GRAIN TRADE AUSTRALIA

GTA

Silo to Port Emissions

Methodology for estimating carbon emissions

Contents

1. Objective

Marsden Jacob was engaged to develop a carbon emissions model for Grain Trade Australia (GTA). This model would allow GTA's members to understand the embodied carbon emissions for transport movements from grain silos to Australian terminal ports.

2. Scope

The model estimates carbon emissions that result from transporting grain from each grain silo to terminal ports. The grain silos, the destination ports and the transport mode (road/rail) are defined in the GTA Location Differentials. (Link: here)

The model only estimates the carbon dioxide equivalent emissions ($CO_{2\text{-}e}$). It does not estimate emissions of other pollutants (such as particulates or NOx).

Additionally, our analysis is limited to Scope 1 emissions, that is $CO_{2\text{-}e}$ emissions generated from the energy end-use from transport vehicles moving freight, rather than the lifecycle emissions of grain production and storage or of the transport fleet (i.e. Scope 2 and Scope 3 emissions).

Based on discussions with GTA, providing a dollar value for the carbon emissions has been excluded from this report and associated model. A discussion is provided in Appendix 1 to help GTA members understand the different ways carbon is valued for reference.

3. Limitations

The approach outlined in this paper to estimate emissions has limitations which should be acknowledged. In some cases, this relates to key model inputs being based on assumptions about the road and rail network and, in other cases, it relates to the source of key inputs (e.g. European source data). For example:

- In terms of road transport, the modelling assumes that the two heavy vehicles used to transport grain to port are the 6 axle articulated vehicle and the 9 axle b-double, weighted based on the vehicle kilometres travelled of each vehicle type across all industries in each state[1]. The modelling also makes a range of other assumptions on the characteristics of the transport movement, such as average speed, average loads and road roughness. Additionally, road transport emissions are estimated applying a bottom-up approach using data from the Australian Transport Assessment and Planning (ATAP) Guidelines. This data is likely to be updated in the short term and may change the emissions values.
- In terms of rail transport, the estimated emissions are based on the Australian Transport Assessment and Planning (ATAP) Guideline published values for $ per tonne-kilometre, which in turn are based on European values. This approach results in a range of extrapolation issues. Additionally, the modelling incorporates values for laden tonnes and the mix of container and bulk rail transport for grain.

[1] In absence of grain transport specific vehicle mix the NTC PayGo model has been used to determine the weighting of vehicle type. https://www.ntc.gov.au/sites/default/files/assets/files/PAYGO-model-version-2.3.XLSM

4. Approach

At a high level, quantifying the carbon emissions per grain tonne for each silo to port route is estimated by multiplying the quantity of emissions per tonne-kilometre travelled by the transport movement distance (kilometres), as illustrated in Figure 1.

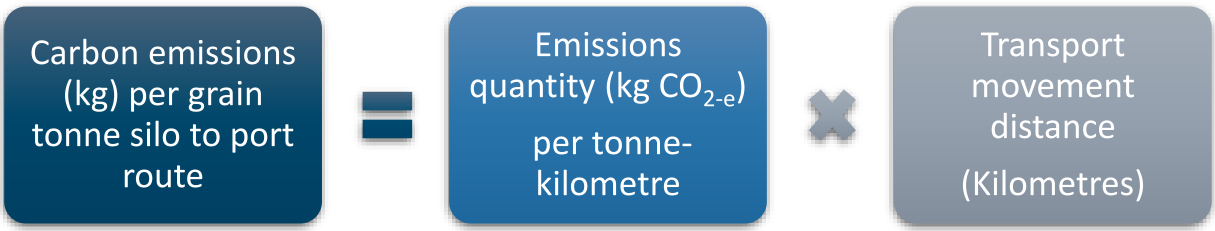
The most accurate method for quantifying the emissions for a specific route is to use a bottom-up or detailed approach which considers the specific transport characteristics of the route.

For road transport, a 'bottom-up' methodology has been applied using the Australian Transport Assessment and Planning (ATAP) Guidelines, whereby the emissions from a route can be estimated based on the fuel consumption of the vehicle and the characteristics of the transport route. Section 6.1 of the report explains how the methodology has been applied and what assumptions have been made when applying the method to grain transport.

