sapere

Emissions factors for the Ports of Auckland

Road and rail transport, coastal shipping, and container handling at the Port and Wiri freight hub

Corina Comendant

17 November 2020

Contents

Appendices

Tables

Figures

Glossary

Abbreviation	Stands for
EF	Emissions factor measured as kgCO2e per unit
EF_{tkm}	Emissions factor measured as gCO2/tonne-km
FIGS	Freight Information Gathering System
GVW	Gross vehicle weight
LHV	Long heavy vehicle
TTW	Tank-to-wheel
MfE	Ministry for the Environment
MoT	Ministry of Transport
WTW	Well-to-wheel

Executive summary

Overview

Ports of Auckland (POAL) is currently developing an online calculator that will allow customers to calculate emissions from the transportation of their container cargo on road, by train and by coastal ships.

This report (i) assesses the tonne-km emissions factors (EF_{tkm}) estimated in different sources overseas, and those estimated specifically for New Zealand overall; (ii) compares those EF_{tkm} with the values currently used by POAL; and (iii) provides a recommendation on which values are more appropriate for the purpose of POAL's supply chain.

The current version of the report

The current version is an update to the draft report from December 6, 2019, which has been audited by Toitū Envirocare.

A key observation from the audit was that the initial emissions factors for coastal shipping, whereby the one for international shipping was approximately double that of for domestic shipping, was at odds with other estimates for international ships. This has been significantly reviewed following conversations with Ralph Samuelson, who noted that international ships are almost always full when travelling along the coast, therefore requiring a lower emissions factor for the domestic cargo that is incidental to their international operations. For domestic ships along the coast, additional analysis has been undertaken based on FIGS data from the Ministry of Transport. However, because this data was insufficient to be able to determine the average load on a domestic ship, a conservative EFtkm has been assumed based on the Netherlands STREAM report (CE Delft, 2016).

Another observation was that the previous version recommended split factors for road transport and coastal shipping, whereas POAL's calculator uses "default" emissions factors. In this update, a single emissions factor is recommended for road transport, based on new real-world information published by the Ministry of Transport. Split factors are still advisable in the future if there is enough data allowing a distinction between trucks that carry 1 or 2 TEUs. For coastal shipping, the emissions factors remain split as they are significantly different for international or domestic ships (due to their assumed loads), and there is no real-world estimate that could provide an average similar to MoT's road transport work.

The relevance of the Netherlands STREAM report was also brought up with regards to New Zealand's specific context. In my previous report, it was noted that, of all the international sources investigated, the STREAM report provides most detailed description of on methodology and assumptions, and that the estimates in the report appear to be more conservative than in the other overseas sources.[1] This is why it was the preferred source when NZ-specific data was missing. In the current version of the report, only the emissions factors for coastal shipping are based on STREAM, which I think is

[1] Although it should be noted that a direct comparison amongst these sources was not possible, and a number of assumptions had to be made to enable the comparison on a load/vehicle weight basis.

reasonable for international ships. For domestic ships, this was done in the absence of NZ-specific information that would allow estimating a local emissions factor.

Lastly, emissions from container handling at the Port and at the Wiri freight hub have also been added to this version for completeness.

Summary of emissions factors

Table 1 Summary of recommended emissions factors

Mode of transport	Average load / vehicle weight	Current EFused by POAL	Recommended EF	
			Value	Notes
Road transport	1-2 TEU	62g CO2e/tkm	106.6 gCO2e/tkm	Based on (Wang, et al., 2019), and adjusted for CO2 equivalence
Rail transport	455-750 / 700-950 tons	30.8 gCO2e/tkm	28.9 gCO2e/tkm (diesel only)	Samuelson (2019)
International shipping	International ships (5,000-10,000 TEUs)	8.4 gCO2e/tkm	18.5 gCO2e/tkm	Average for medium-weight container ships of (5,000-7,999 TEUs and 8,000+ based on STREAM report
Coastal shipping	International ships (1,740-5,117 TEUs)	8.4 gCO2e/tkm	17 gCO2e/tkm	Average for medium-weight container ships (2,000-4,999 TEUs) based on STREAM report
Coastal shipping	Domestic ships (1000-1999 TEUs)	8.4 gCO2e/tkm	36 gCO2e/tkm	Netherlands value (STREAM report)
Straddles and reach stackers at Port	NA	NA	7.27 kgCO2e/TEU	Based on actual 2019 POAL energy consumption data
Cranes at Port	NA	NA	0	Assumes zero-emissions renewable energy certificates for electricity
Container handling at Wiri	NA	NA	5.39 kgCO2e/TEU	Based on actual 2019 POAL energy consumption data

Road transport

As POAL's carbon calculator is being rolled out, I recommend using a single emissions factor of 106.6g CO2e/tkm for road transport, based on NZ Ministry of Transport's recent analysis of real-world data. A single value simplifies the usability of the calculator, and is more practical in the absence of readily available information on truck-specific loads.

In the future, however, it is recommended that the emissions factor for road transport is reviewed to determine the feasibility of distinguishing between trucks carrying 1 or 2 TEUs, as emissions factors can vary significantly depending on loads.

By my estimates, the weight of a loaded TEU that is moved through POAL is 9.1-9.8 tons. On this basis, the emissions factor that is appropriate for a truck carrying a single TEU is that proposed by MfE, i.e. 136 CO2e/tkm – double the current value used by POAL.

Mode of transport	Average load[2]	Current EF_{tkm} used by POAL	Recommended EF_{tkm}	
			Value	Notes
Road transport	1 TEU (<10 tons)	62g CO2e/tkm	136g CO2e/tkm	MfE 2019 value

For trucks carrying more than one TEU, a lower emissions factor should be applied. The EF_{tkm} value currently used by POAL for container road transport – 62g CO2/tkm – is based on an estimate by McKinnon (2007) for heavy trucks.[3] Other overseas sources suggest a range of 56 and 73g CO2e/tkm for heavy trucks,[4] depending on actual loads. It is understood that trucks leaving the port are restricted to a maximum of 1- 2 TEU due to full containers exceeding weight limits, and requiring HMPV permits. Therefore, for a truck carrying 2 TEUs with an average load of 9.1-9.8 tons each, a conservative estimate of 73g CO2e/tkm would be appropriate, based on the estimates in the STREAM report.

Mode of transport	Average load[5]	Current EF_{tkm} used by POAL	Recommended EF_{tkm}	
			Value	Notes
Road transport	2 TEUs (16-22 tons)	62g CO2e/tkm	73g CO2e/tkm	Netherlands value (STREAM report)[6]

Rail transport

It is estimated that trains carrying containers in and out of POAL carry between 473 and 546 tons on loaded trips. In the STREAM report, these loads correspond to 27 gCO2e/tkm.

The EF_{tkm} value currently used by POAL for container rail transport – 30.8g CO2/tkm – seems to be based on 2016 estimates by KiwiRail for diesel rail transport. More recent estimates of KiwiRail data (as

[2] Excludes weight of empty containers
[3] 40 tonne articulated truck carrying a maximum payload of 26 tonnes (McKinnon & Piecyk, 2011). The EF_{tkm} value corresponds to an average load of ~19 tonnes (Table 1 in (McKinnon & Piecyk, 2011)).
[4] Note that although these estimates are in terms of CO2e rather than CO2, the difference is small (~1%). MfE states that "Under the reporting requirements of ISO 14064-1:2018 and the GHG Protocol, GHG emissions should be reported in tonnes CO2**e** [emphasis added]" (MfE, 2019)
[5] Excludes weight of empty containers
[6] Note that the STREAM report also provides EF_{tkm} estimates separately for different types of roads. The values in this table are averages

per Samuelson (2019)) suggest 28.9g tCO2/tkm for diesel rail (the trains in POAL's direct supply chain are likely to be all diesel).

Based on international studies, it would be more accurate to distinguish between freight and container transport on rail, as EF_{tkm} values can differ significantly between the types of cargo. However, NZ data specific to container freight on rail is not available, and on this basis I recommend using the average EFtkm value of 28.9g CO2e/tkm.

Coastal shipping

The EF_{tkm} value currently used by POAL for container coastal shipping – 8.4 gCO2/tkm – is based on McKinnon (2007), who provides this estimate for deep-sea shipping, without making allowance for the repositioning of empty containers.[7] Therefore, this value is not directly applicable to NZ coastal shipping.[8]

Emissions factors differ depending on whether the ship travelling along the coast is international or domestic. This is because the former are usually larger and closer to their full TEU capacity, requiring a lower emissions factor than domestic ships.

