually fairly equivalent, which means that the new (detailed) marginal values can be used in exchange for average ones. However, for noise emissions, the marginal values are often different compared to the average values, with this depending on the population density, density of traffic flow and time of day (CE Delft 2019a). Some studies suggest that marginal noise costs are only about 30-60% of the average costs. For details about the differences between average and marginal costs, see Appendix A or refer to CE Delft (2019a, Section 2).

Table 4-8: Level of detail of the parameter value update by impact category

Impact category	Update based on detailed marginal parameter values	Update based on average values	Simple update based on previous Austroads values	Marginal vs. average values comparability	Comments
Air pollution	X	X		Same	Update based on CE Delft (2019a) data
Greenhouse gases (climate change)	X	X		Same	Update based on CE Delft (2019a) data, with subsequent adjustment for Australian estimates of $/tonne of carbon.
Noise	X	X		Different	Update based on CE Delft (2019a) data; marginal difference from average ones
WTT emissions	X	X		Same	Update based on CE Delft (2019a) data, with subsequent adjustment for Australian estimates of $/tonne of carbon.
Soil and water			X	Not applicable (no marginal values available)-	No CE Delft (2019a) data; simple update based on Australian Transport Assessment and Planning (2020)
Nature and landscape		X		Not applicable (no marginal values available)-	CE Delft (2019a) data only available for broader categories like the current set of parameter values
Urban barrier effects			X	Not applicable (no marginal values available)-	No CE Delft (2019a) data; simple update based on Australian Transport Assessment and Planning (2020)
Biodiversity			X	Not applicable (no marginal values available)-	No CE Delft (2019a) data; simple update based on Australian Transport Assessment and Planning (2020)

Note: Data from other jurisdictions such as North America (e.g. Victoria Transport Policy Institute 2016) are available, but is not as comprehensive as the data in CE Delft (2019a), and is relatively outdated. Using an alternative data source was therefore not considered suitable.

5. Parameter values unit cost tables

This section provides the environmental parameter values for practitioners to use. Sections 5.1 and 5.2 produce the average and marginal environmental parameter cost values for passenger and freight transport and all eight impact categories that can be used by practitioners.

Note: Climate change and WTT emissions values provided in this chapter must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.

Transport projects and initiatives will not necessarily have impacts across all environmental impact categories. Practitioners should refer to ATAP Guidelines Part T2 Cost Benefit Analysis (ATAP 2018) for guidance on identifying the benefits and costs of a transport project or initiative. That guidance will help practitioners apply appropriate judgement to identify the right environmental parameters in the context of specific projects or initiatives being assessed. In a CBA, environmental externalities can be expressed as positive or negative benefits of project or initiative options as compared with their base case. Importantly, the calculation of those environmental benefits should take account of any expected induced demand in the project case. Induced demand will lessen the scale of the environmental benefits that would otherwise be expected.

Except for noise impacts, average and marginal cost values are assumed to be the same.

Section 5.3 provides guidance and tools to account for a level of uncertainty in the values provided and Section 5.4 describes how or why the values differ from previous sets of parameter values. It is recommended that practitioners undertake sensitivity testing to assess the robustness of their assessment results, and subsequent decisions, for variations in the environmental unit costs reflected by this range.

It is recommended that practitioners use the unit cost values presented in Sections 5.1 and 5.2 as the mid-point values for the primary central analysis of project assessments and CBAs. Section 5.3 provides some guidance on possible low and high adjustment percentages to be used for sensitivity testing.

5.1 Passenger transport

5.1.1 Passenger transport – urban

Table 5-1: Average parameter values in A$ per 1000 vkt/pkm – passenger transport – urban (June 2023 dollars)

Passenger transport – urban	2-wheelers		Passenger cars		Buses & coaches				Rail	
	Motorcycle		Car		Mini-bus		Bus		Passenger train	
	vkt	pkm	vkt	pkm	vkt	pkm	vkt	pkm	vkt	pkm
Air pollution	10.2	9.7	9.9	6.2	28.2	5.6	124.3	6.5	9.9	0.07
Climate change*	5.0	4.8	10.2	6.3	14.8	3.0	47.0	2.5	0	0
WTT emissions*	2.2	2.1	2.6	1.6	3.3	0.66	12.5	0.65	1,093	8.2
Noise	82.0	78.1	7.8	4.8	9.9	2.0	55.1	2.9	709	12.0
Soil and water	3.3	3.2	3.3	2.2	4.5	0.9	39.1	4.1	54.3	0.92
Nature and landscape	0.69	0.65	1.8	1.1	1.8	0.36	4.1	0.21	98.3	1.7
Urban effects	5.9	5.6	5.9	3.7	5.2	1.0	17.3	1.8	54.3	0.92
Biodiversity	0.81	0.77	0.81	0.46	0.35	0.07	6.4	0.69	0.68	0.012

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

For the impact categories of air pollution, climate change, WTT emissions, noise: all values are based on data from CE Delft (2019a), following the methodology described in Section 4. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

For the impact category of nature and landscape: following Austroads (2014), urban values are 10% of rural values, whereby rural values are based on data from CE Delft (2019a), following the methodology described in Section 4.

For the impact categories of soil and water, urban effects, biodiversity: values are indexed based on ATAP (2020); vehicle occupancy rates and payloads according to CE Delft (2019a) were used where applicable (refer to Appendix C).

Table 5-2: Marginal parameter values for air pollution, climate change and WTT emissions in A$ per 1000 vkt/pkm – passenger transport – urban (June 2023 dollars)

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	pkm	vkt	pkm	vkt	pkm	
2-wheelers	e-bike	Electric	0	0	0	0	0.34	0.32	Assumed to be 20% of electric motorcycle[7]
	Scooter/moped	Petrol	7.4	7.0	3.3	3.2	1.0	0.9	4-stroke only[8]
		Electric	0.20	0.19	0	0	1.7	1.60	Equals motorcycle
	Motorcycle	Petrol	9.5	9.0	6.3	6.0	1.8	1.8	4-stroke only
		Electric	0.20	0.19	0	0	1.7	1.6	
Passenger cars	Mini	Petrol	0.72	0.46	7.3	4.6	2.1	1.4	Euro 4-6 only, hence low value
		LPG	0.63	0.41	7.0	4.5	1.2	0.7	Based on small petrol vs. LPG ratio
		Diesel	15.8	10.1	6.4	4.1	1.2	0.74	
		Hybrid	1.1	0.68	4.5	2.9	1.2	0.78	
		Electric	0.81	0.51	0	0	13.6	8.6	
	Small	Petrol	2.9	1.8	8.3	5.2	2.4	1.5	
		LPG	2.5	1.6	7.9	5.0	1.3	0.84	
		Diesel	21.7	13.8	8.7	5.5	1.6	1.0	
		Hybrid	1.1	0.69	4.5	2.9	1.2	0.8	
		Electric	0.81	0.51	0	0	13.6	8.6	
	Medium	Petrol	3.0	1.9	9.6	6.1	2.8	1.8	
		LPG	2.6	1.6	9.3	5.9	1.5	1.0	Based on small petrol vs. LPG ratio

[7] Baseline dataset did not provide unique values for e-bikes. An alternative reference for e-bike emission values was not found. In recognition that e-bike emissions would be small, the values were assumed to be 20% of those generated by an electric motorbike.

[8] Scooter/moped refers to on-road registered vehicles (e.g. Vespas) and emissions values are assumed to be equivalent to motorbikes. Practitioners should use the e-bike values for micro-mobility small scooters (e.g. electric-powered kick scooters such as Lime scooters).