Rail transport currently has no ready-made 'bottom-up' methodology available for quantifying the emissions generated for a particular route with specific characteristics. However, ATAP does publish emissions costs per tonne-kilometre for an average rail load which can be converted into an emissions quantity per tonne-kilometre. The use of average emissions for rail transport means the quantification will be less accurate than for road transport of grain product. This approach is referred to as a top-down approach and is explained further in Appendix 1.

The distance for each transport movement is defined by the return distance from each silo to each destination port (with the silos and ports defined in the GTA Location Differentials). The route distances were estimated by GTA for use in this report.

Figure 1: Basic formula for calculating carbon emissions



5. Results

The analysis generated an emissions quantity for road and rail per grain tonne-kilometre for Western Australia, South Australia, Victoria, New South Wales, and Queensland. The values are summarised in Table 1. These figures were then applied to each silo to port route to generate a whole of route emission quantity.

On average, a freight tonne kilometre of transport via road produces roughly 8 to 9 times more emissions than a freight tonne kilometre of transport via rail, depending on the State of Australia. The figures are consistent with the understanding that rail transport is more efficient from a fuel consumption perspective and thus has significantly lower emissions when comparing two existing routes.

Road emissions vary across states because of the proportion of b-double's (more fuel efficient per km) to articulated 6-axles (less fuel efficient per km). In absence of grain specific vehicle mix data the NTC

PayGo model has been used to understand the vehicle mix by state[2]. Using the NTC data from all industries, Western Australia and Queensland use a higher proportion of 6-axle articulated vehicles which leads to higher average fuel consumption and, in turn, emissions. This is explained more in section 6.1.

Table 1: Grams of carbon emissions per freight tonne kilometre; Road compared with Rail

Transport type	WA	SA	Vic	NSW	QLD	Average
Road	125.9	119.2	118.2	116.0	134.8	122.8
Rail	13.9	13.9	14.4	14.2	14.3	14.1
Road value/ Rail value	9.1	8.6	8.2	8.1	9.4	8.7

Source: *Marsden Jacob analysis*

5.1 Comparing the results to other studies

The results are generally consistent with other studies reviewed within Australia and internationally.

Using the top-down approach for both road and rail, the ATAP guidelines indicate that an average articulated 50-60 tonne diesel heavy vehicle produces 7 times the emissions of a long-bulk container[3]. In making this comparison, the ATAP rail emissions values are the same as those used in the modelling by Marsden Jacob using the top-down approach. However, the ATAP road emissions values used in this comparison are lower than those quantified in this report. This is consistent with the understanding that the average ATAP values are likely to be different to those estimated by Marsden Jacob in this report using a bottom-up approach.

A study completed for the Australian Railway Association (ARA) found carbon emissions per tonne kilometre for all road freight transport to be 16 times the value for rail transport[3][4]. However, this falls to 8 times when comparing articulated heavy vehicles only to rail transport, noting that rail transport in the ARA report has not been separated into short and long haul.

Applying an international comparison, a recent study from Europe suggests road transport emissions per tonne-kilometre are 5-6 times that of rail transport[5], noting that this is based on an average across all heavy vehicle road types and rail transport types.

The differences in the results in the Marsden Jacob analysis could be somewhat due to the limitations explained in Section 3 and because a bottom-up approach is used for road transport and a top down approach has been used for rail transport. Further detailed investigation and examination of key inputs (for both road and rail transport) and the application of a bottom-up approach for rail may provide more robust estimates of emissions. Additionally, the model values should be updated if the ATAP values change.

5.2 What does this mean for transport of grain?

The carbon emissions for a transport route provide a good indicator of the relative impact of a marginal or additional transport movement compared to other activities within the economy. The values provide a useful metric for understanding the carbon intensity of current business operations.

