Vehicle Emissions Prediction Model: VEPM 6.3 update technical report

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Date: 28 April 2022

Recommended citation:

Metcalfe J & Peeters S (2022). *Vehicle Emissions Prediction Model: VEPM 6.3 technical update report*. Report prepared for Waka Kotahi NZ Transport Agency by Emission Impossible Ltd, April 2022.

Revision history:

No.	Date	Author	Reviewer(s)	Details
1	31 March 2022	Jayne Metcalfe	Serge Peeters	Draft to client
2	28 April 2022	Jayne Metcalfe		Final to client for publication

Acknowledgements:

The authors would like to thank Haobo Wang (Ministry of Transport) for providing updated fleet data.

Executive summary

The Vehicle Emissions Prediction Model (VEPM) has been developed by Waka Kotahi NZ Transport Agency (Waka Kotahi) and Auckland Council to predict emissions from vehicles in the New Zealand fleet under typical road, traffic and operating conditions. The model provides estimates that are suitable for air quality assessments and regional emissions inventories. Since its release in 2008, VEPM has been successfully used in Auckland and around New Zealand to estimate vehicle emissions in air quality assessments for road projects. An important feature of the model is the ability to estimate changes to vehicle emissions in future years (from 2001 to 2050).

The emission factor databases that VEPM utilises to derive New Zealand-relevant factors are constantly being updated with improved factors for new technologies, emerging issues and real-world effects. The previous version of VEPM (VEPM 6.2) was released in July 2021 (Metcalfe *et al* 2021).

Work is currently underway to upgrade VEPM software. The upgraded VEPM 7.0 will be released later in 2022. VEPM 6.3 is an interim update which has been commissioned by Waka Kotahi to ensure that VEPM remains fit for purpose while development of VEPM 7.0 is underway. This report discusses the methodology we followed to update VEPM to include the following:

- Updating the fleet profile based on updated vehicle kilometres travelled (VKT) data from the Vehicle Fleet Emission Model (VFEM3) provided by Ministry of Transport
- Revising assumed emission standards for Japanese used imports from 2010 onwards
- Revising the assumed date of introduction of Euro 6/VI standards in VEPM to reflect a likely "no new policy" scenario
- Updating the application of fuel correction factors

Significant changes to fleet-weighted emission factors as a result of changes implemented in VEPM 6.3 are summarised as follows:

- Fleet weighted average NO_X emission factors are higher in VEPM 6.3 compared with VEPM 6.2 from 2025 onwards. This is primarily due to the change in the assumed implementation date for Euro 6 and Euro VI emission standards.
- Fleet weighted fuel consumption is lower in VEPM 6.3 compared with VEPM 6.2 from 2025 onwards due to higher uptake of electric vehicles.
- Other emission factors are similar in VEPM 6.3 compared to VEPM 6.2 with some small differences due to changes and corrections in the calculation methodologies.

Contents

Glossary of terms and abbreviations

Articulated vehicle	An articulated vehicle has a driver's position, a steering system, motive power and two rigid sections that articulate relative to each other
CO	Carbon monoxide
CO_2	Carbon dioxide, a greenhouse gas
CO_2-e	Carbon dioxide equivalent, a way to express the impact of each different greenhouse gas in terms of the amount of CO_2 that would create the same amount of warming
COPERT	The European Computer Model to Calculate Emissions from Road Transport
EMEP/EEA	European Monitoring and Evaluation Programme/European Environment Agency
g/km	Grams per kilometre
GVM	Gross vehicle mass
GCM	Gross combined mass, which is the combined mass of a truck including the mass of any trailers
HC	Total hydrocarbons
HCV	Heavy commercial vehicle, a commercial vehicle with a GVM >3.5 tonnes
LCV	Light commercial vehicle, a commercial vehicle with a GVM <3.5 tonnes
MoT	Te Manatū Waka: Ministry of Transport
NO_X	Oxides of nitrogen
NO_2	Nitrogen dioxide, an air quality pollutant
N_2O	Nitrous oxide, a greenhouse gas (not to be confused with NO_2 which is an air quality pollutant)
PM	Particulate matter
PEMS	Portable Emissions Monitoring System

Rigid vehicle	A rigid vehicle has a driver's position, a steering system, motive power and a single rigid chassis.
SUV	Sports utility vehicles
VEPM	Vehicle Emissions Prediction Model, developed by Waka Kotahi to predict air emissions and fuel consumption for the New Zealand fleet
VFEM3	Version 3 of the Vehicle Fleet Emissions Model, developed by MoT to predict the makeup, travel, energy (fuel and electricity) use and greenhouse gas emissions of the future New Zealand vehicle fleet
VKT	Vehicle kilometres travelled
WHTC	World Harmonized Transient Cycle
WLTP	Worldwide Harmonized Light Vehicles Test Procedure
VOC	Volatile organic compound

1. Introduction

1.1 Background

The Vehicle Emissions Prediction Model (**VEPM**) has been developed by Waka Kotahi NZ Transport Agency (**Waka Kotahi**) and Auckland Council to predict emissions from vehicles in the New Zealand fleet under typical road, traffic and operating conditions. The model provides estimates that are suitable for air quality assessments and regional emissions inventories. VEPM has been successfully used in Auckland and around New Zealand to estimate vehicle emissions in air quality assessments for road projects. An important feature of the model is the ability to estimate changes to vehicle emissions in future years (from 2001 to 2050).

VEPM is an average speed model which predicts emission factors for New Zealand fleet, based on the different vehicle types/technologies present and the relative kilometres travelled by each vehicle class. Fleet-weighted emission factors are calculated by multiplying the emissions factors in grams per kilometre (**g/km**) for each vehicle class by the proportion of kilometres travelled by that class for any given year.

VEPM derives New Zealand-relevant factors based on emissions factors from the European COPERT model, which is published by the European Environment Agency in a spreadsheet (EEA 2021a). The emission factors are constantly being updated with improved factors for new technologies, emerging issues and real-world effects. Since its original release in 2008, VEPM has undergone regular reviews and updates to ensure its predictions reflect the changing emissions profile of the New Zealand fleet.

1.2 Purpose and scope of this report

The purpose of this 2022 update is to keep VEPM current by updating the fleet and some key assumptions.

1.3 Report structure

This report is structured as follows:

- Chapter 2 outlines the updates that have been implemented to develop VEPM 6.3
- Chapter 3 compares the fleet-weighted emissions factors now predicted by VEPM 6.3 versus those from the previous version VEPM 6.2
- Chapter 4 highlights areas of future work.

The report discusses the methodology followed to update VEPM and includes all assumptions and revised calculations. All references are included at the end.

Further information and technical reports relating to development of the Vehicle Emission Prediction Model are available on the Waka Kotahi Highways Information Portal website[1].

[1] https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/air-quality-climate/planning-and-assessment/vehicle-emissions-prediction-model/

2. Updates

This chapter describes updates that have been implemented to develop VEPM 6.3. The areas covered include:

- Spreadsheet and data processing improvements
- Updating the fleet profile based on updated vehicle kilometres travelled (VKT) data from the Vehicle Fleet Emission Model (VFEM3) provided by Ministry of Transport
- Revising country of origin assumptions, and assumed emission standards for Japanese used imports from 2010 onwards
- Revising the assumed date of introduction of Euro 6/VI standards in VEPM to reflect a likely "no new policy" scenario
- Updating the application of fuel correction factors
- Updating the methodology to breakdown articulated truck VKT to take into account country of origin

2.1 Spreadsheet and data processing improvements

A database module was developed to streamline processing of VKT data from VFEM into VEPM.