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	pkm	vkt	pkm	vkt	pkm	
		Diesel	21.9	13.9	10.4	6.6	1.9	1.2	
		Hybrid	1.1	0.69	4.5	2.9	1.2	0.78	Equals small & large
		Electric	0.81	0.51	0	0	13.6	8.6	
	Large	Petrol	3.0	1.9	12.0	7.6	3.5	2.2	
		LPG	2.6	1.7	11.5	7.3	1.9	1.2	Based on small petrol vs. LPG ratio
		Diesel	22.0	14.0	12.0	7.6	2.2	1.4	
		Hybrid	1.1	0.69	4.5	2.9	1.2	0.78	
		Electric	0.81	0.51	0	0	13.6	8.6	
	SUV/4WD	Petrol	3.0	1.9	10.8	6.9	3.2	2.0	Average medium & large
		LPG	2.6	1.7	10.4	6.6	1.7	1.1	Based on small petrol vs. LPG ratio
		Diesel	21.9	13.9	11.2	7.1	2.0	1.3	Average medium & large
		Hybrid	1.1	0.69	4.5	2.9	1.2	0.78	Equals small & large
		Electric	0.81	0.51	0	0	13.6	8.6	Equals electric
Buses and coaches	Mini-bus	Petrol	3.5	0.70	12.5	2.5	3.7	0.73	Estimation based on goods LCVs; assumed avg. occupancy of 5 passengers per vehicle
		Diesel	38.7	7.7	14.1	2.8	2.8	0.57	Estimation based on goods LCVs; assumed avg. occupancy of 5 passengers per vehicle
		Electric	0.81	0.16	0	0	39.1	7.8	Estimation based on goods LCVs; assumed avg. occupancy of 5 passengers per vehicle
	Small urban bus <15 t	Diesel	96.8	7.2	31.9	2.4	5.8	0.43	Midi bus
		Electric	2.4	0.18	0	0	75.1	5.6	Midi bus
	Medium urban bus 15-18 t	Diesel	125	7.4	40.9	2.4	7.4	0.44	Standard bus
		CNG	277	16.4	82.5	4.9	13.2	0.78	Standard bus; Euro I, II, III, IV only, hence high value

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	pkm	vkt	pkm	vkt	pkm	
		Electric	2.4	0.14	0	0	108.5	6.4	Standard bus
	Large urban bus >18 t	Diesel	153	7.5	51.1	2.5	9.3	0.46	Articulated bus
		Electric	2.4	0.12	0	0	134	6.6	Articulated bus
	Busway	Diesel	153	7.5	51.1	2.5	9.3	0.46	Equals articulated urban bus
		Electric	2.4	0.12	0	0	134	6.6	Equals articulated urban bus
	Coach	Diesel	135	9.0	41.6	2.8	7.5	0.50	Standard coach
Rail	Tram	Electric	7.6	0.15	0	0	502	10.0	Urban only
	Metro single-decker	Electric	15.2	0.06	0	0	1,004	4.0	Urban only
	Metro double-decker	Electric	15.2	0.04	0	0	1,004	2.2	Urban only
	Inter-city	Diesel	522	6.0	93.9	1.1	67.2	0.77	Without exhaust gas recirculation (EGR), or selective catalytic reduction (SCR)
	Regional	Diesel	553	17.8	122.4	4.0	33.6	1.1	Without exhaust gas recirculation (EGR), or selective catalytic reduction (SCR)

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

All values are based on data from CE Delft (2019a), following the methodology described in Section 4. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.In some cases, additional sources were used as noted in the comments column.

Climate change parameter values equal zero for (battery) electric vehicles as they do not produce tailpipe emissions, but their emissions are accounted for in upstream electricity generation activities.

CE Delft (2019a) provides a single unit cost value for (battery) electric vehicles, regardless of the size. Logically, different vehicle sizes would provide different WTT emission values. However, a lack of more detailed data means that the WTT emission values are the same for all passenger cars regardless of size. Due to the small number of electric vehicles in today's fleets, the impact of using a single parameter value for all electric passenger cars is negligible.

Table 5-3: Marginal parameter values for noise pollution in A$ per 1000 vkt/pkm – passenger transport – urban (June 2023 dollars)

Vehicle category	Vehicle type	Time of day	Traffic density	Noise	
				vkt	pkm
2-wheelers	Motorcycle	Day	Dense	51.9	47.2
			Thin	126	115
		Night	Dense	94.6	86.0
			Thin	230	209
Passenger cars		Day	Dense	4.8	3.0
			Thin	11.6	7.3
		Night	Dense	8.7	5.4
			Thin	21.2	13.2
Buses and coaches	Mini-bus	Day	Dense	10.7	2.1
			Thin	25.9	5.2
		Night	Dense	19.4	3.9
			Thin	47.3	9.5
	Bus	Day	Dense	57.5	3.4
			Thin	140	8.3
		Night	Dense	105	6.2
			Thin	255	15.1
	Coach	Day	Dense	33.6	1.8
			Thin	81.7	4.3
		Night	Dense	61.2	3.2
			Thin	149	7.9
Rail	Inter-regional passenger train	Day	Dense	437	3.3

Vehicle category	Vehicle type	Time of day	Traffic density	Noise	
				vkt	pkm
			Thin	718	5.4
		Night	Dense	796	6.0
			Thin	1,307	9.9

Notes:

All values are based on data from CE Delft (2019a), following the methodology described in Section 4.

Marginal noise parameter values for air and water transport are not available.

Dense and thin traffic density refers to heavy and light traffic conditions. Users should interpret this broadly in terms of typical road and rail traffic conditions in Australia. As a guide, the Guide to Pavement Technology Part 2: Pavement Structural Design (Austroads 2019b) *classified roads with high traffic volumes as those with greater than 2000 vehicle per lane per day.*

5.1.2 Passenger transport – rural

Table 5-4: Average parameter values in A$ per 1000 vkt/pkm – passenger transport – rural (June 2023 dollars)

Passenger transport – rural	2-wheelers		Passenger car		Buses & coaches				Rail	
	Motorcycle		Car		Mini-bus		Bus		Passenger train	
	vkt	pkm	vkt	pkm	vkt	pkm	vkt	pkm	vkt	pkm
Air pollution	0.11	0.09	0.09	0.06	0	0	0	0	4.1	0.07
Climate change*	5.0	4.8	10.2	6.3	14.8	3.0	47.0	2.5	108	1.8
WTT emissions*	2.2	2.1	2.6	1.6	3.3	0.66	12.5	0.7	28.1	0.48
Noise	0.82	0.78	0.08	0.05	0.09	0.02	0.55	0.02	70.9	1.2
Soil and water	0.35	0.33	0.35	0.23	0.01	0.00	0.46	0.05	0.68	0.01
Nature and landscape	6.9	6.6	17.6	10.9	17.8	3.6	40.8	2.1	983	16.7
Urban effects	-	-	-	-	-	-	-	-	-	-
Biodiversity	0	0	0	0	0	0	0	0	0	0

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

For the impact categories of air pollution, climate change, WTT emissions, noise, nature and landscape: all values are based on data from CE Delft (2019a), following the methodology described in Section 4. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

Rural air pollution values are estimated based on urban air pollution values, applying the following factors based on Austroads (2014): 0% for buses and coaches, 1% for 2-wheelers, passenger cars, and rail.

Rural climate change and WTT emission values are the same as urban ones.

Rural noise values are estimated based on urban noise values, applying the following factors: 1% for 2-wheelers, passenger cars, buses and coaches, and 10% for rail.

For the impact categories of soil and water, biodiversity: the values are indexed based on ATAP (2020); vehicle occupancy rates and payloads according to CE Delft (2019a) were used where applicable (refer to Appendix C).

The impact category of urban effect is not applicable. Urban values can be used for rural towns.

Table 5-5: Marginal parameter values for air pollution, climate change and WTT emissions in A$ per 1000 vkt/pkm – passenger transport – rural (June 2023 dollars)

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	pkm	vkt	pkm	vkt	pkm	
2-Wheelers	e-Bike	Electric	0	0	0	0	0.34	0.32	Assumed to be 20% of electric motorcycle[9]
	Scooter/ moped	Petrol	3.7	3.5	3.3	3.2	1.0	0.93	4-stroke only[10]
		Electric	0.20	0.20	0	0	1.7	1.6	Equals motorcycle
	Motorcycle	Petrol	5.7	5.4	5.0	4.8	1.5	1.4	4-stroke only
		Electric	0.20	0.20	0	0	1.7	1.6	
Passenger Cars	Mini	Petrol	0.27	0.18	6.1	3.9	1.8	1.1	Euro 4-6 only, hence low value
		LPG	0.23	0.15	5.7	3.6	1.0	0.61	Based on small petrol vs. LPG ratio
		Diesel	8.4	5.3	5.6	3.5	1.0	0.64	
		Hybrid	1.0	0.63	3.7	2.4	1.0	0.64	
		Electric	0.82	0.53	0	0	13.6	8.6	
	Small	Petrol	1.9	1.2	7.0	4.5	2.1	1.3	
		LPG	1.7	1.1	6.7	4.2	1.1	0.71	
		Diesel	10.4	6.6	7.4	4.7	1.4	0.86	
		Hybrid	1.0	0.6	3.7	2.4	1.0	0.65	
		Electric	0.82	0.53	0	0	13.6	8.6	
	Medium	Petrol	2.0	1.3	8.4	5.3	2.5	1.6	
		LPG	1.7	1.1	7.9	5.0	1.3	0.8	Based on small petrol vs. LPG ratio

[9] The baseline dataset did not provide unique values for e-bikes. The study had not identified an alternative reference for e-bike emission values. In recognition that e-bike emissions would be small, the values were assumed to be 20% of those generated by an electric motorbike.