An average value of 18.5g CO2e/tkm is appropriate for the very large international ships (5,000 – 10,000 TEUs). However, data suggests that international ships along the NZ coasts are smaller – up to (and slightly above) 5,000 TEUs. For these ships, the recommended emissions factor is 17 gCO2e/tkm estimated as the average value for medium-weight container ships (2,000-4,999 TEUs) based on the STREAM report.

For domestic ships, data is missing with regards to the average load carried along the coastline. Given this, a (potentially) conservative assumption is made that the average container load carried is 5,000 tons. Based on the STREAM report, an emissions factor of 36 gCO2e/tkm is recommended.

Emissions at the Port and Wiri freight hub

The proposed emissions factors are estimated using 2019 actual data on energy consumption and number of TEUs handled at the Port and the Wiri freight hub. The EFs values for diesel consumption reflect a simple average for all container-handling equipment, i.e. it is not weighted by the diesel volumes consumed by straddles and reach stackers separately. A weighted average EF could be estimated in the future once better data is gathered from the supply-chain simulations. It is also recommended that the emissions factors are updated annually to reflect most recent energy consumption and numbers of TEUs handled.

[7] P.18 in (McKinnon, 2007)

[8] The same author proposes an emissions factor of 16 gCO2/tkm for short-sea shipping.

Background information

Ports of Auckland is currently developing an online calculator that will allow customers to calculate emissions of their container cargo from different modes of transport, i.e. road, train and coastal shipping. The calculator's emissions estimates are based on emissions factors, and therefore establishing the accuracy of these emissions factors is important to provide POAL's customers with a level of confidence in the emissions estimates generated by the calculator.

For the same mode of transport, emission factors can vary significantly due to different attributes describing real-world transport conditions. For example, these attributes could include difference of topography for rail transport; difference in loads, size of trucks and driving conditions in road transport; and the size of a cargo ship for coastal shipping.

There is good international data on emission-factor estimates that distinguish between these attributes. For New Zealand, however, the details on these attributes may be missing or are inconsistent.

Objective

The purpose of this report is to establish the accuracy and appropriateness of emission factors that will be fed into POAL's carbon supply-chain calculator. The focus will be on transporting 22-feet 20ft and 44-feet 40ft containers with reference to tonnage per KM travelled. Transportation of cars and breakbulk is out of scope.

The specific objectives of this work are:

- to establish the accuracy of emissions factors currently used by POAL's carbon calculator
- to recommend new emission factors to calculate CO2 per tkm of cargo moved for both 20ft and 40ft containers using road, rail and coastal shipping options
- to provide the methodology of proposed new emission factors
- to recommend suitable independent verifiers of proposed new emissions factors used, and to provide advice on the appropriate frequency for reviewing and updating the emissions factors used.

Overview of approach

The approach for establishing the accuracy of EF_{tkm} values currently used by POAL involved a detailed analysis of the following four major international sources of EF_{tkm} estimates as identified in (Samuelson, 2019):

- UK Government GHG Conversion Factors for Company Reporting (UK)[9]

[9] Technical report from (DBEIS, 2018) and data from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/715425/Conversion_Factors_2018_-_Condensed_set__for_most_users__v01-01.xls

- STREAM Freight Transport 2016 handbook (Netherlands)[10]
- Methodological Guide for producing CO2 information for transport services (France)[11]
- Network for Transport Measures (EU).[12]

The objective was to map the estimates across these studies to some baseline values of average load and total vehicle weight. These baseline values were derived based on the data from the STREAM report, given the detailed assumptions provided therein. In particular, the STREAM report gives information on the mix of empty vs loaded containers, and empty vs loaded distances, which allowed estimating average loads across total distance (including empty and loaded trips).

The EFtkm estimates from the other three sources were not all reported by tonnage load and/or total vehicle weight, which would have allowed a seamless mapping. In this case, the mapping was done based on other common parameters (e.g MJ/tkm). The detailed assumptions used to do the mapping are presented separately for road transport, rail transport, and coastal shipping in the respective sections further below.

It is worth caveating that by virtue of the several assumptions that had to be made to map overseas EF_{tkm} estimates to a single baseline of loads and vehicle weights, the mapping has its limitations. This is not an issue for the conclusions in in this report, as the recommendation is to use the estimates in the STREAM report anyway, unless EF_{tkm} can be directly estimated using NZ-specific data. The STREAM estimates are more conservative, and are supported by detailed assumptions.

The final step involved comparing the overseas estimates with NZ data (where applicable) from MfE (2019) and Samuelson (2019), and then providing a commentary on the accuracy of POAL's current EF_{tkm} values used.

[10] (CE Delft, 2016)
[11] (ADEME, 2012)
[12] (NTM, 2018)

Road transport

Assumptions that affect the emissions factor

Two key parameters that affect the emissions factor for road transport are (i) vehicle load and (ii) driving conditions. Driving conditions are affected by the types of roads (urban, motorway, rural roads), and the settings for dynamic driving (optimal speed limit for different types of vehicles in relation to speed limits).

Load

For the same type of vehicle, the lighter the cargo load, the lower the emissions. According to DBEIS (2018), if a vehicle at 50 per cent capacity is emptied (fully loaded), the emissions reduction (increase) can range between 18 per cent and 25 per cent as follows:

Table 2 Change in emissions due to change in GVW

Gross vehicle weight	% change in emissions
Rigid (>17t)	+/- 18%
Articulated (<33t)	+/-20%
Articulated (>33t)	+/-25%

Source: Table 25 in DBEIS (2018)

Driving conditions

Different driving conditions affect fuel consumption. In general terms, CO_2 emissions increase with speed, and decrease with reduced dynamic driving (e.g. due to enforced speed limits) (TNO, 2016). More congested urban speeds will reduce fuel efficiency.

Comparison of estimates in overseas studies

Table 3 below compares the assumptions used for estimating road transport EF_{tkm} in the four overseas jurisdictions. As can be seen, the STREAM report (Netherlands)[13] is the only one that distinguishes between types of roads, while also providing detailed assumptions around the container load factors and loaded kilometres covered. On this basis, the values in the STREAM report are used as baseline for mapping the other overseas estimates. Appendix A provides the assumptions used in the STREAM report to estimate EF_{tkm} for road transport.

[13] (CE Delft, 2016)

Table 3 Comparison of assumptions used to estimate overseas values of road transport EF_{tkm}

	Netherlands	France	UK	EU
Estimates distinguish between container and other container cargo	Yes	No, but provides values by GVW	No	No
Assumptions distinguish between types of road	Yes	No	No	No
Assumptions distinguish between load factors	The mix of full vs empty is 72%/28%, which is applied to different container weights	For containers, only a load of 12.5 tons is reflected for a vehicle with a GVW of 40t	Yes	No
Estimates are weighted for loaded vs empty km	Yes (weighted average of 70% loaded and 30% unloaded kilometres)	Yes (not clear if weighted average as per STREAM or a simple average as per UK report)	This is implied by the fact the EF_{tkm} is the ratio between average gCO2/vkm and tkm/vkm[14]	Unclear
Estimates are separate for TTW emissions	Yes	Can be derived	No	No

The estimates from the French, UK, and EU reports were first converted to TTW based on a TTW/WTW conversion factor of 81 per cent,[15] and then were mapped to the estimates in the STREAM report as follows:

- France: for container road transport, (ADEME, 2012) provides EF_{tkm} estimates only for semi-trailer trucks with a GVW of 40 tons. This value was mapped to the STREAM category of "heavy-weight container, truck >20t" on the basis of similar TEU load.
- EU: the EF_{tkm} estimates were mapped based on the similarity of energy consumption use (MJ/tkm) and vehicle category.
- UK: an average of the estimate for 50 per cent and 100 per cent load was first calculated to derive the values for a 75 per cent load, which is close to the 72 per cent load factor in the STREAM report. The UK values were then mapped on the basis of vehicle category.

One point that is worth highlighting is that some overseas sources distinguish between container and bulk cargo, and others don't. The estimates for different types of cargo could differ, for example, due

[14] Para 6.11 in the UK report
[15] This is based on the upstream and operation diesel emission factors in (ADEME, 2012)

to the weight of empty containers not being included in the calculation of average load,[16] or due to containers being transported on different road conditions than other types of freight. The mapping therefore has its limitations.

The results of the mapping are presented in Table 4, which lists average EF_{tkm} values (average across all road types) by total vehicle weight and corresponding average load. These results are also illustrated in

Figure 1.