Changes were made to the spreadsheet to:

- Facilitate streamlined VKT data from the new database module.
- Simplify the calculation of emission factors for New Zealand manufactured vehicles.
- Correct the calculation of the brake and tyre wear emission factors for electric LCV's. These were previously assigned emission factors for passenger cars in VEPM 6.2
- Fix a number of minor errors.

Changes are summarised in the *Changelog* worksheet of VEPM 6.3.

2.2 Vehicle fleet

VKT data from VFEM are used to calculate the proportions of VKT travelled for each vehicle category in VEPM.

2.2.1 Updated VKT data

VEPM 6.2 was based on data from the VFEM3[2] including actual travel data to end 2019 with projections for years to 2050. Updated data from VFEM3 were provided by Te Manatū Waka: Ministry of Transport (MoT) for VEPM 6.3. These data are from VFEM3 based on a higher carbon price scenario compared with data provided for VEPM 6.2. MoT consider that this scenario now provides a more realistic projection compared with the scenario used in VEPM 6.2. The updated/high carbon

[2] The VFEM model is described on the Ministry of Transport website at https://www.transport.govt.nz/assets/Uploads/Data/Transport-outlook-updated/Vehicle-Fleet-Emissions-Model-Documentation-20190719.pdf. The model has been updated since the publication of this documentation with updated fleet data and new electric vehicle uptake projections. However, at the time of writing, updated documentation was not available.

price scenario has a higher uptake of electric vehicles compared with VEPM 6.2. Historical fleet and actual travel data up to end 2019 are not changed in VEPM 6.3 compared to VEPM 6.2.

The revised data covered all years from 2001 to 2050 broken down by:

- vehicle type
- fuel type
- engine capacity (light duty vehicles) or vehicle mass (heavy duty vehicles)
- year of manufacture.

Note: Since the development of the current VFEM3 fleet projection, the government has introduced a clean car policy package to incentivise the uptake of low emission vehicles. The effect of this policy package has not been incorporated into VFEM3 at the time of writing and will be considered in future updates of VFEM.

2.2.2 Overall fleet breakdown

Table 1 contrasts the overall default fleet composition (in terms of %VKT) in VEPM 6.2 with the updated fleet composition in VEPM 6.3 (see Table 2).

The vehicle categories include:

- Light duty vehicles:
  - Cars: passenger cars and sports utility vehicles (SUVs)
  - Light commercial vehicles (LCVs): Utes and vans with gross vehicle mass (GVM) up to 3.5 tonnes
- Heavy duty vehicles:
  - Heavy commercial vehicles (HCVs): commercial vehicles with GVM > 3.5 tonnes
  - Buses > 3.5 tonnes

Figure 1 and Figure 2 show the change in the overall proportions of light duty petrol, light duty diesel, light duty hybrid/electric and heavy-duty diesel vehicles from 2001 to 2050 for both of the default fleets. The trends are similar but VEPM 6.3 now predicts a faster uptake in electric vehicles by 2050 relative to VEPM 6.2.

Table 1: Default fleet (% VKT by vehicle class) in VEPM 6.2

	Light duty vehicles <3.5tonnes										Heavy vehicles >3.5tonnes			
Year	Car petrol	Car diesel	Car hybrid	Car plug-in hybrid	Car electric	LCV petrol	LCV diesel	LCV hybrid	LCV plug-in	LCV electric	Diesel HCV	Diesel Buses	Electric HCV	Electric Buses
2001	72.5%	6.9%	0.0%	0.0%	0.0%	6.4%	7.9%	0.0%	0.0%	0.0%	5.9%	0.4%	0.0%	0.0%
2005	71.1%	7.9%	0.0%	0.0%	0.0%	5.0%	9.1%	0.0%	0.0%	0.0%	6.4%	0.5%	0.0%	0.0%
2010	70.2%	7.6%	0.2%	0.0%	0.0%	4.1%	11.0%	0.0%	0.0%	0.0%	6.3%	0.6%	0.0%	0.0%
2015	67.6%	7.8%	0.6%	0.0%	0.0%	3.5%	13.4%	0.0%	0.0%	0.0%	6.4%	0.6%	0.0%	0.0%
2020	63.3%	7.7%	2.1%	0.1%	0.3%	2.8%	16.5%	0.0%	0.0%	0.0%	6.4%	0.7%	0.0%	0.0%
2025	58.6%	7.4%	6.1%	0.5%	1.0%	2.7%	17.0%	0.0%	0.0%	0.1%	5.9%	0.7%	0.0%	0.0%
2030	52.7%	6.7%	10.0%	1.1%	2.8%	2.6%	17.0%	0.1%	0.1%	0.3%	5.7%	0.7%	0.1%	0.1%
2035	45.1%	5.5%	12.3%	1.8%	8.4%	2.6%	16.2%	0.2%	0.1%	1.4%	5.5%	0.7%	0.1%	0.1%
2040	34.5%	4.0%	11.2%	2.5%	20.7%	2.3%	14.3%	0.3%	0.2%	3.7%	5.2%	0.8%	0.2%	0.1%
2045	22.0%	2.7%	7.6%	2.8%	37.7%	2.0%	11.8%	0.2%	0.2%	6.8%	4.9%	0.8%	0.4%	0.2%
2050	14.0%	1.7%	4.1%	2.6%	50.2%	1.7%	9.5%	0.2%	0.2%	9.6%	4.5%	0.8%	0.6%	0.3%

Table 2: Updated default fleet (% VKT by vehicle class) in VEPM 6.3

	Light duty vehicles <3.5tonnes										Heavy vehicles >3.5tonnes			
Year	Car petrol	Car diesel	Car hybrid	Car plug-in hybrid	Car electric	LCV petrol	LCV diesel	LCV hybrid	LCV plug-in	LCV electric	Diesel HCV	Diesel Buses	Electric HCV	Electric Buses
2001	72.5%	6.9%	0.0%	0.0%	0.0%	6.4%	7.9%	0.0%	0.0%	0.0%	5.9%	0.4%	0.0%	0.0%
2005	71.1%	7.9%	0.0%	0.0%	0.0%	5.0%	9.1%	0.0%	0.0%	0.0%	6.4%	0.5%	0.0%	0.0%
2010	70.2%	7.6%	0.2%	0.0%	0.0%	4.1%	11.0%	0.0%	0.0%	0.0%	6.3%	0.6%	0.0%	0.0%
2015	67.6%	7.8%	0.6%	0.0%	0.0%	3.5%	13.4%	0.0%	0.0%	0.0%	6.4%	0.6%	0.0%	0.0%
2020	63.3%	7.7%	2.1%	0.1%	0.3%	2.8%	16.5%	0.0%	0.0%	0.0%	6.4%	0.7%	0.0%	0.0%
2025	57.8%	7.4%	6.7%	0.6%	1.0%	2.7%	17.0%	0.1%	0.0%	0.1%	5.9%	0.7%	0.0%	0.0%
2030	49.8%	6.6%	12.3%	1.2%	3.3%	2.6%	16.9%	0.2%	0.1%	0.5%	5.7%	0.7%	0.1%	0.1%
2035	41.0%	5.3%	14.9%	2.0%	10.0%	2.4%	15.7%	0.3%	0.1%	1.9%	5.3%	0.7%	0.2%	0.1%
2040	31.2%	3.7%	12.1%	2.7%	23.3%	2.0%	13.2%	0.3%	0.2%	5.0%	4.9%	0.7%	0.5%	0.2%
2045	18.8%	2.2%	7.4%	2.7%	41.5%	1.6%	10.1%	0.3%	0.2%	8.8%	4.5%	0.7%	0.8%	0.3%
2050	10.5%	1.3%	3.9%	2.4%	54.5%	1.3%	7.3%	0.2%	0.2%	12.2%	4.0%	0.6%	1.2%	0.4%