[2] https://www.ntc.gov.au/sites/default/files/assets/files/PAYGO-model-version-2.3.XLSM
[3] https://www.atap.gov.au/parameter-values/road-transport/5-vehicle-operating-cost-voc-models table 5.13.
[4] https://ara.net.au/wp-content/uploads/REPORT-ValueofRail2020-1.pdf Table 4.1
[5] https://www.eea.europa.eu/publications/rail-and-waterborne-transport

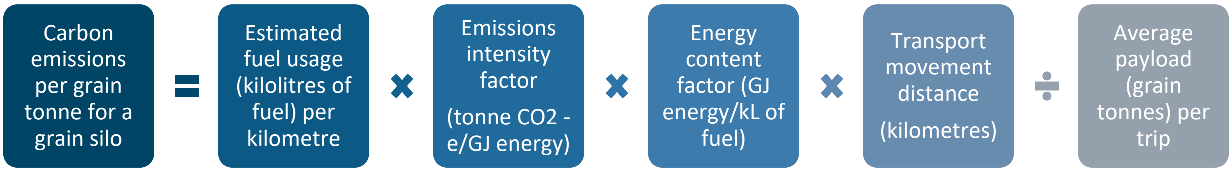
However, it is important to stress that these values are only one consideration when investing in road or rail transport infrastructure. Infrastructure investments would also need to consider the relative construction, operation and maintenance of road and rail infrastructure as well as their expected use.

6. Detailed approach

6.1 Bottom-up approach - Road

Under the bottom-up approach, carbon emissions are estimated using the formula in Figure 2.

Figure 2: Bottom-up emissions estimation



Under this formula, the carbon emissions per tonne of grain (based on the transport movement from each silo to port) requires an estimate of fuel usage or consumption (e.g., diesel oil or petrol) per kilometre. Fuel consumption has been calculated for a 6-axle articulated vehicle and a b-double, using diesel as the fuel source, based on the most likely vehicle selection for grain transport.

With respect to road transport, the rural uninterrupted fuel consumption model in the *Australian Transport Assessment and Planning (ATAP) Guidelines*[6] is used to quantify fuel consumption per 100 kilometres for different vehicle types using the following formula:

$$Fuel\ consumption\ (L/km)\ =\ BaseFuel(k_1\ +\ k_2/Speed\ + k_3/Speed^2 +\ K_4 * IRI\ +\ K_5 * GVM)$$

In using this formula and calculating fuel consumption:

- Base Fuel and the coefficients are based on the curvature and gradient of the road. For modelling purposes, the parameters applied are based on a standard flat, straight segment of road.
- Speed, IRI (international Roughness Index) and GVM (Gross Vehicle Mass) are key inputs. State based averages have been used to generate estimates for GVM.
- The fuel consumption (kilolitres of fuel) for the return road transport movement from silo to its nominated terminal port is calculated based on the total return distance (kilometres) multiplied by the fuel consumption rate (L/km) multiplied by 1,000.
- The energy content factor and emissions intensity factor is sourced from the National Greenhouse Accounts Factors tables (2021) [7].

The assumptions applied to each variable are explained further in Table 2.

[6] https://www.atap.gov.au/parameter-values/road-transport/5-vehicle-operating-cost-voc-models
[7] https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-accounts-factors

Table 2: Road fuel consumption formula parameter assumptions

Parameter	Calculation
L (litres)	Litres of fuel
BaseFuel	Parameter provided by the ATAP Guidelines as part of the fuel consumption model based on a flat, straight road.
Speed	Speed is assumed to be 70 km per hour, considering the types of roads that will be used for the majority of the transport from silo to port and that average speeds are lower than posted speeds.
IRI	IRI refers to International Roughness Index. IRI will be assumed to be a value of4as an average across all roads, based on Austroads (2017, page 32)[8] using road classes R2, R3 and R4, which cover urban highways, urban arterials, rural highways, and collector/distributor roads respectively.
GVM	GVM refers to gross vehicle mass. The GVM value will be calculated separately for a fully laden (silo to port) trip and an unladen trip (port to grain silo). The fully laden GVM will be estimated based on the non-capital city GVM values for each State of Australia using the Survey of Motor Vehicle Use (Year). The unladen GVM will be based on the tare of the vehicle configuration (including trailers).
K_1, k_2, k_3 and k_4	Coefficients provided by the ATAP Guidelines as part of the fuel consumption model based on a flat, straight road.

Table 3 shows the emissions per freight-tonne-kilometre calculated for each state and vehicle type and the weighting to convert the individual vehicle emissions to weighted average emissions based on the vehicle mix within each state. These figures could be updated if grain sector specific vehicle usage data became available.