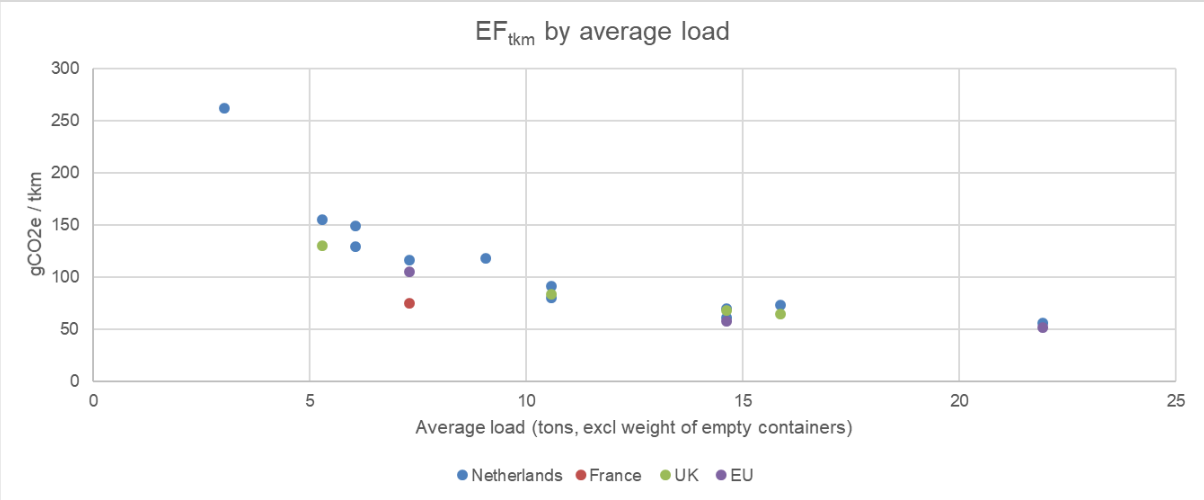
Table 4 Comparison of overseas average TTW EF_{tkm} values for road transport load

Average load (tons)[17]	Total vehicle weight[18] (tons)	Vehicle category[19]	Average gCO2e/tkm			
			Netherlands	France	UK	EU
3.0	19.9	Truck > 20t	262			
5.3	22.2	Truck > 20t	155		130.35	
6.0	27.8	Truck > 20t + trailer	149			
6.0	23.5	Tractor-semitrailer, heavy	129			
7.3	24.3	Truck > 20t	116	74.84		105.44
9.1	34.0	Truck > 20t + trailer	91			
10.6	32.5	LHV	118			
10.6	29.2	Truck > 20t	80		83.65	
14.6	36.6	Truck > 20t + trailer	70			57.59
14.6	34.3	Tractor-semitrailer, heavy	61		67.729	
15.9	40.9	LHV	73		64.339	
21.9	47.1	LHV	56			51.91

Source: Sapere analysis based on (DBEIS, 2018), (ADEME, 2012), (CE Delft, 2016), (NTM, 2018)

[16] See the note following formula (4) on p. 39 in (CE Delft, 2016)
[17] Excludes the weight of empty containers
[18] Includes the weight of empty containers
[19] Categories as per (CE Delft, 2016)

Figure 1 EF_{tkm} by total average load (road transport)



Discussion

The figure above suggests that EF_{tkm} values tend to decrease exponentially with a reduction in average load (although beyond a certain load, the reduction is more linear). This means that using a single average EF_{tkm} may overestimate emissions for heavy loads and underestimate emissions for lighter loads.

Note that for a particular average load, the EF_{tkm} value can differ depending on the total vehicle weight (e.g. see the case of 10.6 average tons in Table 4) – a lighter vehicle will correspond to a lower EF_{tkm}. Therefore, EF_{tkm} estimates should distinguish not only between container load, but also between vehicle weights if more than one type of vehicle is used.

The Ministry for the Environment suggests using an EF_{tkm} of 136g CO2e/tkm,[20] which is also the estimate provided by Samuelson (2019). However, this value is an average for *both* medium and heavy trucks (an average load of 9.5 tonnes[21]).[22] On the basis of the analysis above, this figure is appropriate for containers with an average load of 8-15 tons, for a total vehicle weight of up to 35 tons.

For heavier loads (>16 tons) and vehicles, a lower EF_{tkm} would be more appropriate (between 56 and 73g CO2e/tkm). POAL currently uses an estimate of 62g CO2e/tkm, which appears to be based on McKinnon's (2007) values for heavy trucks.[23] [24] This value is appropriate as an *average* for loads higher than 16 tons.

---

[20] (MfE, 2019)
[21] 2016 figure from Tables 11.1 and 11.2 in the MoT Annual Vehicle Statistics at https://www.transport.govt.nz/mot-resources/vehicle-fleet-statistics/ . Note that the 2018 figure is 8.2 tonnes
[22] This emission factor was calculated by dividing MoT's 2016 total estimates of truck tkm (MoT's Annual Vehicle Statistics spreadsheet) by MoT's estimates of gCO2e emitted by heavy and medium trucks (MoT's Vehicle Fleet Emission Model). Unfortunately, the tkm estimate is an aggregate for heavy and medium trucks, so an EF_{tkm} for heavy trucks alone cannot be estimated given the data available.
[23] 40 tonne articulated truck carrying a maximum payload of 26 tonnes (McKinnon & Piecyk, 2011).
[24] Note that this value is for CO2 not CO2e – the difference, however, is small, ~1%.

Recently, the NZ Ministry of Transport has released updated emissions intensity factors for heavy trucks on NZ roads, based on real-world data (Wang, et al., 2019). For long-haul trucks,[25] they estimate a median emissions factor of 105g CO2/tkm in 2018, or 106.6g CO2e/tkm.[26] This value could be used as a midpoint between the higher and lower emissions factors of 136g CO2e/tkm and 73 CO2e/tkm.[27]

POAL context

MoT data on imports and exports going through POAL suggest that the average TEU load over the period between Q3 2018 and Q2 2019 was 9.1 tons/loaded TEU (see Appendix D:). POAL data on container loads transported by rail suggests an average of 9.8 tons/loaded TEU. A range of 9.1-9.8 tons/loaded TEU is therefore assumed for the purpose of this paper.

Given these values, MfE's recommended EF_{tkm} of 136g CO2e/tkm is appropriate for a truck carrying a single TEU, as this value applies to an average vehicle load of 9.5 tonnes. For trucks carrying more than a single TEU, a lower emissions factor would be more appropriate.

Generally, trucks leaving the port are restricted to a maximum of 1-2 TEU due to full containers exceeding weight limits and requiring HMPV permits. A truck with 3 TEUs will only be seen when these containers are transported empty for/from the Link Service. Based on Table 4, for a truck carrying 2 TEUs, a conservative estimate of 73g CO2e/tkm would apply.

Nevertheless, although it would be more accurate to distinguish trucks by their loads, this would add a layer of complexity to the usability for POAL's carbon calculator as it is being rolled out. On this basis, a midpoint emissions factor of 106.6g CO2e/tkm could be used in the beginning. The emissions factor for road transport could be reviewed later on to determine the feasibility of it being replaced with split factors distinguishing between trucks carrying 1 or 2 TEUs.

---

[25] These refer to trucks types 6, 14 and 1 under the Road User Charge rules

[26] This conversion is based on MfE's diesel emissions factors of 2.69kg CO2e/litre or CO2kg/litre, i.e. the emissions factor for all GHGs (rather than CO2 only) is 1.51% higher.

[27] Note that the MoT estimates are in terms of CO_2 rather than CO_2 equivalents. Based on the STREAM report estimates, the difference is negligible - between 0.4%-1% depending on vehicle class and weight,

Rail transport

Assumptions that affect the emissions factor

Estimates for rail transport EF_{tkm} values depend on rail traffic route, speed, train weight and fuel used. Our comparison of overseas EF_{tkm} values primarily focuses on the weight parameter in diesel rail transport, as information on the traffic route and rail speed was not provided in the literature assessed.

Furthermore, for the purpose of comparing overseas EFtkm values, the focus is on diesel trains because the NZ electricity generation mix is substantially different from other jurisdictions; comparing EFtkm estimates that are based on a mixed electric-diesel rail fleet, although more representative of the real-world mix, would not be useful for the NZ context.

It is worth noting that the UK EF_{tkm} value of 33.5 gCO2e/tkm[28] encompasses UK rail transport by *both* electric and diesel locomotives. Although it is estimated that emissions from diesel rail freight is ~96 per cent of total rail emissions,[29] it is not possible to determine on this basis alone what the EF_{tkm} for UK diesel rail transport would be. UK values are therefore excluded from the comparison of overseas EF_{tkm} values.