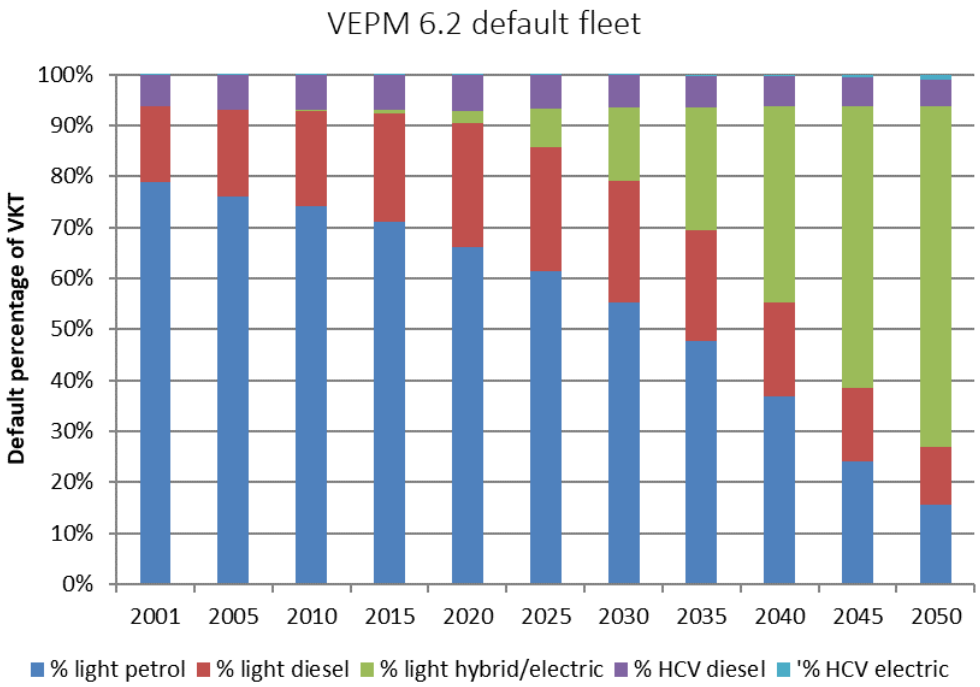

Figure 1: Default fleet (%VKT by vehicle class) in VEPM 6.2. Note that HCV includes buses

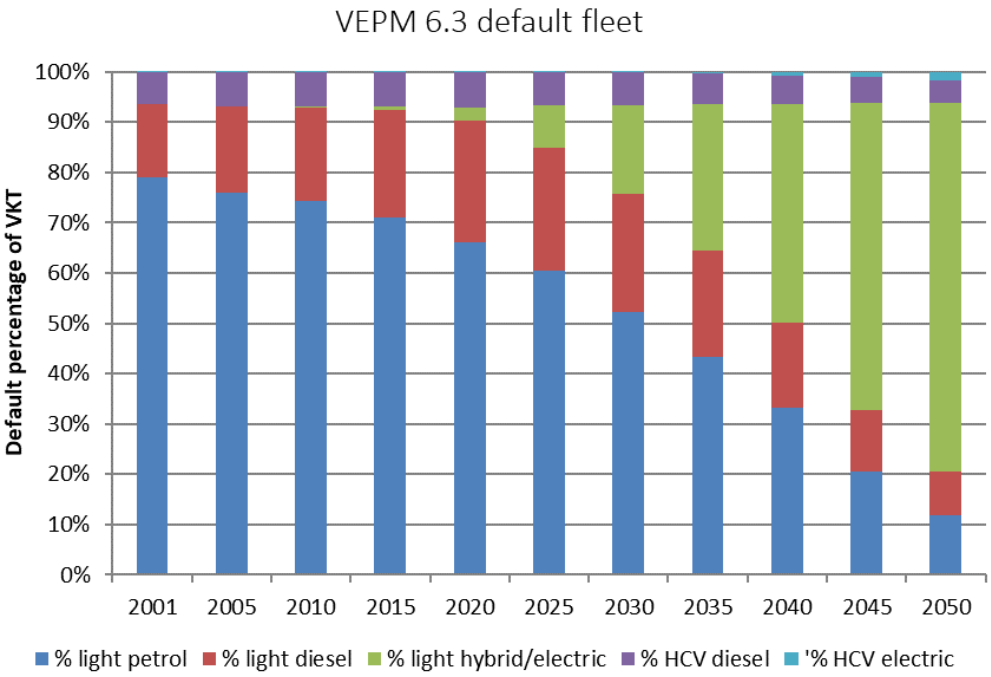

Figure 2: Default fleet (%VKT by vehicle class) in VEPM 6.3. Note that HCV includes buses

2.3 Country of origin assumptions

VFEM vehicle fleet data does not include a breakdown by country of origin. Country of origin is particularly important for vehicles from the 70s to the late 90s when there was considerable variation between the emissions standards of vehicles from different parts of the world.

In previous versions of VEPM, the country of origin breakdown was based on:

- For vehicles up to year of manufacture 2009 country of origin was based on a detailed country of origin breakdown of the fleet, which was developed for VEPM 5.3 based on analysis of fleet data up to 2014[3].
- For vehicles from year of manufacture 2010 onwards, it was assumed that the same emission standards apply to all vehicles, including new and used vehicles.

Implementation of Euro 6 and VI emission standards for new vehicles in New Zealand has been delayed. This means that there are likely to be significant differences in emissions between Japanese used and New Zealand new vehicles of the same year of manufacture in recent years. This means that the assumption for vehicles with year of manufacture 2010 onwards needs to be updated.

For vehicles imported from 2010 onwards, we know that the vast majority of vehicles entering the fleet are manufactured to European standards (new vehicles) or Japanese standards (used vehicles) as shown in Figure 3.