[10] Scooter/moped refers to on-road registered vehicles (e.g. Vespa) and emission values are assumed to be equivalent to motorbikes. Practitioners should use the e-bike values for micro-mobility small scooters (e.g. electric-powered kick scooters such as Lime scooters).

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	pkm	vkt	pkm	vkt	pkm	
		Diesel	10.5	6.7	8.7	5.5	1.6	1.0	
		Hybrid	1.0	0.63	3.7	2.4	1.0	0.65	Equals small & large
		Electric	0.8	0.5	0	0	13.6	8.6	
	Large	Petrol	2.0	1.3	10.6	6.7	3.1	2.0	
		LPG	1.7	1.1	10.0	6.3	1.7	1.1	Based on small petrol vs. LPG ratio
		Diesel	10.6	6.7	10.0	6.3	1.8	1.1	
		Hybrid	1.0	0.63	3.7	2.4	1.0	0.65	
		Electric	0.82	0.53	0	0	13.6	8.6	
	SUV/4WD	Petrol	2.0	1.3	9.5	6.0	2.8	1.8	Average medium & large
		LPG	1.7	1.1	8.9	5.7	1.5	0.95	Based on small petrol vs. LPG ratio
		Diesel	10.6	6.7	9.3	5.9	1.7	1.1	Average medium & large
		Hybrid	1.0	0.63	3.7	2.4	1.0	0.65	Equals small & large
		Electric	0.82	0.53	0	0	13.6	8.6	Equals electric
Buses and Coaches	Mini-Bus	Petrol	2.3	0.46	10.0	2.0	2.9	0.59	Estimation based on goods LCVs; assumed avg. 5 pax. vehicle occupancy
		Diesel	18.7	3.7	10.4	2.1	2.1	0.42	Estimation based on goods LCVs; assumed avg. 5 pax. vehicle occupancy
		Electric	0.82	0.16	0	0	39.1	7.8	Estimation based on goods LCVs; assumed avg. 5 pax. vehicle occupancy
	Small Urban Bus <15t	Diesel	42.9	3.2	28.3	2.1	5.1	0.38	Midi bus
		Electric	1.8	0.13	0	0	75.1	5.6	Midi bus
	Medium Urban Bus 15-18t	Diesel	55.3	3.3	36.5	2.2	6.6	0.39	Standard bus
		CNG	158	9.4	81.9	4.9	13.2	0.78	Standard bus; Euro I, II, III, IV only, hence high value
		Electric	1.8	0.11	0	0	109	6.4	Standard bus

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	pkm	vkt	pkm	vkt	pkm	
	Large Urban Bus >18t	Diesel	67.4	3.3	46.8	2.3	8.5	0.42	Articulated bus
		Electric	1.8	0.08	0.0	0.0	134	6.6	Articulated bus
	Busway	Diesel	67.4	3.3	46.8	2.3	8.5	0.42	Equals articulated urban bus
		Electric	1.8	0.08	0	0	134	6.6	Equals articulated urban bus
	Coach	Diesel	56.6	3.8	36.0	2.4	6.5	0.43	Standard coach
Rail	Tram	Electric	-	-	-	-	-	-	Not applicable, urban only
	Metro Single-Decker	Electric	-	-	-	-	-	-	Not applicable, urban only
	Metro Double-Decker	Electric	-	-	-	-	-	-	Not applicable, urban only
	Inter-City	Diesel	306	3.5	93.9	1.1	67.2	0.77	Without exhaust gas recirculation (EGR), or selective catalytic reduction (SCR)
	Regional	Diesel	324	10.4	122	4.0	33.6	1.1	Without exhaust gas recirculation (EGR), or selective catalytic reduction (SCR)

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

All values are based on data from CE Delft (2019a), following the methodology described in Section 4. In some cases, additional sources were used as noted in the comments column. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

Climate change parameter values equal zero for (battery) electric vehicles as they do not produce tailpipe emissions, but their emissions are accounted for in upstream electricity generation activities.

CE Delft (2019a) provides a single unit cost value for (battery) electric vehicles, regardless of the size. Logically, different vehicle sizes would provide different WTT emission values. However, a lack of more detailed data means that the WTT emission values are the same for all passenger cars regardless of size. Due to the small number of electric vehicles in today's fleets, the impact of using a single parameter value for all electric passenger cars is negligible.

Table 5-6: Marginal parameter values for noise pollution in A$ per 1000 vkt/pkm – passenger transport – rural (June 2023 dollars)

Vehicle category	Vehicle type	Time of day	Traffic density	Noise	
				vkt	pkm
2-wheelers	Motorcycle	Day	Dense	0.61	0.55
			Thin	1.31	1.18
		Night	Dense	1.08	0.97
			Thin	2.33	2.12
Passenger car		Day	Dense	0.05	0.04
			Thin	0.12	0.07
		Night	Dense	0.11	0.06
			Thin	0.21	0.13
Bus	Mini-bus	Day	Dense	0.12	0.02
			Thin	0.27	0.06
		Night	Dense	0.22	0.05
			Thin	0.48	0.09
	Bus	Day	Dense	0.65	0.04
			Thin	1.43	0.08
		Night	Dense	1.19	0.07
			Thin	2.59	0.15
	Coach	Day	Dense	0.39	0.02
			Thin	0.83	0.05
		Night	Dense	0.70	0.04
			Thin	1.52	0.08
Rail	Inter-regional passenger train	Day	Dense	32.9	0.25

Vehicle category	Vehicle type	Time of day	Traffic density	Noise	
				vkt	pkm
			Thin	54.5	0.41
		Night	Dense	60.2	0.46
			Thin	99.1	0.75

Notes:

All values are based on data from CE Delft (2019a), following the methodology described in Section 4.

Marginal noise parameter values for air and water transport are not available.

Dense and thin traffic density refers to heavy and light traffic conditions. Users should interpret this broadly in terms of typical road and rail traffic conditions in Australia. As a guide, the Guide to Pavement Technology Part 2: Pavement Structural Design (Austroads 2019b) *classified roads with high traffic volumes as those with greater than 2000 vehicle per lane per day.*

5.1.3 Passenger transport – other

Table 5-7: Average parameter values in A$ per 1000 vkt/pkm – passenger transport – other (June 2023 dollars)

Passenger transport – other	Aviation		Water transport	
	vkt	pkm	vkt	pkm
Air pollution	355	2.7	11,089	117
Climate change*	1,318	9.9	279	2.9
WTT emissions*	503	3.8	105	1.1
Noise	278	2.1		
Soil and water				
Nature and landscape	18.2	0.14		
Urban effects				
Biodiversity				

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

There is no differentiation between urban and rural values for aviation and water transport.

For passenger water transport, values are based on Transport for NSW (2016) and represent the average Sydney ferry fleet. The WTT emission value is estimated based on the climate change value as no explicit WTT emission values were available in Transport for NSW (2016).

For the impact categories of air pollution, climate change, WTT emissions, noise, nature and landscape: all values are based on data from CE Delft (2019a), following the methodology described in Section 4. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

For the impact categories of soil and water, urban effects, biodiversity: data is not available or not applicable.

Table 5-8: Marginal parameter values for air pollution, climate change and WTT emissions in A$ per 1000 vkt/pkm – passenger transport – other (June 2023 dollars)

Vehicle category	Vehicle type	Fuel type	Distance	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a), and additional sources used
				vkt	pkm	vkt	pkm	vkt	pkm	
Aviation	Small aircraft	Other	500 km	497	8.5	1,369	23.5	579	9.9	Estimation based on Qantas (2020a) in relation to data from CE Delft (2019a)
	Medium-small aircraft	Other	1000 km	371	4.7	1,335	16.9	507	6.4	Estimation based on Qantas (2020a) in relation to data from CE Delft (2019a)
	Medium aircraft (low emissions)	Other	1500 km	231	1.6	1,226	8.2	409	2.7	
		Other	3000 km	153	1.0	1,146	7.7	459	3.1	
	Medium aircraft (high emissions)	Other	1500 km	259	2.2	1,374	11.7	459	3.9	
		Other	3000 km	171	1.5	1,284	10.9	515	4.4	
Water transport	Local ferry	Diesel		11,089	117	279	2.9	105	1.1	WTT values estimated based on climate change values reported in Transport for NSW (2016); the values represent the average Sydney ferry fleet
	Large (RoPax) ferry[11]	Diesel	100 km	357,392	677	31,145	59.0	11,762	22.3	
		Diesel	500 km	249,402	472	15,679	29.7	5,921	11.2	

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

All values are based on data from CE Delft (2019a), following the methodology described in Section 4. In some cases, additional sources were used, as noted in the comments column. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

Aircraft types considered: small = Bombardier Dash 8 Q400, medium-small = Fokker 100, medium low emission = Airbus A320, medium high emission = Boeing 737.