Comparison of estimates in overseas studies

Table 5 below compares the assumptions used to estimate estimates rail transport EF_{tkm} in the four overseas jurisdictions. Similar to road transport estimates, the STREAM report provides most detailed assumptions and estimates for rail transport EF_{tkm} based on train length, load and loaded km. On this basis, the values in the STREAM report are used as baseline for mapping the other overseas estimates. Appendix B: provides the assumptions used in the STREAM report to estimate EF_{tkm} for rail transport.

Table 5 Comparison of assumptions used to estimate overseas values of rail transport EF_{tkm}

	Netherlands	**France**	**UK**	**EU**
Estimates distinguish between container and other cargo	Yes	No, but provides details by density (kg/m3)	No	No
Assumptions distinguish between length of trains	Yes	No	No	No

[28] (DBEIS, 2018)

[29] Para 6.21 on p. 66 in (DBEIS, 2018)

	Netherlands	France	UK	EU
Assumptions distinguish between load factors	The mix of full vs empty is 72%/28%, which is applied to different container weights	Yes, based on density of kg load/m^3	No[30]	No
Estimates are weighted for loaded vs empty km	Yes (weighted average of 80% loaded and 20% unloaded kilometres)	Yes[31]	Unclear	Unclear
Estimates are separate for diesel end electricity	Yes	Yes	No	Yes
Estimates are separate for TTW emissions	Yes	Can be derived	No	Yes

The estimates from the French and EU reports were mapped to the estimates in the STREAM report as follows:

- France: Density estimates (kg/m^3) were first calculated for light, medium and heavy containers as defined in the STREAM report, assuming that a 20ft TEU has 39 m^3. The French EF_{tkm} estimates were first converted to a TTW basis using a TTW/WTW conversion factor of 81 per cent (for diesel), and then mapped to STREAM EF_{tkm} estimates on the basis of similar densities.
- EU: EF_{tkm} estimates were mapped based on the similarity of energy consumption (MJ/tkm).

Similar to road transport, the mapping above has limitations by virtue of the assumptions needed to be made to enable the mapping, and also due to the fact that not all sources distinguish between container and other types of cargo. Based on the STREAM report, similar rail gross vehicle weights (GVW) could deliver significantly different EF_{tkm} estimates. [32] Some of the difference could be for example due to the weight of empty containers note being included in the calculation of average load, but which would affect total emissions.[33]

[30] "Traffic-, route- and freight-specific factors are not currently available, though these would present a more appropriate means of comparing modes (e.g. for bulk aggregates, intermodal, other types of freight)" - 17 – p.66 in the UK report

[31] It is embedded in the split by three categories: 400 tonnes, 520 tonnes, and 600 tonnes for a 1,000 tone full train. Our understanding is that these three tonnage values are average across loaded and unloaded trips. However, it is not clear what the value for %loaded vkm is

[32] For example, in (CE Delft, 2016) the EF_{tkm} value for a medium-length diesel train transporting light bulk cargo or light containers is 34g CO2e/tkm, whereas that for light containers is 57g CO2e/ntkm, even though their gross vehicle weights are on a similar scale - 769 and 786 tonnes respectively (Table 42).

[33] See the note following formula (4) on p. 39 in (CE Delft, 2016)

The results of the mapping are presented in Table 6, which lists the EF_{tkm} values by total train weight and corresponding average load. These results are also illustrated in Figure 2. Similar to road transport, EF_{tkm} values for rail transport decrease exponentially with an increase in total train weight and container load.

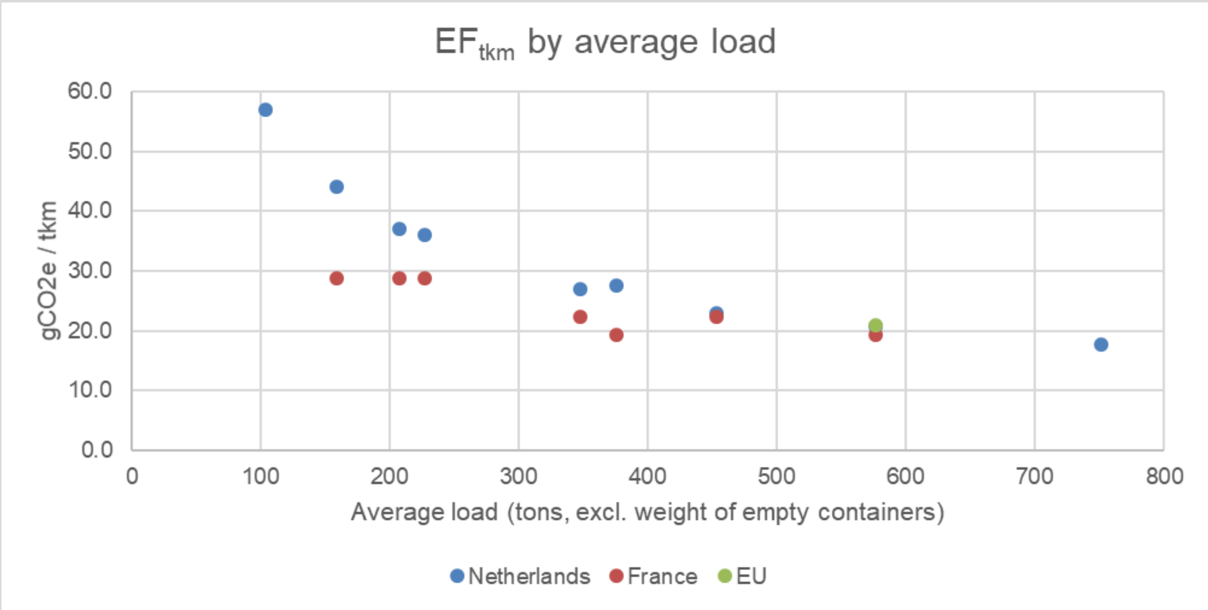
Table 6 Comparison of overseas TTW EF_{tkm} values for rail transport

Average load (tons)[34]	Total train weight (tons)[35]	Train category[36]	Average gCO2e/tkm		
			Netherlands	France	EU
103.7	160.7	Short train, light containers	57		
159.0	246.4	Mid-length train, light containers	44	28.8	
207.4	321.4	Long train, light containers	37		
226.8	299.9	Short train, medium-weight containers	36		
347.8	459.9	Short train, heavy containers	27.6		
375.8	465.8	Mid-length train, medium-weight containers	27	22.4	
453.6	599.9	Long train, medium-weight containers	23		
576.3	714.3	Mid-length train, heavy containers	20.7	19.2	21.0
751.7	931.7	Long train, heavy containers	17.4		

Source: Sapere analysis based on (ADEME, 2012), (CE Delft, 2016), (NTM, 2018)

[34] Excludes the weight of empty containers
[35] Includes the weight of empty containers, excludes the weight of locomotive
[36] Categories as per (CE Delft, 2016)

Figure 2 EF_{tkm} by average load (rail transport)



Discussion

MfE suggests that the emissions factor for NZ rail freight is 28g CO2e/tkm (MfE, 2019). Based on Samuelson (2019), who provides detail on how this value was derived, it can be concluded that this value is an average for all freight, i.e. it does not distinguish between bulk/packed cargo and container freight.

It would be more accurate to establish the EF_{tkm} value for container rail separately.

In 2018, around 46 per cent of NZ rail tkm was for shipping containers,[37] and Samuelson (2019) reports that the estimate of ntkm diesel-hail rail freight for 2017-18 was 3,826.6 million. On this basis, the value for ntkm of diesel-hauled container rail transport in 2018 can be estimated to be 1,760 million. To estimate the EF_{tkm} value for container rail transport specifically, one would need to know total diesel consumption (litres) by container rail, assuming an emissions factor of 2,720 gCO2e/litre diesel. However, this data is difficult to obtain given that containers can be transported together with bulk freight on the same train; in this case, separating out diesel consumption for container transport only is almost impossible.

Meanwhile, using the values in Table 6 as guidance, the MfE emission factor of 28g CO2e/tkm could be used for trains with total weights of ~400-600 tons (excl. locomotive weight), and average container loads of 300-500 tons. On the basis that the average export load per 20ft container in NZ is 14.56t,[38] this would correspond to 21-34 export TEUs. Imports generally have a lower weight per container than exports[39] and would therefore correspond to a greater number of TEUs.

[37] https://www.transport.govt.nz/mot-resources/freight-resources/figs/rail/commodity-and-container-trends/
[38] Table 13 in (MoT, 2014)
[39] P.49 in (MoT, 2014)

It is also worth noting that the value of 28.9g CO2e/tkm is an average for electric and diesel-hauled freight in New Zealand, and the value for diesel-only freight by rail is 28.9 g CO2e/tkm (Samuelson, 2019). The latter value should be used if it is known that only diesel locomotives are used to transport the respective containers. This estimate is slightly lower than the 30.8 g CO2/tkm currently used by POAL, which seems to reflect KiwiRail 2016 data.[40]

POAL context

The typical length of trains leaving the port is

- 26 Wagons on SAFH train (52 TEU Capacity)
- 30 Wagons on Southdown/MetroPort Train (60 TEU Capacity).