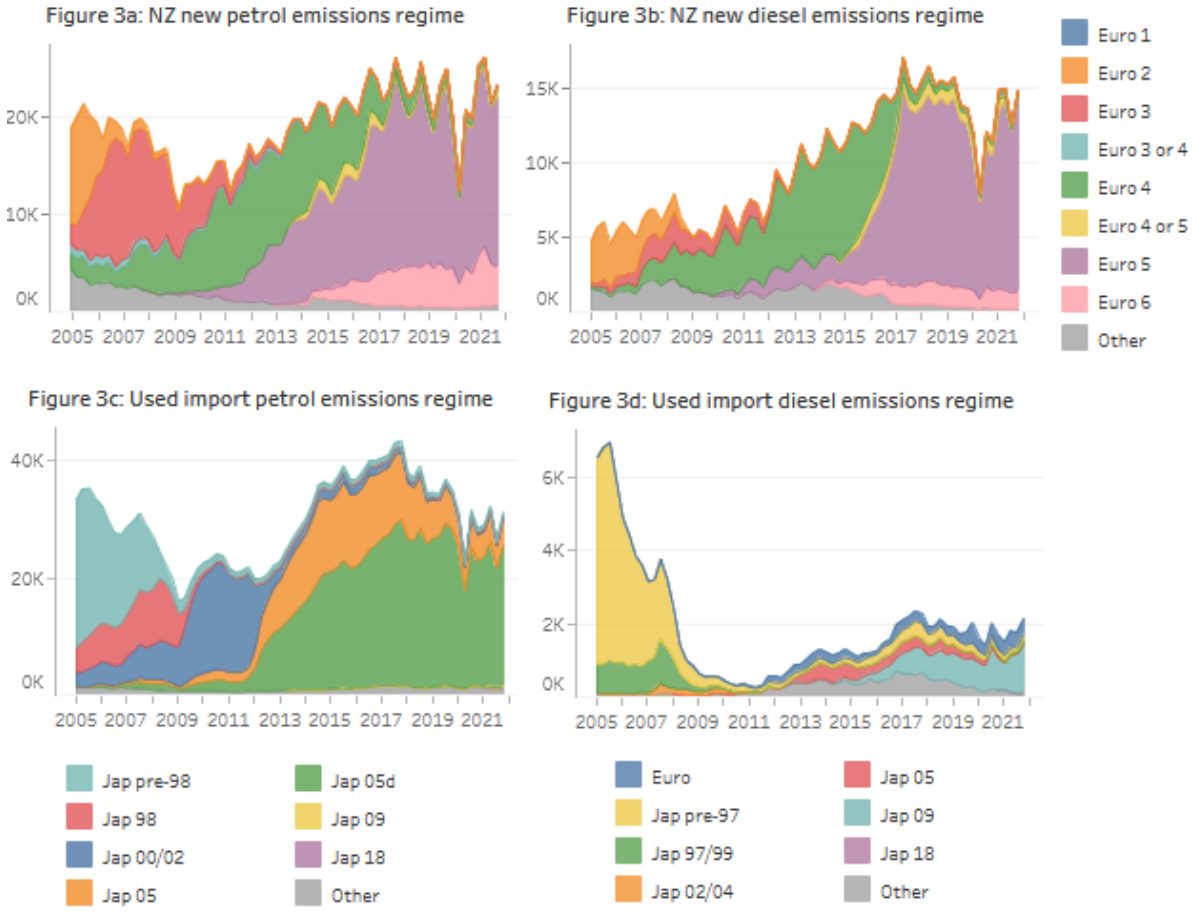

Figure 3: emissions standards of light vehicle registrations. Source Te Manatū Waka: Ministry of Transport[4]

[3] This country of origin breakdown was developed in 2016 for incorporation into VEPM 5.3.
[4] https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/quarterly-fleet-statistics/

2.3.1 Assumptions in VEPM 6.3

In VEPM 6.3, the country of origin breakdown is based on:

- For vehicles up to year of manufacture 2009 country of origin is based on detailed country of origin data consistent with previous versions of VEPM (from VEPM 5.3)
- For vehicles from year of manufacture 2010 onwards, it is assumed that all new vehicles are manufactured to European emission standards and all used vehicles are manufactured to Japanese emission standards.

The detailed methodology and assumptions are described in the following section.

2.3.2 Detailed country of origin methodology in VEPM 6.3

Country of origin is assigned using detailed country of origin data (from VEPM 5.3) for years of manufacture up to 2009 and based on import status (new or used) from VFEM for year of manufacture 2010 onwards. The detailed methodology depends on the fleet year as follows:

For VEPM fleets from 2001-2009 there is no change from VEPM 6.2. The detailed country of origin breakdown (proportion of VKT) for each vehicle year of manufacture and vehicle category (type, fuel, size segment and import status) is copied from VEPM 5.3 for the corresponding fleet year. Note that the VEPM 5.3 breakdown was calculated as follows:

- Light duty vehicles:
    - country of origin data for the entire fleet was extracted from the motor vehicle register for all years between 2001 and 2014. This data included the vehicle import status.
    - the proportion of vehicles from each country of origin (New Zealand, Australia, Japan and Europe) was calculated for each year of manufacture for each vehicle category (type, fuel, size segment and import status).
    - the country of origin proportions were applied to VKT for each year of manufacture for each vehicle category to calculate VKT broken down by country of origin, year of manufacture and vehicle category.
- Heavy duty vehicles:
    - country of origin data for the entire fleet was extracted from the motor vehicle register for all years between 2001 and 2014. This data did not include the vehicle import status which was not available at the time.
    - the proportion of vehicles from each country of origin (New Zealand, Australia, Japan and Europe) was calculated for each year of manufacture for each vehicle category (type, fuel, size segment).
    - the country of origin proportions were applied to VKT for each year of manufacture for each vehicle category to calculate VKT broken down by country of origin, year of manufacture and vehicle category (type, fuel, size segment).
    - The split between new and used vehicles was based on 2015 fleet data as follows:
        - For years of manufacture up to 2007, heavy duty VKT was split between new and used based on the total percentage of used heavy duty vehicles, by year

of manufacture, in the 2015 fleet[5]. It was assumed that all used vehicles were Japanese country of origin.

- For years of manufacture from 2008 onwards, it was assumed that the proportion of Japanese country of origin vehicles that are used stayed constant at 50% (compared to 48% in 2007).
- The split between new and used vehicles by year of manufacture was assumed to be the same for all fleet years.

For VEPM fleets from 2010 to 2014 country of origin is assigned as follows in VEPM 6.3:

- For years of manufacture 1968-2009 the detailed country of origin breakdown is assumed to be the same as VEPM 5.3 for the corresponding fleet year.
- For years of manufacture 2010 onwards, the country of origin is based on import status (new or used) from VFEM. It is assumed that all NZ New vehicles are European country of origin and all used imports are Japanese country of origin.

For VEPM fleets from 2015 onwards country of origin is assigned as follows in VEPM 6.3:

- For years of manufacture 1968-2009, the detailed country of origin breakdown is assumed to be the same as VEPM 5.3 fleet 2014.
- For years of manufacture 2010 onwards, the assumption is the same as for VEPM fleets from 2010 to 2014. (The country of origin is based on import status (new or used) from VFEM. It is assumed that all NZ New vehicles are European country of origin and all used imports are Japanese country of origin).

2.4 Emission standards assumed for Japanese used vehicles

A substantial proportion of the New Zealand fleet is second hand Japanese domestic vehicles, which are manufactured to Japanese emission standards. VEPM does not include Japanese emission factors, which are not readily available. For these vehicles, the closest equivalent European emission factor is used in VEPM.

Previous versions of VEPM we based on the following assumptions:

- Up to year of manufacture 2010, it was assumed that Japanese used vehicles comply with the Japanese emission standard required by Japanese legislation at the year of manufacture. An equivalent European emission factor was assumed for each Japanese vehicle category, emission standard and pollutant. The methodology and assumptions are described fully in the VEPM Development report (EFRU 2008).
- From year of manufacture 2010 onwards, it was assumed that the same emission standards apply to Japanese and European vehicles for the same year of manufacture.

In VEPM 6.3 the equivalent emission standards for Japanese used vehicles manufactured from 2010 has been updated to reflect the date of introduction of Japanese emissions standards and comparison of these with European standards as described in the following sections.