[11] Large ferry values based on a RoPax ferry (25 500 gt). RoPax ferries have both passenger and vehicle carrying capacities. The Spirit of Tasmania vessels that service the Melbourne-Devonport route are examples of RoPax used in Australia. Pkm unit values may be overstated where RoPax vessels also carry freight (as the Spirit of Tasmania vessels do).

5.2 Freight Transport

5.2.1 Freight transport – urban

Table 5-9: Average parameter values in A$ per 1000 vkt/tkm – freight transport – urban (June 2023 dollars)

Freight transport – urban	LCV (vans and utes)		HVs		Rail (freight trains)	
	vkt	tkm	vkt	tkm	vkt	tkm
Air pollution	28.2	40.8	81.7	6.6	2,661	5.9
Climate change*	14.8	21.4	34.8	2.8	604	1.3
WTT emissions*	3.3	4.8	10.4	0.84	256	0.57
Noise	9.9	14.3	51.1	9.9	1,753	3.9
Soil and water	4.5	6.5	35.7	3.2	612	0.57
Nature and landscape	1.8	2.6	4.8	0.39	220	0.49
Urban effects	5.2	7.5	26.5	2.3	367	0.35
Biodiversity	0.35	0.50	12.7	1.1	12.2	0.01

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

For the impact categories of air pollution, climate change, WTT emissions, noise: all values are based on data from CE Delft (2019a), following the methodology described in Section 4. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

For the impact category of nature and landscape: following Austroads (2014), urban values are 10% of rural values, whereby rural values are based on data from CE Delft (2019a), following the methodology described in Section 4

For the impact categories of soil and water, urban effects, biodiversity: the values are indexed based on ATAP (2020); vehicle occupancy rates and payloads according to CE Delft (2019a) were used where applicable (refer to Appendix C).

Table 5-10: Marginal parameter values for air pollution, climate change and WTT emissions in A$ per 1000 vkt/tkm – freight transport – urban (June 2023 dollars)

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	tkm	vkt	tkm	vkt	tkm	
LCV	All: van, ute	Petrol	3.5	5.1	12.5	18.1	3.7	5.3	
		Diesel	38.7	55.8	14.1	20.3	2.8	4.1	
		Electric	0.8	1.2	0.0	0.0	39.1	56.5	
Heavy vehicles	Rigid <7.5 t	Diesel	57.2	69.3	18.8	22.8	3.4	4.1	
		Electric	2.4	2.9	0	0	75.1	91.1	Estimation based on small electric bus; assumed load of equivalent diesel HV
	Rigid 7.5-12 t	Diesel	81.0	38.6	25.5	12.1	4.6	2.2	
		Electric	2.4	1.2	0	0	109	51.8	Estimation based on medium electric bus; assumed load of equivalent diesel HV
	Rigid 12-14 t	Diesel	87.2	22.5	26.4	6.8	4.8	1.2	
	Rigid 14-20 t	Diesel	107	26.0	31.1	7.6	5.6	1.4	
	Rigid 20-26 t	Diesel	131	15.5	37.9	4.5	6.9	0.81	
	Rigid 26-28 t	Diesel	134	11.3	40.0	3.4	7.3	0.61	
	Rigid 28-32 t	Diesel	152	10.4	46.2	3.2	8.4	0.57	
	Rigid >32 t	Diesel	155	9.3	45.7	2.7	8.3	0.49	
	Artic. 14 - 20 t	Diesel	98.8	13.9	29.9	4.2	5.4	0.76	
	Artic. 20 - 28 t	Diesel	127	14.7	38.0	4.4	6.9	0.79	
	Artic. 28 - 34 t	Diesel	133	9.1	40.3	2.8	7.3	0.50	
	Artic. 34 - 40 t	Diesel	154	9.2	45.7	2.7	8.3	0.50	
	Artic. 40 - 50 t	Diesel	168	8.6	51.1	2.6	9.3	0.47	
	Artic. 50 - 60 t	Diesel	198	8.9	61.7	2.8	11.2	0.50	
Rail	Short container	Diesel	3,091	6.2	634	0.84	175	0.13	

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	tkm	vkt	tkm	vkt	tkm	
	Short bulk	Diesel	3,094	4.1	658	0.47	182	0.11	
	Long container	Diesel	3,103	2.2	554	0.40	153	0.31	
	Long bulk	Diesel	3,106	1.9	569	0.36	157	0.21	

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

All values are based on data from CE Delft (2019a), following the methodology described in Section 4. In some cases, additional sources were used as noted in the comments column. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

Climate change parameter values equal zero for (battery) electric vehicles as they do not produce tailpipe emissions, but their emissions are accounted for in upstream electricity generation activities.

Table 5-11: Marginal parameter values for noise pollution in A$ per 1000 vkt/tkm – freight transport – urban (June 2023 dollars)

Vehicle category	Vehicle type	Time of day	Traffic density	Noise	
				vkt	tkm
LCV		Day	Dense	10.7	15.4
			Thin	25.9	37.5
		Night	Dense	19.4	28.1
			Thin	47.3	68.3
Heavy vehicles	HV 3.5-7.5 t	Day	Dense	34.9	9.4
			Thin	85.0	22.9
		Night	Dense	63.6	17.1
			Thin	155	41.7
	HV 7.5-16 t	Day	Dense	50.0	4.6
			Thin	122	11.3
		Night	Dense	91.0	8.4
			Thin	221	20.6
	HV 16-32 t	Day	Dense	56.1	3.5
			Thin	136	8.6
		Night	Dense	102	6.4
			Thin	248	15.7
	HV >32 t	Day	Dense	62.9	3.8
			Thin	153	9.2
		Night	Dense	114	6.8
			Thin	278	16.7
Rail	Freight train	Day	Dense	489	0.93

Vehicle category	Vehicle type	Time of day	Traffic density	Noise	
				vkt	tkm
			Thin	665	1.3
		Night	Dense	890	1.7
			Thin	1,460	2.8

Notes:

Marginal noise parameter values for air and water transport are not available.

Dense and thin traffic density refers to heavy and light traffic conditions. Users should interpret this broadly in terms of typical road and rail traffic conditions in Australia. As a guide, the Guide to Pavement Technology Part 2: Pavement Structural Design (Austroads 2019b) *classified roads with high traffic volumes as those with greater than 2000 vehicle per lane per day.*

5.2.2 Freight transport – rural

Table 5-12: Average parameter values in A$ per 1000 vkt/tkm – freight transport – rural (June 2023 dollars)

Freight transport – rural	LCVs (vans and utes)		HVs		Rail (freight trains)	
	vkt	tkm	vkt	tkm	vkt	tkm
Air pollution	0	0	8.2	0.67	26.6	0.06
Climate change*	14.8	21.4	34.8	2.8	604	1.3
WTT emissions*	3.3	4.8	10.4	0.84	256	0.57
Noise	0.09	0.14	0.51	0.09	175	0.39
Soil and water	0	0	12.7	1.1	12.2	0.01
Nature and landscape	17.8	25.9	47.7	3.9	2,200	4.9
Urban effects	-	-	-	-	-	-
Biodiversity	0	0	36.8	3.3	245	0.23

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

For the impact categories of air pollution, climate change, WTT emissions, noise, nature and landscape: all values are based on data from CE Delft (2019a), following the methodology described in Section 4. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

Rural air pollution values are estimated based on urban air pollution values, applying the following factors based on Austroads (2014): 0% for LCVs, 1% for rail, 10% for HVs.

Rural climate change and WTT emission values are the same as urban ones.