Assuming an average TEU weight of 9.1-9.8 tons/loaded TEU, the above translates to 473-588 tonnage on loaded trips (excluding weight of empty containers). These loads correspond to an EF_{tkm} values of 21 gCO2e/tkm in the STREAM report.

Given New Zealand's more difficult topography, the appropriate emission factor would be higher than this. Furthermore, it is worth noting that electric trains have been running only between Palmerston North and Hamilton.[41] On this basis, the recommended emissions factor is that estimated by Samuelson (2019) for diesel trains, i.e. 28.9gCO2e/tkm.

[40] As per table 3 in (Samuelson, 2019)

[41] https://www.rnz.co.nz/news/political/357007/govt-s-electric-train-promise-now-off-the-rails-union. Although the government was initially planning to decommission the electric locomotives, recent development suggest otherwise https://www.kiwirail.co.nz/media/electric-locomotives-to-continue-with-government-investment/

Coastal shipping

Assumptions that affect the emissions factor

Estimates for coastal shipping EF_{tkm} values depend on the vessel size, average sailing speed, installed capacity and output of the main engine, all of which affect the vessel's energy consumption. The specific fuel consumption by engines depends on load, and it has been shown that vessels consume less energy on ballast trips when loaded (CE Delft, 2016).

Emission factor estimates in the reports studies are generally presented relative to load (e.g. ADEME (2012)), and/or energy consumption (e.g. TNO (2016)).

It is also worth noting that in the context of shipping, a distinction is made between deep-sea shipping, inland shipping, and short-sea shipping. Deep-sea shipping applies to very long distances, inland shipping applies to inland waterway transport (e.g. canals in Netherlands), and short-sea shipping would cover transport over shorter distances at sea. In this report, coastal shipping refers to the latter case. Estimates of EF_{tkm} for short-sea shipping can be twice as high as those for deep-sea shipping.[42]

Not all of the reports studied distinguish between these categories:

- CE Delft (2016) provides separate estimates for inland shipping and maritime short sea. In their definition, short sea seems to cover the Netherlands Continental Shelf (12-mile zone).[43]
- ADEME (2012) provides general estimates for "freight by sea".
- NTM (2018) provides separate estimates for general sea cargo shipping, and separate for container inland waterway transport.
- DBEIS (2018) provides general estimates for "sea shipping".

Comparison of estimates in overseas studies

Table 7 below compares the assumptions used to estimate coastal shipping EF_{tkm} in the four overseas jurisdictions. Similar to the estimate for the other types of transport, the STREAM report provides most detailed assumptions and estimates for short-sea shipping. On this basis, the values in the STREAM report are used as baseline for mapping the other overseas estimates. Appendix C: provides the assumptions used in the STREAM report to estimate EF_{tkm} for short-sea shipping.

---

[42] (McKinnon, 2007) reports a value of 16.0 gCO2/tkm for short-sea shipping, and 8.4 gCO2/tkm for deep-sea shipping.

[43] Section 7.2 on page 50 in https://www.pbl.nl/sites/default/files/downloads/PBL2016_Methods_for_calculating_the_emissions_of_transport_in_the_Netherlands_2425.pdf

Table 7 Comparison of assumptions used to estimate overseas values of shipping EF_{tkm}

	Netherlands	France	UK	EU
Estimates distinguish between container and other cargo	Yes	Yes	Yes	Yes
Assumptions distinguish between types of shipping	Yes	No - general estimates for "freight by sea"	No - general estimates for "sea shipping"	Yes, but it is unclear what distance is covered by "general sea cargo"
Assumptions distinguish between load factors	The mix of full vs empty is 72%/28%, which is applied to different container weights	Yes, although assumptions on mix are not provided	No	No
Estimates are weighted for loaded vs empty km	Yes – different weights are applied to different container vessel class	Yes	Unclear	Unclear
Estimates are separate for TTW emissions	Yes	Can be derived	No	Yes

The estimate form the French, UK and EU reports were mapped to the estimates in the STREAM report as follows:

- France: EF_{tkm} estimates were mapped by comparable vessels class (in terms of nr of TEUs) and load. The French estimates were converted to a TTW basis using a TTW/WTW conversion factor of 87 per cent (for fuel oil)[44]
- EU: EF_{tkm} estimates were mapped based on the similarity of energy consumption use (MJ/tkm).
- UK: EF_{tkm} estimates were mapped by comparable vessels class (in terms of nr of TEUs). The average freight unit for the UK numbers is 13.624 tons. In STREAM classification this falls between medium-weight and heavy-weight containers. For ships with 2000+ TEUs, medium-weight containers were assumed. For ships <2000 TEU, light-weight containers were assumed.

The results are presented in Table 8, which lists the EF_{tkm} values by total vessel weight and corresponding average load. These results are also illustrated in Figure 3 and Figure 4.

[44] This factor was estimated based on fuel oil emission factors from Table 14 in (ADEME, 2012).

Table 8 Comparison of overseas TTW EF_{tkm} values for short-sea shipping

Average load (tons)[45]	Total vessel weight[46] (tons)	Vessel class[47]	Average gCO2e/tkm			
			Netherlands	France	UK	EU
2,222.0	3,428.5	0-999 TEUs, light weight containers	46	29.0	32.1	
3,888.5	5,126.7	0-999 TEUs, medium-weight containers	27			25.4
5,054.4	7,904.4	1000-1999 TEUs, light-weight containers	36	29.0	28.4	
5,369.8	6,639.8	0-999 TEUs, heavy-weight containers	20			
7,840.8	13,065.8	2000-2999 TEUs, light-weight containers	31			
8,845.2	11,770.2	1000-1999 TEUs, medium-weight containers	21	19.2		
11,225.1	18,939.1	3000-4999 TEUs, light-weight containers	28			
12,214.8	15,214.8	1000-1999 TEUs, heavy-weight containers	16			
13,721.4	19,083.9	2000-2999 TEUs, medium-weight containers	18	17.9	17.7	
15,241.0	25,881.0	5000-7999 TEUs, light-weight containers	24			
18,928.6	24,448.6	2000-2999 TEUs, heavy-weight containers	13			
19,643.9	27,560.9	3000-4999 TEUs, medium-weight containers	16		14.7	
21,529.6	37,052.6	8000-11999 TEUs, light-weight containers	21			
26,671.7	37,591.7	5000-7999 TEUs, medium-weight containers	24		14.7	14.4
27,127.3	35,247.3	3000-4999 TEUs, heavy-weight containers	12	11.9		
36,832.3	48,032.3	5000-7999 TEUs, heavy-weight containers	11	11.9		
37,676.8	53,608.3	8000-11999 TEUs, medium-weight containers	12		11.0	

[45] Excludes the weight of empty containers
[46] Includes the weight of empty containers
[47] Categories as per (CE Delft, 2016)

Average load (tons)[45]	Total vessel weight[46] (tons)	Vessel class[47]	Average gCO2e/tkm			
			Nether lands	France	UK	EU
52,029.8	68,369.8	8000-11999 TEUs, heavy-weight containers	9	9.0		

Source: Sapere analysis based on (DBEIS, 2018), (ADEME, 2012), (CE Delft, 2016), (NTM, 2018)

Figure 3 EF_{tkm} by total average load (shipping)