[5] This data was obtained from Ministry of Transport 2015 annual fleet statistics spreadsheet (sheet 2.5a to 2.8a)

2.4.1 Japanese emission standards for passenger cars and light commercial vehicles

Japan's "Post New Long-Term Emissions Standards" have applied to all new light-duty vehicles since 2010. As shown in Table 5 and Table 6 these standards are broadly equivalent to Euro 5 and Euro 6 standards for petrol vehicles, and Euro 5 standards for diesel vehicles.

Table 3: Comparison of Japanese and European emission standards for year of manufacture >2009; passenger cars (data from dieselnet.com)

Vehicle type	Emission standard	Date	Test cycle	CO	NMHC	NOx	PM
				(g/km)			
Petrol passenger car	Euro 5	2011[a]	NEDC	1.0	0.068	0.06	0.005[b]
	Euro 6	2014[c]	NEDC	1.0	0.068	0.06	0.005[b]
	Euro 6	2018[d]	WLTC				
Petrol passenger car	Japan's Post New Long Term Standards	2009	JC08	1.15	0.05	0.05	0.005[e]
		2018	WLTC	1.15	0.1	0.05	0.005[e]
Diesel passenger car	Euro 5	2011[a]	NEDC	0.5	-	0.18	0.005[e]
	Euro 6	2014[c]	NEDC	0.5		0.08	0.005
	Euro 6	2018[d]	WLTC				
Diesel passenger car >1250kg	Japan's Post New Long Term Standards	2010[f]	JC08	0.63	0.024	0.08	0.005
		2019	WLTC	0.63	0.024	0.15	0.005

Note: JC08 = Japanese transient emission test cycle introduced in 2005 for light duty vehicles; WLTC = World Harmonised Light Vehicle Test Cycle; NEDC = New European Driving Cycle; CO = carbon monoxide; NMHC = non methane hydrocarbons; NOx = nitrogen oxides; PM = particulate matter.

a. 2011.01 for all models

b. applicable only to vehicles using DI engines

c. 2014.09

d. all vehicles from 2018.09

e. From 2009, PM values apply only to vehicles with lean-burn DI gasoline engines equipped with NOx adsorber catalysts; from 2020, PM values apply to all vehicles with DI gasoline engines, including stoichiometric DI vehicles

f. 2010.09 for all models

Table 4: Comparison of Japanese and European emission standards for year of manufacture >2009; light commercial vehicles (data from dieselnet.com)

Vehicle type	Emission standard	Date	Test cycle	CO	NMHC	NOx	PM
				(g/km)			
Petrol LCV > 1760kg	Euro 5	2012[a]	NEDC	2.27	0.108	0.082	0.005[b]
	Euro 6	2015[c]	NEDC	0.74	0.108	0.082	0.005[b]
	Euro 6	2018[d]	WLTC				
Petrol LCV >1700kg	Japan's Post New Long Term Standards	2009	JC08	2.55	0.05	0.07	0.007[e]
		2019	WLTC	2.55	0.15	0.07	0.007[e]
Diesel LCV > 1760kg	Euro 5	2012[a]	NEDC	0.74	-	0.28	0.005
	Euro 6	2015[b]	NEDC	0.74		0.125	0.005
	Euro 6	2019[f]	WLTC				
Diesel LCV >1700kg	Japan's Post New Long Term Standards	2010[e]	JC08	0.63	0.024	0.15	0.007
		2019	WLTC	0.63	0.024	0.24	0.007

Note: JC08 = Japanese transient emission test cycle introduced in 2005 for light duty vehicles; WLTC = World Harmonised Light Vehicle Test Cycle; NEDC = New European Driving Cycle; CO = carbon monoxide; NMHC = non methane hydrocarbons; NOx = nitrogen oxides; PM = particulate matter.
a. 2012.01 for all models
b. applicable only to vehicles using DI engines
c. 2015.09
d all vehicles from 2019.09
e. From 2009, PM values apply only to vehicles with lean-burn DI gasoline engines equipped with NOx adsorber catalysts; from 2020, PM values apply to all vehicles with DI gasoline engines, including stoichiometric DI vehicles
f. all vehicles from 2020.09

The Worldwide Harmonized Light Vehicles Test Procedure (**WLTP**) has been used for all vehicles from 2018 in Europe, and from 2019 in Japan. From 2018, European test requirements have also included in service conformity testing based on in-use vehicle **PEMS** (portable emissions monitoring system) testing. Japan plans to begin implementing in service conformity testing in October 2022, and to fully implement requirements by October 2024[6].

2.4.2 Heavy commercial vehicles

Japan's "Post New Long-Term Emissions Standards" have applied to all new heavy commercial vehicles since 2010. As shown in Table 5, Japanese standards from 2010 are broadly equivalent to Euro VI. From 2016 the NOx standard was tightened and the standards apply the World Harmonized Transient Cycle (**WHTC**) for certification testing.

[6] https://unece.org/DAM/trans/doc/2018/wp29grpe/GRPE-76-18e.pdf

Table 5: Comparison of Japanese and European emission standards for year of manufacture >2009; diesel heavy commercial vehicles (data from dieselnet.com)

Emission standard	Date	Test cycle	CO	NMHC	NOx	PM
			(g/kWh)			
Japan's Post New Long Term Standards	2010	JE05	2.22	0.17	0.7	0.01
	2016-18	WHTC	2.22	0.17	0.4	0.01
Euro V	2008	ETC	4.0	0.55	2.0	0.03
Euro VI	2013	WHTC	4.0	0.16	0.46	0.01

Note: JE05 = Japanese transient emission test cycle introduced in 2005 for heavy duty vehicles; WHTC = World Harmonised Transient Cycle; ETC = European transient cycle; CO = carbon monoxide; NMHC = non methane hydrocarbons; NOx = nitrogen oxides; PM = particulate matter.

Euro VI emission standards are specified as stage A, B, C, D or E. These stages have different testing requirements, including in service conformity testing based on in-use vehicle PEMS testing. In service conformity testing requirements have not yet been introduced in Japanese emission test requirements for heavy commercial vehicles.

At the time of writing, the COPERT emission factors for Euro VI stages A/B/C and Euro VI stages D/E are identical, so VEPM 6.3 includes only one category for Euro VI vehicles.

2.4.3 Assumptions in VEPM 6.3

In VEPM, it is assumed that Japanese used vehicles comply with the Japanese emission standard required by Japanese legislation at the year of manufacture. An equivalent European emission factor is assumed for each Japanese vehicle category, emission standard and pollutant.

For **Japanese used vehicles up to year of manufacture 2010** the equivalent European emission factors that are assumed in VEPM 6.3 are unchanged (compared with previous versions of VEPM). The methodology and assumptions are described fully in the VEPM Development report (EFRU 2008).

For **Japanese used vehicles manufactured from 2010 onwards** table 8 summarises the equivalencies that are assumed in VEPM 6.3

Table 6: Assumptions in VEPM for Japanese vehicle equivalency from 2010 onwards

Vehicle type	Fuel	Year of manufacture	Equivalent emission factor assumed
Passenger car	Petrol	2010-17	Euro 5
		2018-23	Euro 6 a/b/c
		2024 onwards	Euro 6d
	Diesel	2010 onwards	Euro 5
LCV	Petrol	2010 onwards	Euro 5
	Diesel	2010 onwards	Euro 5
HCV	Diesel	2010 onwards	Euro 6 (A/B/C)

2.5 Euro 6/VI introduction dates

Euro 6 and Euro VI standards are yet to be adopted in New Zealand emissions regulations. MoT data show that some new vehicle imports are built to Euro 6 standards, however the majority are still Euro 5 (Figure 4).