Rural noise values are estimated based on urban noise values, applying the following factors: 1% for 2-wheelers, passenger cars, buses and coaches, and 10% for rail.

For the impact categories of soil and water, biodiversity: the values are indexed based on ATAP (2020); vehicle occupancy rates and payloads according to CE Delft (2019a) were used where applicable (refer to Appendix C).

The impact category of urban effect is not applicable. Urban values can be used for rural towns.

Table 5-13: Marginal parameter values for air pollution, climate change and WTT emissions in A$ per 1000 vkt/tkm – freight transport – rural (June 2023 dollars)

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	tkm	vkt	tkm	vkt	tkm	
Light	All: van, ute	Petrol	2.3	3.3	10.0	14.5	2.9	4.2	
		Diesel	18.7	27.0	10.4	15.0	2.1	3.0	
		Electric	0.82	1.2	0	0	39.1	56.5	
Heavy	Rigid <7.5 t	Diesel	29.5	35.7	16.0	19.4	2.9	3.5	
		Electric	1.8	2.1	0	0	75.1	91.1	Estimation based on small electric bus; assumed load of equivalent diesel HV
	Rigid 7.5-12 t	Diesel	39.8	19.0	22.8	10.9	4.1	2.0	
		Electric	1.8	0.8	0	0	109	51.8	Estimation based on medium electric bus; assumed load of equivalent diesel HV
	Rigid 12-14 t	Diesel	41.9	10.8	24.2	6.3	4.4	1.1	
	Rigid 14-20 t	Diesel	49.8	12.1	28.5	6.9	5.2	1.3	
	Rigid 20-26 t	Diesel	60.4	7.1	34.8	4.1	6.3	0.74	
	Rigid 26-28 t	Diesel	61.3	5.2	37.1	3.1	6.7	0.57	
	Rigid 28-32 t	Diesel	70.2	4.8	43.1	2.9	7.8	0.53	
	Rigid >32 t	Diesel	70.8	4.2	42.2	2.5	7.6	0.46	
	Artic. 14 - 20 t	Diesel	45.0	6.3	27.5	3.9	5.0	0.70	
	Artic. 20 - 28 t	Diesel	57.7	6.6	35.3	4.1	6.4	0.74	
	Artic. 28 - 34 t	Diesel	59.7	4.1	37.4	2.6	6.8	0.46	
	Artic. 34 - 40 t	Diesel	68.9	4.1	42.3	2.5	7.7	0.46	
	Artic. 40 - 50 t	Diesel	75.4	3.9	47.1	2.4	8.5	0.44	
	Artic. 50 - 60 t	Diesel	87.9	3.9	56.2	2.5	10.2	0.46	
Rail	Short container	Diesel	1,644	3.3	634	0.84	175	0.13	

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a)
			vkt	tkm	vkt	tkm	vkt	tkm	
	Short bulk	Diesel	1,647	2.2	658	0.47	182	0.11	
	Long container	Diesel	1,657	1.2	554	0.40	153	0.31	
	Long bulk	Diesel	1,660	1.0	569	0.36	157	0.21	

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

All values are based on data from CE Delft (2019a), following the methodology described in Section 4. In some cases, additional sources were used as noted in the comments column. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

Climate change parameter values equal zero for (battery) electric vehicles as they do not produce tailpipe emissions, but their emissions are accounted for in upstream electricity generation activities.

Table 5-14: Marginal parameter values for noise pollution in A$ per 1000 vkt/tkm –freight transport – rural (June 2023 dollars)

Vehicle category	Vehicle type	Time of day	Traffic density	Noise	
				vkt	tkm
LCV		Day	Dense	0.12	0.18
			Thin	0.27	0.39
		Night	Dense	0.22	0.32
			Thin	0.48	0.70
Heavy vehicles	HV 3.5-7.5 t	Day	Dense	0.40	0.11
			Thin	0.86	0.23
		Night	Dense	0.72	0.20
			Thin	1.6	0.42
	HV 7.5-16 t	Day	Dense	0.6	0.05
			Thin	1.2	0.12
		Night	Dense	1.0	0.09
			Thin	2.2	0.21
	HV 16-32 t	Day	Dense	0.63	0.04
			Thin	1.4	0.08
		Night	Dense	1.2	0.07
			Thin	2.5	0.16
	HV >32 t	Day	Dense	0.71	0.05
			Thin	1.6	0.09
		Night	Dense	1.3	0.08
			Thin	2.8	0.16
Rail	Freight train	Day	Dense	33.7	0.06

Vehicle category	Vehicle type	Time of day	Traffic density	Noise	
				vkt	tkm
			Thin	55.4	0.11
		Night	Dense	61.3	0.12
			Thin	101	0.19

Notes:

All values are based on data from CE Delft (2019a), following the methodology described in Section 4.

Marginal noise parameter values for air and water transport are not available.

Dense and thin traffic density refers to heavy and light traffic conditions. Users should interpret this broadly in terms of typical road and rail traffic conditions in Australia. As a guide, the Guide to Pavement Technology Part 2: Pavement Structural Design (Austroads 2019b) *classified roads with high traffic volumes as those with greater than 2000 vehicle per lane per day.*

5.2.3 Freight transport – other

Table 5-15: Average parameter values in A$ per 1000 vkt/tkm – freight transport – other (June 2023 dollars)

Freight transport – other	Aviation		Water transport	
	vkt	tkm	vkt	tkm
Air pollution	355	12.2	596,273	9.3
Climate change*	1,318	45.3	5,502	0.9
WTT emissions*	503	17.3	20,477	0.3
Noise	278	9.5		
Soil and water				
Nature and landscape	18.2	0.62		
Urban effects				
Biodiversity				

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

There is no differentiation between urban and rural values for aviation and water transport.

For the impact categories of air pollution, climate change, WTT emissions, noise, nature and landscape: all values are based on data from CE Delft (2019a), following the methodology described in Section 4. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

For the impact categories of soil and water, urban effects, biodiversity: data is not available or not applicable.

Table 5-16: Marginal parameter values for air pollution, climate change and WTT emissions in A$ per 1000 vkt/tkm – freight transport – other (June 2023 dollars)

Vehicle category	Vehicle type	Fuel type	Distance	Air pollution		Climate change*		WTT emissions*		Comments or clarifications based on CE Delft (2019a), and additional sources used
				vkt	tkm	vkt	tkm	vkt	tkm	
Aviation	Small aircraft	Other	1000 km	371	37.1	500	50.0	190	19.0	Estimation based on Qantas Freight (2020) in relation to data from CE Delft (2019a); payloads based on Air Charter Service (2020)
	Medium aircraft	Other	1500 km	259	13.4	515	26.7	172	8.9	Payloads based on Air Charter Service (2020)
		Other	3000 km	171	8.9	481	25.0	193	10.0	Payloads based on Air Charter Service (2020)
Water transport (maritime)	Small container vessel	Other	500 km	510,025	21.2	16,463	0.69	6,217	0.26	Average tier 0, 1, 2
		Other	3000 km	219,588	9.2	9,046	0.38	3,416	0.14	Average tier 0, 1, 2
	Small bulk vessel	Other	500 km	177,209	11.8	4,808	0.32	1,816	0.12	Average tier 0, 1, 2
		Other	3000 km	988,348	8.6	3,466	0.23	1,309	0.09	Average tier 0, 1, 2
	Large container vessel	Other	500 km	521,754	4.5	24,889	0.22	9,399	0.08	Average tier 0, 1, 2
		Other	3000 km	436,293	4.2	19,586	0.17	7,397	0.06	Average tier 0, 1, 2
	Large bulk vessel	Other	500 km	215,449	2.1	11,717	0.11	4,425	0.04	Average tier 0, 1, 2
		Other	3000 km	371	37.1	500	50.0	190	19.0	Average tier 0, 1, 2

Notes:

**Climate change and WTT emissions values must be adjusted using the factors in Table 4-2 over the period FY2024 to FY2050.*

All values are based on data from CE Delft (2019a), following the methodology described in Section 4. In some cases, additional sources were used, which are mentioned in the comments column. In addition, for climate change and WTT emissions, the values are estimated using the $ per tonne of carbon values reported in Table 4-1.

Aircraft types considered: small = BAE146-300QT, medium high = Boeing B737-300F.

5.3 Confidence levels

Section 2.3 noted that estimating the costs of environmental externalities is complex and can lead to a significant degree of uncertainty in the values presented. To account for such uncertainty, practitioners are encouraged to use value ranges in their environmental evaluations of transport projects and initiatives.