Table 3: Grams of carbon emissions per freight tonne kilometre by vehicle type

Transport type	WA	SA	Vic	NSW	QLD	Average
Artic 6-Axle	145	150	140	134	151	145
B-double	105	101	102	102	115	105
Weighting of Artic 6-Axle	52%	37%	42%	43%	56%	46%
Weighted average	125.9	119.2	118.2	116.0	134.8	122.8

Source: NTC PayGo model

[8] https://austroads.com.au/publications/freight/ap-r545-17/media/AP-R545-17-Community_Obligations_Framework_for_the_Roads_Sector.pdf

6.2 Top-down approach - Rail

For rail freight transport, there is currently insufficient publicly available Australian data to build a fuel consumption model (and in-turn, emissions) via the bottom-up format. As a result, the basic formula in Figure 1 is used to estimate carbon emissions per grain tonne for each silo to port route.

Applying the basic formula for calculating carbon emissions in Figure 1 requires estimating rail transport emissions (tonnes of $CO_{2\text{-}e}$) per tonne-kilometre. Consistent with Figure 3, rail transport emissions (tonnes of $CO_{2\text{-}e}$) per tonne-kilometre is estimated as the carbon cost per tonne-kilometre divided by the carbon cost per tonne of emissions – using a $60/ tonne cost of emissions. This is illustrated in **Error! Reference source not found.**. The *Australian Transport Assessment and Planning Guidelines,* in particular the PV5 Environmental Parameter Values, provides a carbon cost per tonne-kilometre travelled for different types of rail transport.

Figure 3: Formula to calculate emissions quantities

The carbon cost per tonne-kilometre value provided by ATAP is calculated using an average load for each rail transport type, which is applied for the laden trip. For the purposes of quantifying the unladen trip, emissions are set equal to that under the laden trip multiplied by the proportion of fuel used by an empty train relative to a laden trip. This proportion is assumed to be the same as calculated under the road transport bottom-up model.

The carbon emissions per tonne-kilometre (Table 1**Error! Reference source not found.**) for rail transport is then based on a weighted average of the two rail transport types (long container and long bulk), with the weighting based on the proportion of shipments via bulk and container by state as published in the Australian Competition and Consumer Commission's Bulk grain ports monitoring report (2020-21).

The marginal ATAP parameter monetary emissions values (A$/tonne-kilometre) for rail transport have been used in the analysis. The marginal values reflect the emissions cost of an individual transport movement.

Table

Table 4: ATAP carbon cost per 1000 tonne-kilometre travelled (TKM) or VKT - rural

Rail transport type	fuel type	Average load	ATAP $ value $/1000 tkm	Tonne $CO_{2\text{-}e}$ $CO_{2\text{-}e}$ /1000 tkm
Long container (620 metres)	Diesel	1,388	$0.50	0.008
Long bulk (440 metres)	Diesel	1,583	$0.45	0.008

Marsden Jacob analysis of ATAP Guidelines: PV5 Environmental parameter values (2021), Table 5-13: Marginal parameter values for air pollution, climate change and WTT emissions in A$ per 1000 vkt/tkm – freight transport – rural (June 2020 dollars) and Table C-2: Vehicle occupancy and payloads – freight transport.

Note: a carbon cost of $60/tonne CO2-e was taken from ATAP and used to convert $/1000tkm to $CO_{2\text{-}e}$/1000tkm

The marginal ATAP parameter monetary emissions values (A$/tonne-kilometre) for rail transport have been used in the analysis. The marginal values reflect the emissions cost of an individual transport movement.

Table 5: Proportion of bulk and containerised shipments by state, Average of 2014-15 to 2020-21

Average	WA	SA	Vic	NSW	Qld	Total
Bulk	97%	94%	64%	72%	66%	88%
Containers	3%	6%	36%	28%	34%	12%

Source: *ACCC (2020-21) Bulk Grain ports monitoring report – data update (Table 4.4)*

Appendix 1. Monetary values for carbon

Two methodologies are available to place a monetary value on carbon emissions. The most appropriate method depends on the purpose of the valuation. The two methodologies are explained below. Table summarises the range of values which could be used.

Table 6: Carbon cost values used ($2022 AUD)

Method	Sensitivity	Value ($/tonne CO2-e)	Source
Abatement cost	Short-term	$17.35	ACCU[9].
	Medium-term	$60.00	ATAP[10]
Social cost	Lower bound	$45.00	MJA analysis of Interagency Working Group on Social Cost of Greenhouse Gases, United States Government.
	Central	$58.00	
	Upper bound	$101.00	

Method 1: Abatement cost of carbon

The abatement cost of carbon takes two forms, short-term and medium to long term.