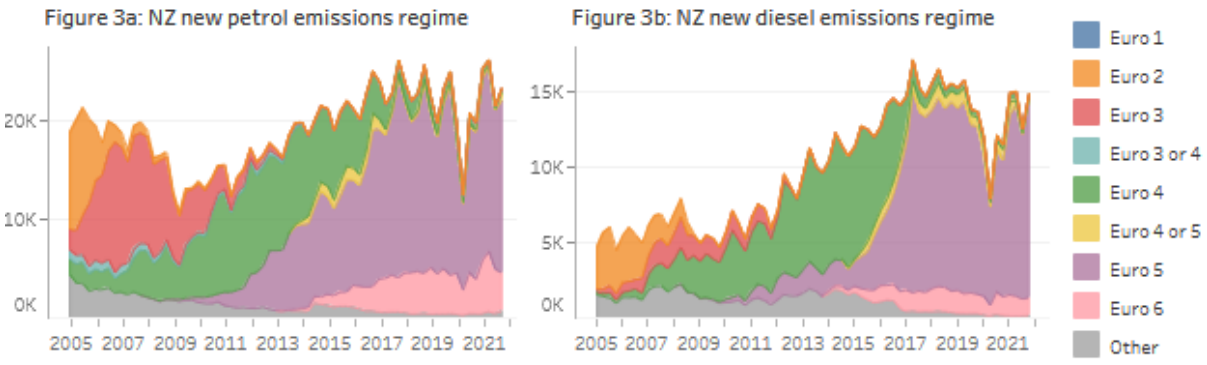

Figure 4: Emission standards of light registrations. Source: Te Manatū Waka: Ministry of Transport Quarterly Fleet Statistics, October to December 2021[7]

At the time of writing, MoT have Cabinet approval to propose regulations for the implementation of Euro 6 and Euro VI emission standards. However, the time frames are not confirmed.

For VEPM 6.2 it was assumed that Euro 6 and Euro VI standards would be implemented in 2025 to the standard regulated in Europe five years earlier. For this VEPM 6.3 update we have assumed that Euro 6 and Euro VI standards will be implemented in 2030. This assumption has been developed in consultation with MoT to represent a base case, "no further policy" scenario. The likely impact of earlier dates of introduction of Euro 6 and Euro VI is currently being investigated by MoT. Implementation dates will be updated in future versions of VEPM when regulations are implemented.

[7] https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/quarterly-fleet-statistics/

2.5.1 Assumptions in VEPM 6.3

The assumed dates of introduction for light and heavy vehicles are shown in Table 7 and Table 8, respectively.

Table 7: Assumed date of implementation of Euro 6 emissions standards in VEPM 6.3 for light duty vehicles (European implementation dates from Table 2.2 of EEA 2019)

Euro standard	Date of implementation in Europe	Assumed date of introduction in VEPM for new vehicles
Passenger vehicles		
Euro 6 a/b/c	2014-2019	N/A
Euro 6 d-temp	2019-2020	N/A
Euro 6 d	2021+	>=2030
Light commercial vehicles		
Euro 6 a/b/c	2016 – 2017	N/A
Euro 6 d-temp	2018 - 2020	N/A
Euro 6 d	2021+	>=2030

Table 8: Assumed date of introduction of Euro VI emissions standards in VEPM 6.3 for heavy duty vehicles (European implementation dates from Table 2.2 of EEA 2019)

Euro Standard	Date of implementation in Europe	Assumed date of introduction in VEPM for new vehicles
Euro VI A/B/C	2013-2019	N/A
Euro VI D/E	2019+	=>2030

2.6 Emission factors

The source of emission factors and equivalencies in VEPM is described fully in previous technical reports (EFRU 2008, EFRU 2011, Sridhar & Metcalfe 2017, Sridhar & Metcalfe 2019, Metcalfe & Peeters 2020, Metcalfe *et al* 2021).

2.6.1 Assumptions in VEPM 6.3

All hot emission factors have been updated in VEPM 6.3 to ensure consistency with the latest version of the COPERT emission factors in the EMEP/EEA spreadsheet (EEA 2021a), except PM exhaust factors which are based on the previous version (EEA 2020). PM emission factors are discussed further in the following section.

2.6.2 PM exhaust emission factors

PM exhaust emission factors for Euro 5/6 and Euro V/VI have not been updated in VEPM 6.3, although updated emission factors are available in the EEA spreadsheet (EEA 2021). The updated EEA factors are not straightforward replacements for previous factors in VEPM because:

- For light duty vehicles, PM emission factors are provided for hot and cold modes. In previous versions hot emission factors (only) were provided and cold emission factors were calculated from these (consistent with the method for other pollutants). This is a methodological change, which will require changes to the emission factor calculation method in VEPM.
- For heavy duty vehicles, PM emission factors are provided in g/kWh. In previous versions emission factors were provided in g/km. This is a substantial change, which would require a new methodology for estimating heavy vehicle activity data (kWh as opposed to VKT).

Further work is required to develop a methodology for implementation of these new PM emission factors in VEPM. At the time of writing, the EEA guidebook (EEA 2021) does not provide specific guidance on how to implement the new factors.

2.7 Correction factors

The calculation of fuel correction factors has been updated in VEPM 6.3. There are no changes to other correction factors.

The source of correction factors in VEPM is described fully in previous technical reports (EFRU 2008, EFRU 2011, Sridhar & Metcalfe 2017, Sridhar & Metcalfe 2019, Metcalfe & Peeters 2020, Metcalfe *et al* 2021).

The detailed methodology for calculation of fuel correction factors in VEPM is described in the VEPM 6.2 update technical report (Metcalfe *et al* 2021). In VEPM 6.2 fuel correction factors were applied to hot emissions only and were applied equally to all vehicles in the fleet, irrespective of their technology (Metcalfe *et al* 2021).

2.7.1 Assumptions in VEPM 6.3

In VEPM 6.3 the application of fuel correction factors has been updated to be consistent with EMEP/EEA guidance (EEA 2021) as follows:

- Fuel correction factors are applied to hot emission factors and the cold emission penalty
- Fuel correction factors are calculated for each vehicle emission standard relative to the specified base fuel for that vehicle emission standard

The base fuels and the available improved fuel qualities assumed in VEPM 6.3 for each vehicle emission standard are shown in Table 9 (for petrol) and Table 10 (for diesel). The fuel correction factors are calculated relative to the applicable base fuel for the vehicle emission standard.

Table 9: Base fuels used to correct petrol fuel quality for each vehicle technology class in VEPM

Vehicle Technology	Base Fuel	Available Improved Fuel Qualities
Pre-Euro 3	Base (petrol type 0)	Petrol types 1-7
Euro 3	Jan 2006 (petrol type 4)	Petrol types 5-7
Euro 4	Jan 2012 (petrol type 6)	Petrol type 7
Euro 5 and later	Jul 2018 (petrol type 7)	-

Table 10: Base fuels used to correct diesel fuel quality for each vehicle technology class in VEPM

Vehicle Technology	Base Fuel	Available Improved Fuel Qualities
Pre-Euro 3	Base (diesel type 0)	Diesel types 1-5
Euro 3	Jan 2004 (diesel type 3)	Diesel types 4-5
Euro 4	Jan 2006 (diesel type 4)	Diesel type 5
Euro 5 and later	Jan 2009 (diesel type 5)	-

The assumptions, calculation methodology and the fuel types are described in detail in the VEPM 6.2 update technical report (Metcalfe *et al* 2021).