The *Handbook on the External Costs of Transport* (CE Delft 2019a) does not provide low or high estimates for the parameter values. However, ATAP (2020) provides value ranges (low and high estimates) based on Austroads (2012 & 2014) values.

In this update, parameter values presented in Sections 5.1 and 5.2 represent a central, or mid-point estimate. Table 5-17 to Table 5-20 provide low and high estimate percentages which can be applied to the central parameter values to obtain low and high parameter values. The low and high percentages refer to the relative difference between low and mid values as well as mid and high values for all eight impact categories as reported in Austroads (2014) and in ATAP (2020).

Low and high estimates are provided for passenger cars, buses and passenger rail (Table 5-17 and Table 5-18), LCV, HV and freight rail Table 5-19 and Table 5-20)[12].

Due to the lack of confidence levels for the parameter values, it is recommended to always test the sensitivity of the results when used in individual road or transport projects. This may provide a greater insight into what effect changes in parameter values have in particular circumstances or environments.

Table 5-17: Passenger transport – low estimates (mid-value = 100%)

Passenger transport – low estimates	Urban			Rural		
	Passenger cars	Buses	Rail	Passenger cars	Buses	Rail
Air pollution	97%	71%	71%	67%	67%	67%
Climate change						
WTT emissions						
Noise	86%	80%	80%	86%	80%	80%
Soil and water	95%	71%	71%	100%	60%	60%
Nature and landscape	100%	100%	100%	100%	100%	100%
Urban effects	59%	62%	62%	100%	100%	100%
Biodiversity	97%	71%	71%	67%	67%	67%

Note: Climate change and WTT values should be adjusted using factors in Table 4-2 over the period FY2024 to FY2050.

[12] ATAP (2020) did not provide value ranges for 2-wheelers, air and water transport.

Table 5-18: Passenger transport – high estimates (mid-value = 100%)

Passenger transport – high estimates	Urban			Rural		
	Passenger cars	Buses	Rail	Passenger cars	Buses	Rail
Air pollution	102%	111%	111%	100%	100%	100%
Climate change						
WTT emissions						
Noise	114%	120%	120%	114%	120%	120%
Soil and water	102%	111%	111%	100%	100%	100%
Nature and landscape	380%	471%	471%	353%	463%	463%
Urban effects	141%	137%	137%	100%	100%	100%
Biodiversity	102%	111%	111%	100%	100%	100%

Note: Climate change and WTT values should be adjusted using factors in Table 4-2 over the period FY2024 to FY2050.

Table 5-19: Freight transport – low estimates (mid-value = 100%)

Freight transport – low estimates	Urban			Rural		
	LCV	HV	Rail	LCV	HV	Rail
Air pollution	74%	49%	49%	100%	52%	52%
Climate change						
WTT emissions						
Noise	71%	87%	87%	71%	87%	87%
Soil and water	74%	33%	33%	77%	50%	50%
Nature and landscape	100%	100%	100%	100%	100%	100%
Urban effects	59%	50%	50%	100%	100%	100%
Biodiversity	74%	49%	49%	100%	52%	52%

Note: Climate change and WTT values should be adjusted using factors in Table 4-2 over the period FY2024 to FY2050.

Table 5-20: Freight transport – high estimates (mid-value = 100%)

Freight transport – high estimates	Urban			Rural		
	LCV	HV	Rail	LCV	HV	Rail
Air pollution	165%	122%	122%	100%	122%	122%
Climate change						
WTT emissions						
Noise	129%	112%	112%	112%	112%	112%
Soil and water	164%	122%	122%	177%	122%	122%
Nature and landscape	193%	205%	205%	185%	200%	200%
Urban effects	141%	150%	150%	100%	100%	100%
Biodiversity	165%	122%	122%	100%	122%	122%

Note: Climate change and WTT values should be adjusted using factors in Table 4-2 over the period FY2024 to FY2050.

5.4 Comparison to previous studies

The sections below summarise major differences in parameter values in the underlying data sources, namely CE Delft et al. (2011) and CE Delft (2019a), which translates into differences in previous Australian parameter values (i.e. Austroads 2012 & 2014) compared to this report. The differences noted should be considered as a reminder to use the values with care, considering aspects such as changes of scope, new estimation methodologies and data sources which cause the differences for Australian values between this and previous reports.

5.4.1 Air pollution

The average air pollution costs are slightly higher, but generally on a similar level compared to the air pollution costs reported in CE Delft et al. (2011), which was the basis for the values reported in Austroads (2014). However, air pollution costs for light commercial vehicles have increased in CE Delft (2019a) due to better transport activity data. A direct comparison of data in CE Delft et al. (2011) and CE Delft (2019a) shows that air pollution parameter values for rail and passenger air travel have also increased.

5.4.2 Greenhouse gas emission (climate change)

The average cost for greenhouse gas emissions (climate change) in this version of PV5 differ from earlier versions, due partly to the use of a different unit cost ($ per tonne of CO2-e) for carbon emissions. Austroads (2014) values were based on the low scenario of CE Delft et al. (2011) — 25€ per tonne CO2-e, approx. A$37, and CE Delft (2019a) used a mid-value of 100€ per tonne CO_2 equivalent (approx. A$150-160). ATAP (2021) used a value of approximately $60 per tonne (June 2021 dollars).

For this report, the values are based on the $/tonne CO2-e figures endorsed by ITMM and published by Infrastructure Australia (2024) — as discussed in Section 4.2.1.

5.4.3 Well-to-tank emissions

CE Delft (2019a) states that the data base for the WTT emissions is completely new. For road transport, higher cost factors are compensated by lower emission factors, whereas for rail and aviation, both cost and emission factors are higher. However, overall, average WTT parameter values are on a similar level compared to Austroads (2014).

Like air pollution costs, average costs for WTT emissions in CE Delft (2019a) are on a similar level to CE Delft et al. (2011), although they are slightly higher on average. However, rail WTT emission costs have dropped, which could be due to the increased decarbonisation of electricity (used to power electric trains). As mentioned in Box 2 in section 4.3.4, for electric vehicles the translation of these CE Delft (2019a) European factors to Australian ones is very approximate – and may overestimate WTT impacts (see Table 5-21 for comparison results based on Australian data).

5.4.4 Noise

Average noise costs in CE Delft (2019a) are substantially higher than in CE Delft et al. (2011) (by factors of 2 to 6 times for different vehicle classes, with motorcycle being the highest). This change is reflected in the values in this report. The following factors are considered to play a role:

- higher valuation of the cost of noise, in particular noise annoyance

- updated noise maps, reflecting increased urbanisation, i.e. more people being exposed to higher noise levels
- better correction for incomplete noise maps.

Noise costs for rail and air travel are also higher due to different underlying assumptions and a change of scope.

5.4.5 Nature and Landscape

Comparing CE Delft (2019a) to CE Delft et al. (2011), parameter values for most transport modes are on a similar level. However, the costs for air travel have dropped significantly, which may be due to a change of scope (only 33 European airports are considered in CE Delft (2019a).

5.4.6 Other parameter values

CE Delft (2019a) did not provide updates for the soil and water pollution, urban barrier effects and biodiversity categories. Values provided in this update are therefore based on CE Delft et al. (2011) data, adapted for Australia and indexed to June 2023.

5.5 Comparison with alternative Australian sources

This section provides some alternative numbers, based on Australian studies, as a base against which the numbers in sections 5.1 and 5.2 (based on European studies and data) can be broadly compared.

As discussed at several points in this report, the estimation of environmental externality values is a complex and difficult task, with any results generally being very approximate and involving significant levels of uncertainty. The cost values derived for such environmental impacts will tend to vary significantly from study to study. The tables given in Section 5.3 provide an indication of some typical variation levels in the literature values for the various cost categories.

Not only should any central parameter values (such as given in this report) be used with suitable caution (i.e. acknowledging their uncertainty and only generally *indicative* nature), it is also recommended that appropriate sensitivity testing (around those central values) be conducted, especially whenever the results of a project assessment are heavily reliant on the exact level of any particular impact parameters.

This report of environmental parameter values has been based on a European study (CE Delft 2019a), chosen due to its comprehensive coverage of the relevant impact categories, and generally transparent methodologies. However, this means not only dealing with the uncertainty inherent to the original estimation of these European parameter values, but also extra ambiguity around translating those values into Australian costings, and reservations over how applicable some overseas cost inputs are to Australian conditions.