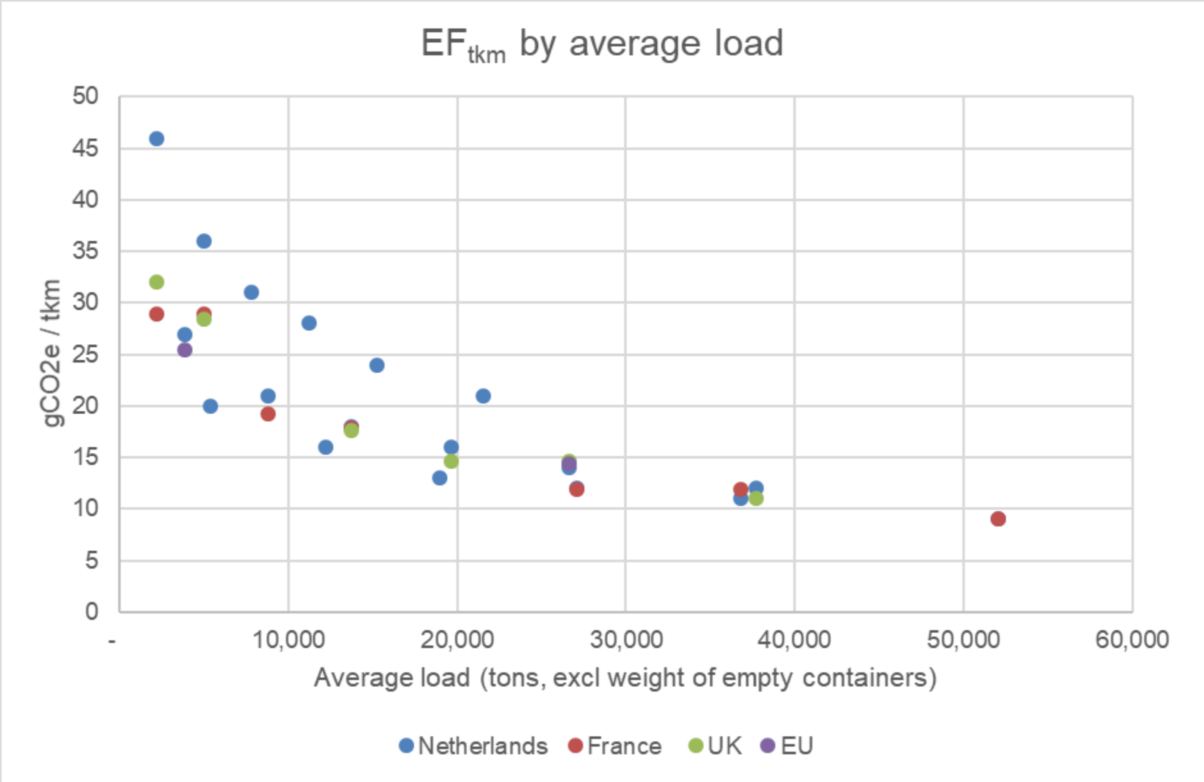
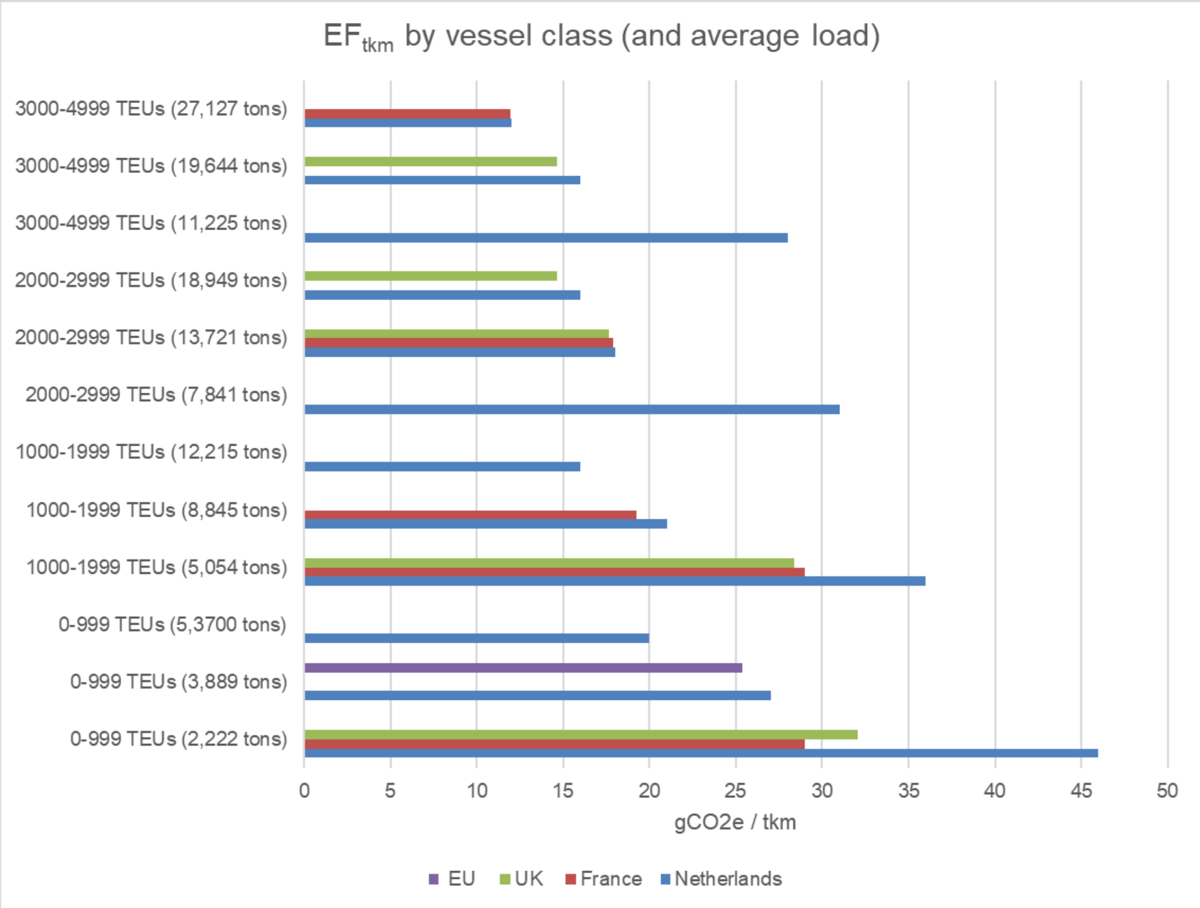


Figure 4 EF_{tkm} by vessel class and average load



Discussion

Similar to the other modes of transport, the figure above suggests an exponential decrease in shipping EF_{tkm} with a decrease in average load. This means that using a single average EF_{tkm} may overestimate emissions for heavy loads and underestimate emissions for lighter loads.

Note also that the EF_{tkm} value depends not only on average load, but also on total vessel weight, as illustrated by the fact that the values in the figure are scattered within a "corridor" rather than along a single line. For similar average loads, EF_{tkm} will be higher for larger (heavier) vessels.

MfE (2019) suggests that the EF_{tkm} for container freight coastal shipping is 45 gCO2e/tkm, citing Samuelson (2019). In turn, Samuelson (2019) reports this figure on a TTW basis and in relation to the STREAM report estimates for 0-999 TEU light-weight containers.[48] However, based on follow-up conversations with Ralph Samuelson, it emerged that the recommended emissions factor should have referenced medium-weight containers from the STREAM report, i.e. 27 gCO2e/tkm.

Apart from domestic vessels (i.e. the Spirit of Canterbury), NZ coastal shipping, however, is also undertaken by international shipping lines "primarily for the purposes of repositioning empty

[48] Samuelson reports this to be for light-weight containers, but this is incorrect as per STREAM report

containers to where the cargo is located or transhipping loaded export containers to utilise international services. There is also some transport of loaded import containers being distributed domestically using international line services up and down the New Zealand coast" (MoT, 2014). Overall, domestic carriage of containers by international carriers is incidental to their international operations and is, therefore, limited.

For international ships, MfE (2019) suggests that the EF_{tkm} values from the UK DBEIS (2018) report should be used. Note that the UK values reported in MfE (2019) are on a WTW basis, and have been converted here to a TTW metric to be able to compare with the values above. These converted values are presented in the "UK" column in Table 8. Furthermore, as mentioned previously, UK estimates do not distinguish between types of shipping (e.g. deep-sea vs short-sea), so it is unclear how transferrable those values are specifically to NZ *coastal shipping* by international ships.

Table 8 and Figure 4 suggest that for average loads of up to ~25,000 tons, the UK estimates are below those for Netherlands. This can also be seen in Figure 4 which presents overseas EF_{tkm} estimates by vessels class (as defined by nr of TEUs) and average loads (in parenthesis). It is therefore recommended that for these loads, the UK estimates should be used as a lower bound for coastal shipping by international ships in NZ. For a more conservative approach, the Netherlands estimates should be used.

For larger average loads, Figure 3 shows that overseas EF_{tkm} estimates tend to be more closely aligned, with loads beyond 35,000 tons converging to an EF_{tkm} estimate of 9-12 gCO2e/tkm. The EF_{tkm} of 8.4 gCO2/tkm that is currently used by POAL seems to be based on McKinnon (2007); however, as noted previously (footnote 42), this value relates to deep-sea shipping.