2.8 Rigid versus articulated trucks and trailers

Heavy commercial vehicle VKT data from the MoT VFEM3 model is broken down by vehicle weight category according to the gross vehicle mass (GVM) of the powered unit (truck) only. The weight of any separately registered trailer unit/s is not included in the GVM, and there is no breakdown in VFEM3 to indicate whether vehicles have trailers or not.

Emission factors are provided in COPERT for rigid and articulated trucks separately. The articulated truck emission factors are based on the Gross Combined Mass (GCM) which is the combined mass of the truck and trailer(s).

To ensure that trailer travel is accounted for, HCV VKT is split between rigid and articulated trucks in VEPM. The assumptions and methodology are described in the VEPM 6.2 update technical report (Metcalfe *et al* 2021). As described in the VEPM 6.2 report, VKT is assigned to articulated trucks from GVM categories.

Articulated truck VKT is further broken down by emission standard based on year of manufacture. In VEPM 6.2:

- The breakdown of articulated truck VKT by year of manufacture was assumed to be the same as the GVM category it was assigned from.
- The emission standard was assigned by year of manufacture based on the emission standards assumed in VEPM for European (New Zealand new) HCVs based on year of manufacture.

2.8.1 Assumptions in VEPM 6.3

In VEPM 6.3 the methodology to break down articulated truck VKT by year of manufacture has been updated to take into account country of origin. In VEPM 6.3:

- The breakdown of articulated truck VKT by year of manufacture and country of origin is assumed to be the same as the GVM category it is assigned from.
- The emission standard is assigned based on the emission standards assumed in VEPM for HCVs based on year of manufacture and country of origin, except for Japanese used vehicles.
- For Japanese used vehicles, the emission standard is assigned based on the emission standard assumed in VEPM for HCVs for carbon monoxide based on year of manufacture for Japanese used vehicles[8].

[8] For Japanese used vehicles, the closest equivalent European emission factor is assumed in VEPM based on year of manufacture for each pollutant. In some cases, a different European emission standard is assumed for different pollutants (for the same year of manufacture).

3. VEPM 6.2 versus VEPM 6.3

This chapter compares the fleet-weighted emissions factors now predicted by VEPM 6.3 versus those from the previous version VEPM 6.2 to show the effect of the changes in assumptions and methodology.

3.1 Effect on fleet-weighted average emission factors

Figure 5 through to Figure 10 compare the fleet-weighted emission factors for carbon monoxide (CO), total hydrocarbons (HC), nitrogen oxides (NO_X), $PM_{2.5}$, brake and tyre and fuel consumption.