The CE Delft 2019a work that underpins this report is a comprehensive framework using an extensive European database. Although no similar fully comprehensive such data-set is currently available for Australia, a number of relatively recent environmental studies provide some Australian-based data, allowing reasonable quantification attempts for at least a few of the impact categories. These include Department of Infrastructure, Transport, Regional Development and Communications (2020a, 2020b) *Vehicle Emission Standards for Cleaner Air*, Marsden Jacob Associates & Pacific Environment (2016, 2018), Department of the Environment and Energy (2018) *Better fuel for cleaner air*, and Smit 2020).

As an example of what future work in this area might look like, Table 5-21 and Table 5-22 are presented for urban passenger transport. They provide some interim/provisional estimates, for a sample of the emission-based parameter values, using Australian source data. These values can be contrasted with the adjusted European-sourced values appearing in respective Table 5-1 and Table 5-2.

When choosing suitable value ranges for sensitivity testing, the tables of Section 5.3 can provide some guide, and comparisons between these particular results obtained from two differing methodologies (values in Table 5-21 and Table 5-22 contrasted with Tables 5-1 and 5-2) can give some further indication of the inherent variation underlying such evaluation processes.

The Climate change and WTT parameter estimates in Table 5-21 and Table 5-22 in the 2021 version of PV5 were derived using a central estimate for domestic carbon avoidance costs of A$60 per tonne of CO_2-e in June 2020 dollars. The values in Table 5-21 and Table 5-22 in this 2024 version of PV5 have been adjusted to reflect the 2024 value reported in Table 4-1 using the adjustment factor in Table 4-2.

For the transport modes looked at (urban passenger) here, the provisional estimates based on Australian data (Table 5-21 and Table 5-22) are generally higher than the European-based numbers (Table 5-1 and Table 5-2). The comparative difference is more significant for air pollution than for both Climate change from direct vehicle emissions, and for upstream ‘Well-to-tank’ emissions due to vehicles’ energy use. Overall, however, given the considerable uncertainties discussed earlier, the results from the two sources could be considered to be of a similar comparative order of magnitude.

Table 5-21: Alternate average parameter values in A$ per 1000 vkt/pkm – passenger transport – urban (June 2023 dollars)

Passenger transport – urban	2-wheelers		Passenger cars		Buses & coaches				Rail	
	Motorcycle		Car		Mini-bus		Bus		Electric passenger train	
	vkt	pkm	vkt	pkm	vkt	pkm	vkt	pkm	vkt	pkm
Air pollution	21.5	20.5	17.4	11.6	48.7	13.9	142	15.8	23.4	0.1
Climate change	7.0	6.7	12.5	8.3	18.7	5.4	43.1	4.8	0	0
WTT emissions	2.2	2.2	4.2	2.9	6.4	1.8	11.4	1.3	1,398	7.0

Notes:

For the impact category of Air pollution (noxious emissions directly from transport vehicles), estimates are primarily based on Bureau of Infrastructure and Transport Research Economics (BITRE) analysis (pers.com. D Cosgrove) performed for Department of Infrastructure, Transport, Regional Development and Communications (2020a, 2020b) regulation impact statements on the benefits of tighter vehicle emission standards in Australia ('Vehicle Emission Standards for Cleaner Air'); using results from cost of air pollution modelling, performed for Australian capital cities (Marsden Jacob Associates & Pacific Environment 2016, 2018) as part of reviews of Australian fuel quality standards (Department of the Environment and Energy 2018, 'Better fuel for cleaner air'). Values will tend to fall over time whenever stricter vehicle emission standards are enacted in Australia, or under a significant electrification of the Australian vehicle fleet.

For the impact category of Climate change (greenhouse emissions directly from transport vehicles), estimates are primarily based on BITRE values for greenhouse gas emissions from Australian transport, as published in the Bureau of Infrastructure and Transport Research Economics 'Infrastructure Yearbook' (BITRE 2020); using results from the National Greenhouse Gas Inventory (DISER 2020b) and National Greenhouse Accounts Factors (DISER 2020a), average vehicle fuel consumption data from the Australian Bureau of Statistics (2020c) 'Survey of Motor Vehicle Use', and recent analysis of probable life-cycle greenhouse gas emissions from Australian passenger vehicles (Smit 2020).

For the impact category of WTT emissions (well-to-tank emissions, i.e. upstream emissions both noxious and greenhouse – from fuel extraction, processing or supply – due to energy end-use in transport vehicles) estimates use data from the National Greenhouse Gas Inventory (DISER 2020b), National Greenhouse Accounts Factors (DISER 2020a), and National Pollutant Inventory (Department of Agriculture, Water and the Environment 2020); along with the recent analyses of life-cycle emissions for Australian vehicles (Smit 2020).

Estimated occupancy values used reflect actual average operating conditions typical of Australian urban transport systems (across all trip times and purposes, e.g. include off-peak travel for transit vehicles), so are well below vehicle capacity levels (e.g. generally around 20-30 per cent of full loading for most vehicle types).

For the electric train estimates, CO_2 emissions (within the WTT values) reflect the Australian average fuel mix for electricity generation (see National Greenhouse Accounts Factors, DISER 2020a), which still currently relies on substantial levels of coal consumption, but with a growing contribution from renewable sources. Emissions of CO_2 per unit of electricity use vary significantly from state to state (e.g. see Figure 4.1 – where the average emission rate in Tasmania is only about a fifth of the national average, while that of Victoria is about a quarter higher than the national level), and will tend to fall over time if the proportion of generation by renewables continues to climb.

The air pollution values derived here are generally of a similar magnitude to those estimated by CE Delft (2019a).

The climate change, costings are based on a 2024 unit cost of A$56/t$CO_2$-equiv — see section 4.2.1.

Table 5-22: Alternate parameter values for air pollution, climate change and WTT emissions in A$ per 1000 vkt/pkm – car passenger transport by fuel – urban (June 2023 dollars)

Vehicle category	Vehicle type	Fuel type	Air pollution		Climate change		WTT emissions		Comments or clarifications
			vkt	pkm	vkt	pkm	vkt	pkm	
Passenger cars	Medium	Petrol	14.5	9.7	12.2	8.1	4.3	2.9	
		Diesel	35.3	23.5	14.6	9.7	4.2	2.8	
		Electric	1.2	0.8	0	0	11.3	7.6	Australian average generation

Notes:

For the impact category of Air pollution (noxious emissions directly from transport vehicles), estimates are primarily based on Bureau of Infrastructure and Transport Research Economics (BITRE) analysis (pers.com. D Cosgrove) performed for Department of Infrastructure, Transport, Regional Development and Communications (2020a, 2020b) regulation impact statements on the benefits of tighter vehicle emission standards in Australia ('Vehicle Emission Standards for Cleaner Air'); using results from cost of air pollution modelling, performed for Australian capital cities (Marsden Jacob Associates & Pacific Environment 2016, 2018) as part of reviews of Australian fuel quality standards (Department of the Environment and Energy 2018, 'Better fuel for cleaner air'). Values will tend to fall over time whenever stricter vehicle emission standards are enacted in Australia.

For the impact category of Climate change (greenhouse emissions directly from transport vehicles), estimates are primarily based on BITRE values for greenhouse gas emissions from Australian transport, as published in the Bureau of Infrastructure and Transport Research Economics 'Infrastructure Yearbook' (BITRE 2020); using results from the National Greenhouse Gas Inventory (DISER 2020b) and National Greenhouse Accounts Factors (DISER 2020a), average vehicle fuel consumption data from the Australian Bureau of Statistics (2020c) 'Survey of Motor Vehicle Use', and recent analysis of probable life-cycle greenhouse gas emissions from Australian passenger vehicles (Smit 2020).

For the impact category of WTT emissions (well-to-tank emissions, i.e. upstream emissions both noxious and greenhouse – from fuel extraction, processing or supply – due to energy end-use in transport vehicles) estimates use data from the National Greenhouse Gas Inventory (DISER 2020b), National Greenhouse Accounts Factors (DISER 2020a), and National Pollutant Inventory (Department of Agriculture, Water and the Environment 2020); along with the recent analyses of life-cycle emissions for Australian vehicles (Smit 2020).

An occupancy value of 1.5 passengers per car is assumed to reflect actual average operating conditions typical of Australian urban driving.