POAL context

Domestic ships

MoT FIGS data on coastal shipping via POAL over the Q3 2018 - Q2 2019 period suggests that the maximum tonnage loaded or discharged on a domestic ship was 8,188 tons over this period (the third figure in Appendix E:). Based on this maximum value, Table 8 would suggest using a lower-bound emissions factor of 21 gCO2e/tkm. However, I also estimate that most of the times, the number of full or empty TEU movements on a domestic ship going through POAL was below 50 (the first two figures in Appendix E:). This can either mean that the ship is close to capacity once it has docked at POAL and cannot take more cargo, or conversely, it is under-loaded but there is not much cargo to move on average. Even if the latter where the case, it says nothing of the ship's average load across the overall domestic route. Unfortunately, to the best of my knowledge, there is no publicly available data to quantify this with certainty.

In the absence of such data, I base my recommendation on Swire's recent decision to introduce a larger-capacity domestic ship; with the introduction of Moana Chief in September 2019, the capacity of domestic coastal shipping has increased from 1,100 TEUs to 1,740 TEUs.[49] On this basis, I conclude that it is more likely that the previous 1,100 TEU ship carried at least half of its full TEU capacity on

[49] http://nzsf.org.nz/media/pacifica-upsize-to-larger-vessel-on-coast

average – perhaps a conservative assumption. Assuming an average TEU load of 9.1 tons, this means an average load of ~5,000 tons. Based on Table 8, this suggests an emissions factor of 36 gCO2e/tkm.

International ships. Based on data supplied by POAL, the TEU capacity of international ships coming through the Ports of Auckland ranges between 1,740 TEUs and 5,117 TEUs.[50] Using FIGS data, I estimate that the average number of full TEUs discharged or loaded on international ships for the domestic leg is 13-16, and that the average number of empty TEUs is 17-23 depending on ship size. The relatively small numbers of TEUs loaded or discharged suggests that international ships travelling along the NZ domestic coast are close to full TEU capacity utilisation.[51] Assuming an average TEU load of 9.1 tons, this means that the average load of international ships along the cost is between 15,000 and 46,000 tons. It is not possible to map these settings to a single value in Table 8, so I take an average of STREAM EFtkm values for medium-weight containers for ships with the TEU capacities between 2000 and 4999. The resulting emissions factor is 17 gCO2e/tkm, noting that for the larger ships that are fully loaded (e.g. over 25,000 tons) the value is likely to be smaller.[52]

For international ships of 5,000-10,000 TEU capacity, Table 8 suggests an average emissions factor of between 25 gCO2/tkm (5,000 – 7,999 TEUs) and 12 gCO2/tkm (8,000 – 11,999 TEUs), or a simple average of 18.5 gCO2/tkm.[53]

---

[50] Terminal Callers – Vessel details xls.

[51] This conclusion was also validated in a discussion with Ralph Samuelson.

[52] Note that an argument could be made the because these additional loads moving through POAL are so small, emissions per tonne-km for POAL-specific container cargo in this case would be negligible. The counterargument is that this cargo would need to be transported somehow along the coast anyway, which would generate emissions. In the absence of data that would allow estimating emissions specifically for the domestic cargo that is incidental to international operations, I recommend the STREAM report figures.

[53] Note that this is slightly higher than the average of 15 gCO2e/tkm based on (MfE, 2019) recommendations of 13 gCO2e/tkm and 17 gCO2e/tkm for 5,000-7,999 TEU ships and 8,000 TEU-ships respectively.

Container emissions at port and freight hub

There are generally two ways by which container-related emissions at the Port and the Wiri freight hub could be estimated:

- Top-down, based on annual diesel consumption by container handling equipment, and annual electricity consumption by cranes, or
- Bottom-up, based on data from simulations run by the Port's supply-chain team, specifically focussing on diesel consumption.

The key advantage of the latter method is that it allows disaggregation of TEU handling by reach stackers and straddles, which would allow estimating two separate emission factors depending on the equipment. A weighted average EF could then be estimated using diesel consumption by straddles vs reach stackers as weights. This weighted average would be a more accurate measurement than a simple average estimated as the ratio of total diesel consumption by container-handling equipment and the total number of TEUs handled at the Port during a year.

However, the current data from simulations shows significant discrepancy between the simulated and real-world average diesel consumption by container-handling equipment. Until this discrepancy is addressed, the simpler top-down approach is recommended.

Using this approach, the emissions factors at the Port and the Wiri freight hub for 2019 are shown in Table 9 and Table 10 respectively. The diesel emissions factor is as per MfE (2019), whereas the emissions factor for electricity is assumed zero given that POAL is now purchasing zero-emissions renewable energy certificates for all electricity consumed by the Port's operations.

In the future, it is recommended that the emissions factors are updated annually to reflect most recent energy consumption and numbers of TEUs handled. This will allow capturing any changes in fuel efficiencies, e.g. either worsening due to aging machinery, or improving due to replacement with newer assets with better fuel economy.

Table 9 Emissions factors for container handling at Port

	Energy consumption in 2019	**Nr TEUs in 2019**	**Avg energy per TEU p.a.**	**Emissions factor**	**Average kgCO2e / TEU p.a.**
Straddles and reach stackers	2,376,096.08 litres of diesel	880,781	2.7 litres of diesel	2.69 kgCO2e/ diesel litre	7.27
Cranes	3,079,062.51 kWh	880,781	3.5 kWh	0	0

Table 10 Emissions factors for container handling at Wiri freight hub

	Energy consumption in 2019	Nr TEUs in 2019	Avg energy per TEU p.a.	Emissions factor	Average kgCO2e / TEU p.a.
Container handling plant	271,505.10 litres of diesel	135,808	2 litres of diesel	2.69 kgCO2e/ diesel litre	5.39

References

ADEME, 2012. *CO2 information for transport services. Application of Article L. 1431-3 of the French transport code. Methodological guide*.

CE Delft, 2016. *STREAM freight transport. Emissions of freight transport modes*.

DBEIS, 2018. *2018 Government GHG conversion factors for company reporting. Methodology paper for emissions factors: final report*.

McKinnon, A., 2007. *Measuring and managing CO2 emissions*.

McKinnon, A. & Piecyk, M., 2011. *Measuring and managing CO2 emissions of European Chemical Transport*.

MfE, 2019. *Measuring emissions: A guide for organisations.* [Online].

MoT, 2014. *Future freight scenarios study*.

NTM, 2018. *Default and benchmark transport data.* [Online]
Available at: https://www.transportmeasures.org/en/wiki/evaluation-transport-suppliers/

Samuelson, R., 2019. *What we know and don't know about freight emissions by mode in New Zealand.* [Online].

TNO, 2016. *Dutch CO2 emission factors for road vehicles*.

Wang, H., McGlinchy, I. & Samuelson, R., 2019. *Real-world fuel economy of heavy trucks*.

Appendix A: STREAM assumptions for road transport EFtkm

Vehicle type	Load capacity (nr TEUs)	Average container slot utilisation	Share of loaded containers
Heavy truck > 20 ton	1	70%	72%
Heavy truck + trailer > 20 ton	2	70%	72%
Tractor - semitrailer	2	70%	72%
LHV	3	70%	72%

Appendix B: STREAM assumptions for rail transport EFtkm

Vehicle type	Nr of wagons	Load capacity (nr TEUs)	Average container slot utilisation	Share of loaded containers
Short train	22	45	80%	72%
Medium-length train	33	70	80%	72%
Long train	44	90	80%	72%

Appendix C: STREAM assumptions for short-sea shipping EFtkm

Short-sea vessel class (nr TEUs)	Load capacity (nr TEUs)	Average container slot utilisation	Share of loaded containers
0-999	635	81%	72%
1,000-1,999	1,500	78%	72%
2,000-2,999	2,750	66%	72%
3,000-4,999	4,060	64%	72%
5,000-7,999	5,600	63%	72%
8,000-11,999	8,170	61%	72%
12,000-14,500	13,350	57%	72%