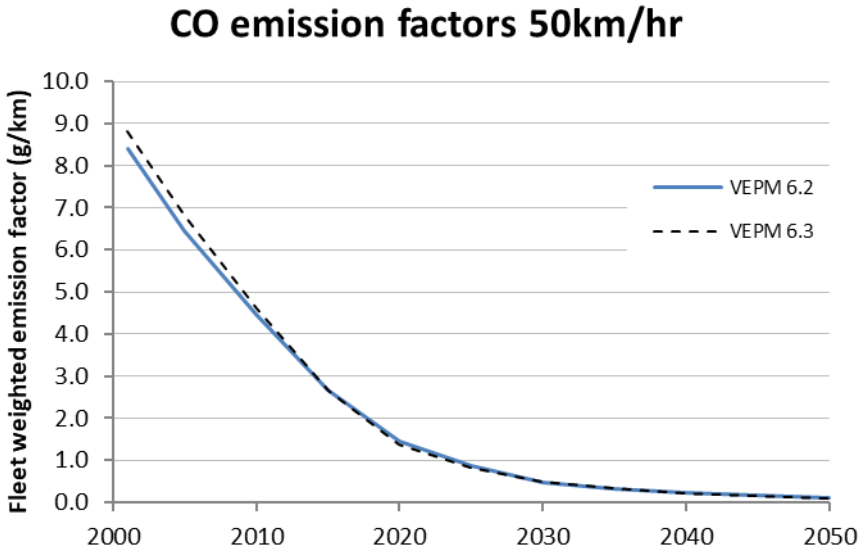

Figure 5: Comparison of CO emission factors from VEPM 6.2 and VEPM 6.3

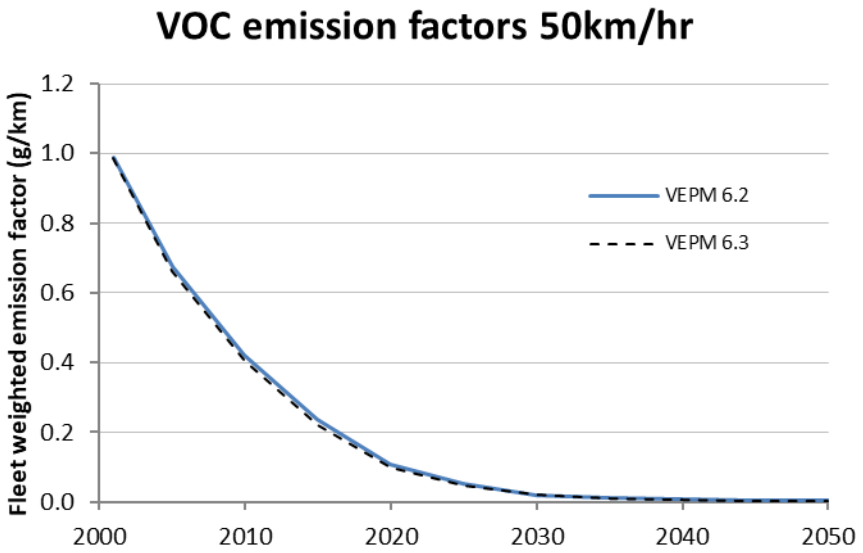

Figure 6: Comparison of VOC emission factors from VEPM 6.2 and VEPM 6.3

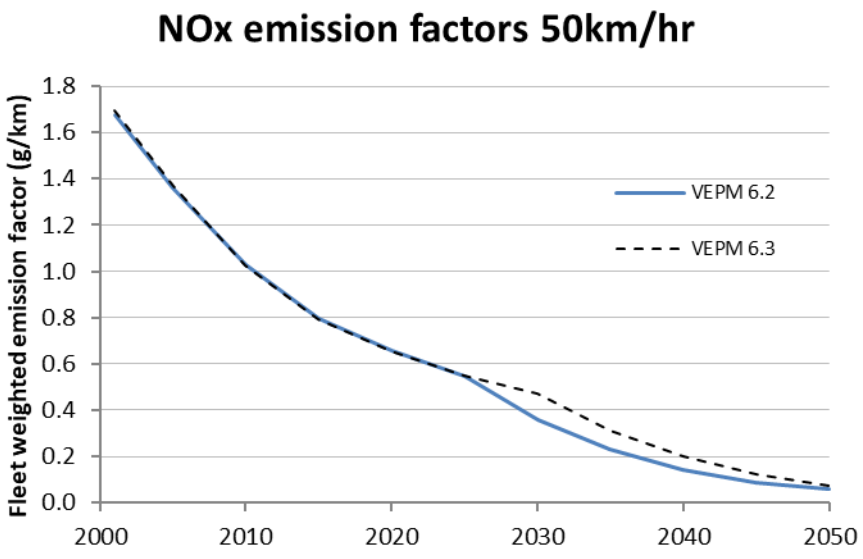

Figure 7: Comparison of NO_x emission factors from VEPM 6.2 and VEPM 6.3

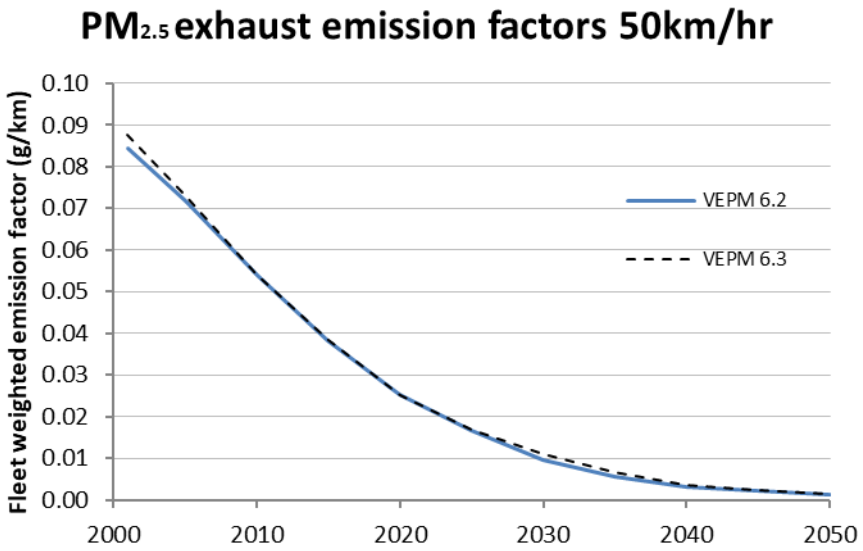

Figure 8: Comparison of $PM_{2.5}$ exhaust emission factors from VEPM 6.2 and VEPM 6.3

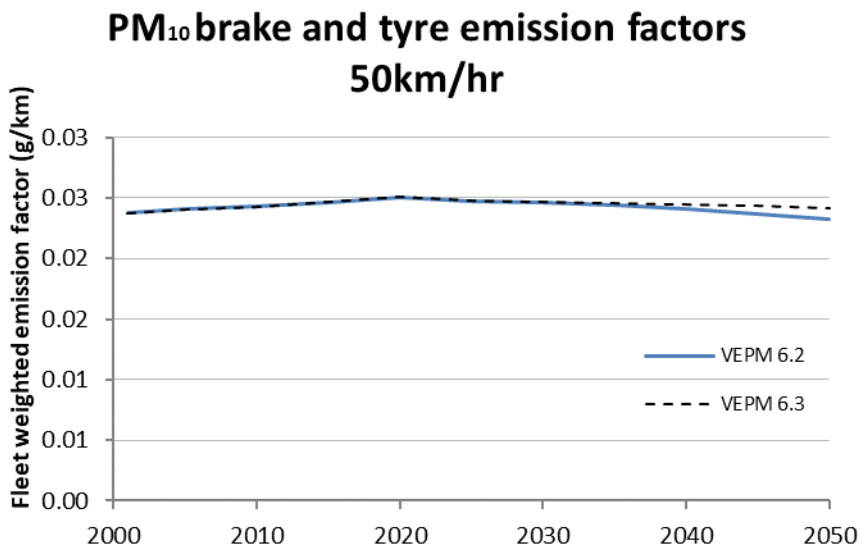

Figure 9: Comparison of PM_{10} brake and tyre emission factors from VEPM 6.2 and VEPM 6.3

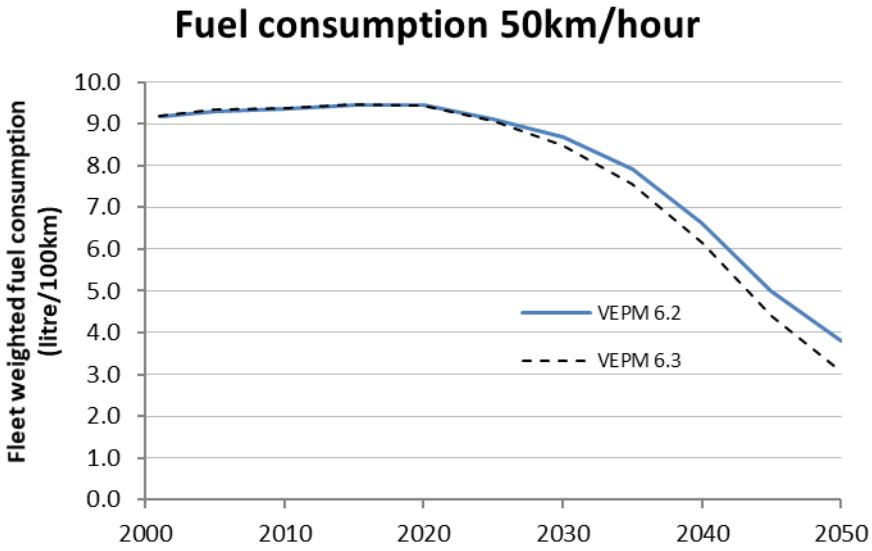

Figure 10: Comparison of fuel consumption factors from VEPM 6.2 and VEPM 6.3

3.1.1 Discussion of differences between VEPM 6.2 and VEPM 6.3

Key changes between emission factors from VEPM 6.2 and VEPM 6.3 are:

- Figure 5 shows that fleet weighted average CO emission factors are slightly higher in VEPM 6.3 compared with VEPM 6.2 up to 2010. This is primarily due to changes in the calculation of fuel correction factors.
- Fleet weighted HC emission factors are similar in VEPM 6.3 compared with VEPM 6.2 as shown in Figure 6.
- Figure 7 shows that fleet weighted average NO_X emission factors are higher in VEPM 6.3 compared with VEPM 6.2 from 2025 onwards. This is primarily due to the change in the assumed implementation date for Euro 6 and Euro VI emission standards.

- Figure 8 shows that fleet weighted exhaust PM emission factors are slightly higher in VEPM 6.3 compared with VEPM 6.2. This is due to changes in the detailed fleet breakdown for articulated trucks.
- Figure 9 shows that fleet weighted emission factors for brake and tyre wear are slightly higher in VEPM 6.3 compared with VEPM 6.2. This is due to correction of the brake and tyre wear emission factors calculation for electric LCV's in VEPM 6.3
- Figure 10 shows that fleet weighted fuel consumption is lower in VEPM 6.3 compared with VEPM 6.2 from 2025 onwards due to higher uptake of electric vehicles.

4. Recommendations for future updates

Improvement of VEPM is an area of ongoing research, and recommendations from previous reports are not repeated here. Specific recommendations relating to this update of the model are as follows:

- Investigate the implications and develop a methodology to incorporate updated PM emission factors from COPERT (EEA 2021a)
- At the time of writing, MoT have Cabinet approval to propose regulations for the implementation of Euro 6 and Euro VI emission standards. Implementation dates for Euro 6 and Euro VI requirements for new vehicles should be update in VEPM when time frames are confirmed.
- The base data used to calculate cumulative VKT, which is used to estimate degradation, has not been updated since 2009. We recommend investigating whether VFEM outputs could be used to update this data regularly.

In general, we recommend updating VEPM whenever COPERT is updated. The default fleet profile should also be updated whenever VFEM is updated.

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