For the battery electric vehicle (EV) estimates, CO_2 emissions (within the WTT values) basically reflect the Australian average fuel mix for electricity generation (see National Greenhouse Accounts Factors, DISER 2020a), which still currently relies on substantial levels of coal consumption, but with a growing contribution from renewable sources. Emissions of CO_2 per unit of electricity use vary significantly from state to state (e.g. see Figure 4.1), and will tend to fall over time if the proportion of generation by renewables continues to climb. The WTT emission rate applying to any particular EV will be highly dependant on the proportion of charging performed on the standard grid (versus renewable sources, such as home solar panels).

The air pollution values derived here are generally of a similar magnitude to those estimated by CE Delft (2019a).

For climate change, costings are based on a 2024 unit cost of A\$56/tCO_2-equiv) — see section 4.2.1.

6. Conclusion

This environmental parameter value report provides estimates for external costs to the environment from transport activity. Consistent with previous Australian environmental parameter studies, the estimates are primarily based on European data, which was last updated in 2019, accounting for new developments, insights, data and methodologies.

Importantly, for environmental impact categories that impact Australia's legislated net zero targets— climate change and well-to-tank impacts — the unit costs in this report reflect agreed national emissions values per tonne of CO2-e (Infrastructure Australia 2024) endorsed at the ITMM in December 2023.

Despite reflecting the latest developments, estimating environmental parameter values remains a challenging task. Consequently, these values should be used with care, and sensitivity testing is recommended to judge the impact on road or transport project outcomes and mitigate the potential negative impacts of mis-estimated values.

Appendix A Glossary of acronyms and abbreviations

ADR	Australian Design Rules
ATAP	Australian Transport Assessment and Planning (Guidelines)
CBA	Cost-benefit analysis
CNG	Compressed natural gas
CO_2	Carbon dioxide
EU	European Union
EU28	28 countries of the European Union
F	Freight vehicle
GHG	Greenhouse gas
HV	Heavy vehicles
IA	Infrastructure Australia
km	Kilometre
LCV	Light commercial vehicles
LPG	Liquid petroleum gas
P	Passenger vehicle
pkm	Passenger-kilometres
RoPax	Passenger ferries with roll-on and roll-off features for the carriage of commercial vehicles and private cars
t	Tonne
tkm	Tonne-kilometres
TTW	Tank-to-wheel
vkt	Vehicle-kilometres-travelled
WF	Weighting factors
WTT	Well-to-tank
WTW	Well-to-wheel

Appendix B Total, average and marginal external costs of transport

For some environmental impacts, CE Delft et al. (2011) and CE Delft (2019a) provided separate values for average external and marginal external costs. This appendix provides a short discussion of the various external cost measures for transport.

- Total external costs refer to the total value arising from a specific type of transport externality (e.g. air pollution) within a geographical boundary (e.g. Australia). The total external costs are measured in dollars.
- Average external costs are closely related to total costs as they are the average value of transport external costs per unit of transport activity. Measures of transport activities include vehicle-kilometres-travelled (vkt) for all transport modes, passenger-kilometres (pkm) for passenger transport modes, or tonne-kilometres (tkm) for freight transport modes. Units of average external costs of transport are therefore in dollars or cents per vkt for all transport modes, pkm for passenger transport modes and tkm for freight transport modes. Average external cost is also the basis for environmental parameter values developed in Austroads (2003, 2012 & 2014).
- Marginal external costs of transport are the changes in total external costs due to an additional transport activity being added to the traffic. They are measured in the same units as average marginal costs. The size of marginal costs therefore, however, may depend on the traffic conditions. Marginal external costs can also be further classified as short-run and long-run marginal costs. Their definitions are reproduced from Austroads (2003):
  - Short-run marginal external costs measure the increase in total external costs from an additional vehicle entering the system without considering the fixed costs for running the system or additional costs for network extension. Their estimation covers only variable costs of operation.
  - Long-run marginal costs also cover costs of system variations (e.g. enlargement of the network), since in the long run infrastructure costs are also to be considered as variable. An example for long-run marginal external costs are external costs related to nature and landscape, which are considered as fixed in the short run.

According to CE Delft (2019a), except for noise pollution, average and marginal external costs are approximately equal for all other externalities considered in this update. This is because the intensity of their impact is typically not strongly dependent on the density of the traffic flow. For example, a car entering a dense traffic flow emits a similar (though generally somewhat higher) amount of air pollution as a car entering a thin traffic flow, assuming all other factors are equal.

However, for noise pollution, traffic density matters. The additional noise emitted from a car entering a quiet street with little traffic is much more discernible, and subsequently considered more costly, to the surrounding residents than a car entering a busy street already filled with traffic noise. The marginal noise cost under light traffic conditions is expected to be higher than its average cost but for heavy traffic conditions, the marginal noise cost will be lower.

Appendix C Vehicle occupancy and payload

Table C-1: Vehicle occupancy and payloads – passenger transport

Vehicle category	Vehicle type	Fuel type	Dis-tance	Avg. occupancy or avg. passenger numbers	Source
Moped/scooter/ motorcycle				1.050	CE Delft (2019a)
Passenger car				1.574	CE Delft (2019a)
LCVs (incl. minibuses)				5.000	assumption
Bus/coach	Urban buses midi <15 t			13.505	CE Delft (2019a)
	Urban buses standard 15-18 t			16.882	CE Delft (2019a)
	Urban buses articulated >18 t			20.258	CE Delft (2019a)
	Coaches standard ≤18 t			15.087	CE Delft (2019a)
	Coaches articulated >18 t			22.631	CE Delft (2019a)
Rail	Intercity train	diesel		87	CE Delft (2019a)
	Regional train	diesel		31	CE Delft (2019a)
	Tram	electricity		50	assumption: avg. 50 pax per tram
	Metro single-decker	electricity		250	Action for Public Transport NSW (2013); assumption 50% full on average
	Metro double-decker	electricity		450	Action for Public Transport NSW (2013); assumption 50% full on average
Aviation	Small aircraft		500	58.3	Qantas (2020a)
	Medium-small aircraft		1000	78.8	Qantas (2020b)
	Medium aircraft (low emissions)		1500	148.9	CE Delft (2019a)
	Medium aircraft (high emissions)		1500	117.4	CE Delft (2019a)
Water transport	Urban ferry (Sydney)			95	Transport for NSW (2016)
	Large (RoPax) ferry (25,500 gt)			528	CE Delft (2019a)

Notes:

Aircraft types considered: small = Bombardier Dash 8 Q400, medium-small = Fokker 100, medium low emission = Airbus A320, medium high emission = Boeing 737.

For road transport, average occupancy numbers are listed. For non-road transport (rail, aviation, water transport), average passenger number are used, excluding driver/crew.

Table C-2: Vehicle occupancy and payloads – freight transport

Vehicle category	Vehicle type	Avg. load (tonnes)	Source
LCVs		0.692	CE Delft (2019a)
Heavy vehicles	Rigid <7.5 t	0.825	CE Delft (2019a)
	Rigid 7.5 -2 t	2.096	CE Delft (2019a)
	Rigid 12-14 t	3.877	CE Delft (2019a)
	Rigid 14-20 t	4.109	CE Delft (2019a)
	Rigid 20-26 t	8.490	CE Delft (2019a)
	Rigid 26-28 t	11.886	CE Delft (2019a)
	Rigid 28-32 t	14.628	CE Delft (2019a)
	Rigid >32 t	16.718	CE Delft (2019a)
	Articulated 14-20 t	7.110	CE Delft (2019a)
	Articulated 20-28 t	8.675	CE Delft (2019a)
	Articulated 28-34 t	14.628	CE Delft (2019a)
	Articulated 34-40 t	16.718	CE Delft (2019a)
	Articulated 40-50 t	19.505	CE Delft (2019a)
	Articulated 50-60 t	22.293	CE Delft (2019a)
Rail	Short container	500	CE Delft (2019a)
	Short bulk	750	CE Delft (2019a)
	Long container	1400	CE Delft (2019a)
	Long bulk	1600	CE Delft (2019a)
Aviation	Small aircraft	10	Air Charter Service (2020)
	Medium aircraft	19	Air Charter Service (2020)
Water transport	Small container vessel (28 500 gt)	24 000	CE Delft (2019a)
	Large container vessel (143 000 gt)	115 000	CE Delft (2019a)
	Small bulk vessel (18 000 gt)	15 000	CE Delft (2019a)
	Large bulk vessel (105 000 gt)	103 000	CE Delft (2019a)

Note:

Aircraft types considered: small = BAE146-300QT, medium = Boeing B737-300F.

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