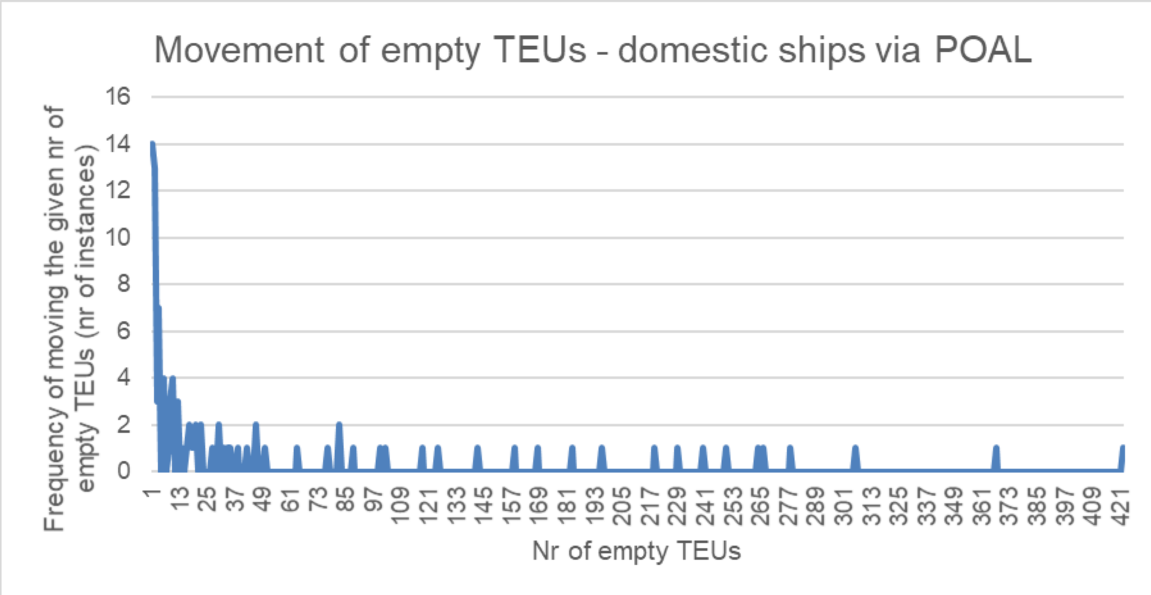
Appendix D: Imports and exports via POAL

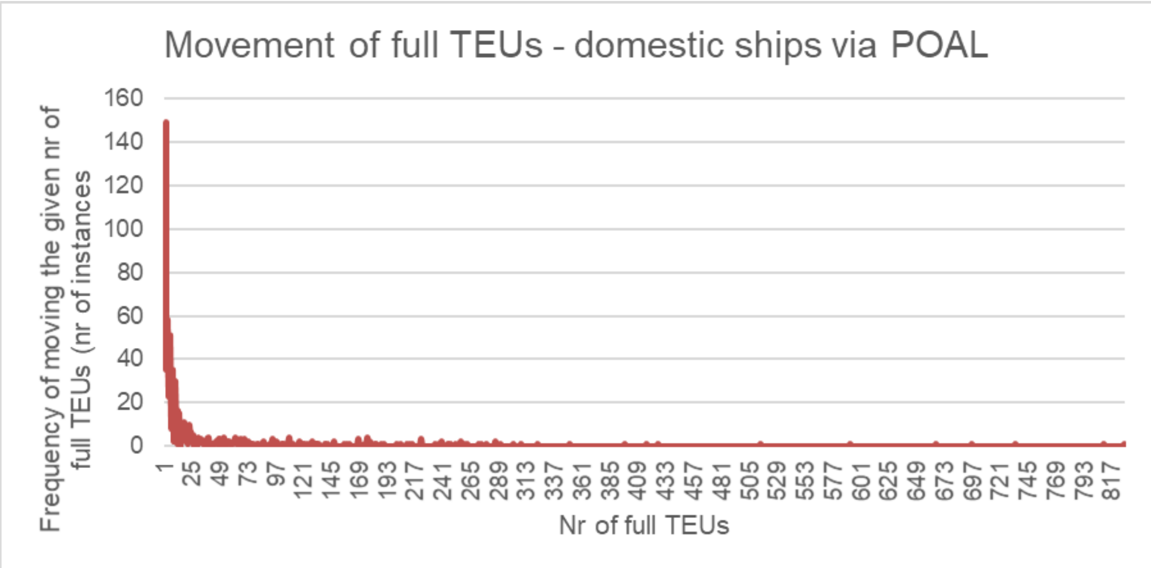
The table below provides the data for dry containers over the period 18Q3-19Q2, based on MoT's Freight Gathering Information System.

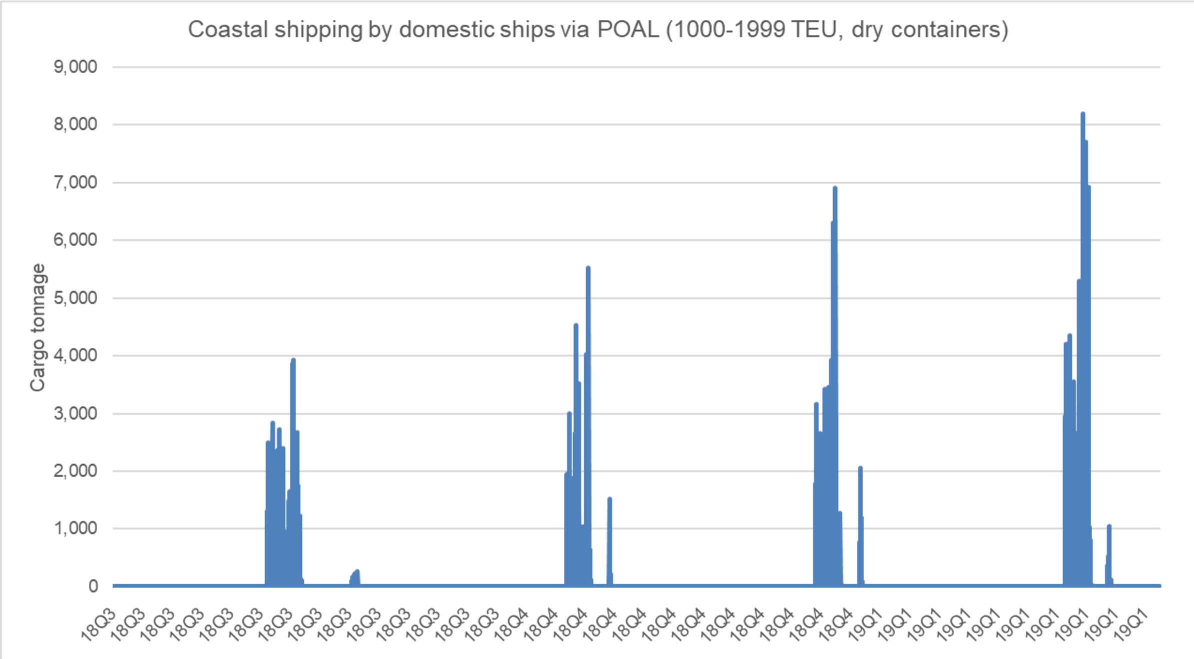
	Cargo tonnage	Tonnage - % total	Avg TEU load	Nr full TEUs	Nr empty TEUs	% Full TEU
Import	11,987,692	80%	8.7	1,373,554	6,854	100%
Export	3,028,470	20%	10.6	286,672	329,216	47%
Total	15,016,162			1,660,226	336,070	
Average			9.1			83%

Appendix E: Coastal shipping via POAL

The figure below are for container freight on domestic ships over the period 18Q3-19Q2, and are based on MoT's Freight Gathering Information System data for Ports of Auckland.






Coastal shipping by domestic ships via POAL (1000-1999 TEU, dry containers)
Cargo tonnage
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
18Q3
18Q4
19Q1

About Sapere

Sapere is one of the largest expert consulting firms in Australasia, and a leader in the provision of independent economic, forensic accounting and public policy services. We provide independent expert testimony, strategic advisory services, data analytics and other advice to Australasia's private sector corporate clients, major law firms, government agencies, and regulatory bodies.

'Sapere' comes from Latin (to be wise) and the phrase 'sapere aude' (dare to be wise). The phrase is associated with German philosopher Immanuel Kant, who promoted the use of reason as a tool of thought; an approach that underpins all Sapere's practice groups.

We build and maintain effective relationships as demonstrated by the volume of repeat work. Many of our experts have held leadership and senior management positions and are experienced in navigating complex relationships in government, industry, and academic settings.

We adopt a collaborative approach to our work and routinely partner with specialist firms in other fields, such as social research, IT design and architecture, and survey design. This enables us to deliver a comprehensive product and to ensure value for money.

For more information, please contact:

Corina Comendant
Phone: +64 9 909 5829
Mobile: +64 21 537 333
Email: ccomendant@thinkSapere.com

Wellington	Auckland	Sydney	Melbourne	Canberra
Level 9 1 Willeston Street PO Box 587 Wellington 6140	Level 8 203 Queen Street PO Box 2475 Shortland Street Auckland 1140	Level 18 135 King Street Sydney NSW 2000	Level 2 161 Collins Street GPO Box 3179 Melbourne 3001	PO Box 252 Canberra City ACT 2601
P +64 4 915 7590 F +64 4 915 7596	P +64 9 909 5810 F +64 9 909 5828	P +61 2 9234 0200 F +61 2 9234 0201	P +61 3 9005 1454 F +61 2 9234 0201 (Syd)	P +61 2 6100 6363 F +61 2 9234 0201 (Syd)

www.thinkSapere.com

independence, integrity and objectivity