Short term abatement cost

The short-term value reflects the cost today to abate current emissions. Carbon is traded via carbon credits markets in Australia and around the world, thereby generating a market value. This value should be used when a financial or accounting value is required and is considered a short-term marginal abatement cost.

A carbon credit is generated from an activity that reduces emissions (such as changing technology to reduce the emissions intensity of production). The carbon credit is then sold to an entity to reduce overall emissions or is sold in the market to offset the emissions generated by someone else who cannot reduce the emissions intensity of their activities. The value is considered a short run carbon price.

The current mechanisms in Australia are Australian Carbon Credit Units (ACCUs), Large-scale Generation Certificates (LGCs) and Small-scale technology certificates (SRES). The Clean Energy Regulator is in the process of procuring an Australian Carbon Exchange which will make trading these mechanisms easier by creating an online market similar to stock exchange markets. The average price per tonne generated by ACCUs via the Emissions Reduction Fund is $17.35/tonne of abatement[11].

The short-term value does not consider future emissions abatement and how abating those emissions is likely to cost more to achieve. For example, a business can reduce its emissions by changing all lights to LED and improving the insulation levels in buildings. These activities will cost less per quantity of emissions reduced than changing the entire fleet of vehicles to electric or installing solar panels and batteries to make electricity consumption 100% renewable.

[9] https://www.cleanenergyregulator.gov.au/ERF/auctions-results/april-2022

[10] ATAP Steering Committee Secretariat, 2020. *Australian Transport Assessment and Planning Guidelines: PV5: Environmental Parameter Values*, Commonwealth Department of Infrastructure, Regional Development and Cities, November 2020. https://www.atap.gov.au/parameter-values/road-transport/5-vehicle-operating-cost-voc-models

[11] https://www.cleanenergyregulator.gov.au/ERF/auctions-results/april-2022

Medium term abatement cost

Valuing abatement emissions over the medium term will generally consider the average cost of abatement with a given policy objective in mind. For example, a widely agreed policy objective is to reduce greenhouse gas emissions to a level necessary to prevent temperature rises above 1.5-2.0 degrees Celsius (thus avoiding potentially catastrophic climate changes). This, in turn requires countries (and sectors and industries within those countries) to achieve emission reduction objectives over a given timeframe (e.g., net zero emissions by 2050). Emissions reduction pathways towards those objectives will then provide medium term (e.g., 2030) and longer term (e.g., 2050) abatement cost estimates.

There are a number of Australian studies that are potential sources for valuing medium to long term abatement costs in Australia. Those studies are detailed in the Australian Transport Assessment and Planning (ATAP) Guidelines.[12] A medium to long term abatement cost of $60/ tonne can be considered a current guideline.

Method 2: Social cost of carbon

The social cost of carbon (SCC) monetises the damages (or costs) associated with an incremental increase in carbon emissions in a given year. The value is an economic value and should generally be used when aiming to assess the climate-related damages associated with a particular activity. Marsden Jacob currently recommends the approach taken by the US Government presented in “Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis” from the Interagency Working Group on Social Cost of Greenhouse Gases, United States Government.

Four estimates are generated in the US Government report. The first three are based on an average social cost of carbon at three different discount rates (2.5%, 3% and 5%), while the fourth is based on a low likelihood and high impact damage cost. Different discount rates are applied to take account of different perspectives on valuing intergenerational costs of climate change. Since the cost of damages associated with emissions are expected to increase over time as atmospheric concentrations of greenhouse gases increases, the report has quantified SCC values for each year through 2050. The 2022 values range from AUD$23 to AUD$99/tonne CO_{2-e} when converted to Australian dollars. The range represent the level of uncertainty in developing these estimates and should provide a minimum and maximum for sensitivity testing.

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[12] ATAP Steering Committee Secretariat, 2020. *Australian Transport Assessment and Planning Guidelines: PV5: Environmental Parameter Values*, Commonwealth Department of Infrastructure, Regional Development and Cities, November 2020. https://www.atap.gov.au/parameter-values/road-transport/5-vehicle-operating-cost-voc-models