Vehicle Emissions Prediction Model:
VEPM 7.1 technical report

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Executive summary

The Vehicle Emissions Prediction Model (VEPM) predicts 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 previous version of VEPM (VEPM 7.0) was released in May 2023 (Metcalfe & Peeters 2023). Key updates in VEPM 7.1 include:

- Updated fleet information, based on Ministry of Transport data provided in June 2024.
- Updated exhaust particulate (PM) factors for Euro 5/6 and V/VI vehicles.
- Updated calculation of brake and tyre wear emission factors. VEPM 7.1 now includes different brake and tyre wear factors for light duty hybrid, plug in hybrid, light duty electric and internal combustion engine vehicles.
- New emission factors for plug-in hybrid vehicles and for different categories of hybrid and plug in hybrid vehicles.
- Updated cold start methodology for Euro 6 vehicles and implementation of some corrections in the cold start methodology for other light duty vehicle categories.
- Inclusion of cold start emissions for heavy duty vehicles.
- Updated emission degradation methodology for light duty and heavy duty vehicles.
- A separate degradation calculation for buses.
- Updated fuel density and calorific values based on real fuel data.
- Updated emission factors and assumptions for calculation of fuel consumption and CO_2. In previous versions of VEPM these were incorrectly based on gross calorific values of fuels.

The purpose of this technical report is to provide technical information for VEPM users, including a description of the detailed assumptions and methodologies for calculating emission factors in VEPM 7.1. Changes and updates in VEPM 7.1 compared to VEPM 7.0 are described and recommendations for future updates are provided. This VEPM 7.1 technical report supersedes previous technical reports.

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
AR4	IPCC Fourth Assessment Report
AR5	IPCC Fifth Assessment Report
CH_4	Methane, a greenhouse gas
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 Programme to calculate Emissions from Road Transport
DPF	Diesel particulate filter
EC	Energy consumption
EGR	Exhaust gas recirculation (a type of NOx emission control technology)
EMEP/EEA	European Monitoring and Evaluation Programme/European Environment Agency
Euro	European vehicle emission legislation
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
GDI	Gasoline direct injection (a type of vehicle technology)
GWP	Global warming potential
Heavy duty vehicle	A general term including heavy commercial vehicles with a GVM > 3.5 tonnes as well as buses and coaches with GVM > 3.5 tonnes

HCV	Heavy commercial vehicle, a commercial vehicle with a GVM >3.5 tonnes
IPCC	Intergovernmental Panel on Climate Change
LCV	Light commercial vehicle, a commercial vehicle with a GVM <3.5 tonnes
MoT	Ministry of Transport Te Manatū Waka
MOVES 3	USEPA Motor Vehicle Emission Simulator (version 3)
NO_X	Oxides of nitrogen, including nitric oxide nitrogen dioxide and nitrous oxide
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)
NZTA	New Zealand Transport Agency Waka Kotahi
PFI	Port fuel injection (a type of vehicle technology)
PM	Particulate matter
Rigid vehicle	A rigid vehicle has a driver’s position, a steering system, motive power and a single rigid chassis.
RUC	Road user charges
SCR	Selective Catalytic Reduction (a type of NOx emissions control technology)
SUV	Sports utility vehicles
T&M	Tampering and mal-maintenance. A term from the USEPA MOVES 3 model.
VEPM	Vehicle Emissions Prediction Model, developed by NZTA to predict air emissions and fuel consumption for the New Zealand fleet
VFEM	The Vehicle Fleet Emissions Model – now known as the vehicle fleet model (VFM)
VFM	The Vehicle Fleet Model developed by MoT to predict the makeup, travel, energy (fuel and electricity) use and greenhouse gas emissions of the New Zealand vehicle fleet for all years from 2001 to 2055. It was previously

	known as the VFEM, but its name was changed to reflect the model's multiple uses.
VKT	Vehicle kilometres travelled
VOC	Volatile organic compound
YOM	Year of manufacture

1. Introduction

The NZ Transport Agency Waka Kotahi (NZTA) Vehicle Emissions Prediction Model (VEPM) predicts emissions from vehicles in the New Zealand fleet under typical road, traffic and operating conditions.

This report provides technical information for VEPM users, including a description of the detailed methodology and assumptions for calculation of emission factors in VEPM 7.1. The VEPM User Guide provides instructions for running VEPM[1]. The NZTA Traffic Model Emissions Tool provides a method for calculating emissions from transport model outputs with VEPM emission factors[2].

1.1 VEPM

To assess the air quality effects of road projects, or changes in vehicle technology or fleet characteristics it is necessary to estimate emissions from motor vehicles. This can be achieved using emission factors.

Emissions factors are the quantity of pollutants emitted per kilometre driven. Vehicle emissions are primarily dependent on the vehicle type and fuel. Vehicle emissions are also dependent on the driving conditions. For example, emissions are different for any given vehicle under acceleration or deceleration, at different speeds and engine loads.

VEPM is an average speed model which predicts emission factors for the New Zealand fleet under typical road, traffic and operating conditions. Average speed models are based on the fact that the average emissions factor for a pollutant and vehicle type/technology varies as a function of the average speed during a trip.

VEPM calculates New Zealand fleet weighted emission factors for:

- Exhaust emission factors for harmful pollutants:
    - Particulate matter ($PM_{2.5}$[3])
    - Nitrogen oxides (NO_X)
    - Nitrogen dioxide (NO_2)
    - Volatile organic compounds (VOC)
    - Carbon monoxide (CO)
- Exhaust emission factors for greenhouse gases:
    - Carbon dioxide (CO_2)
    - Methane (CH_4)
    - Nitrous oxide (N_2O)
    - Carbon dioxide equivalent, which is calculated from CO_2, CH_4 and N_2O factors (CO_2e)
- Brake and tyre wear factors for particulate matter smaller than 10 µm (PM_{10}) or smaller than 2.5 µm ($PM_{2.5}$)

[1] The model and user guide are available at nzta.govt.nz
[2] The traffic model emissions tool is available at nzta.govt.nz
[3] Exhaust PM is denoted as $PM_{2.5}$ in VEPM, however almost all PM from vehicle exhaust is less than 1 micron (PM_1), with the majority being in the 10-100 nanometre range.

VEPM also calculates New Zealand fleet weighted fuel consumption.

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

VEPM derives New Zealand-relevant factors based on emissions factors from the European COPERT model (Computer Programme to calculate Emissions from Road Transport). COPERT is a widely used software tool for calculating real world air pollutant and greenhouse gas emissions from the road transport sector. COPERT emission factors are published by the European Monitoring and Evaluation Programme and the European Environment Agency (EMEP/EEA) in a spreadsheet (EEA 2024a). The emission factors are constantly being updated with improved factors for new technologies, emerging issues and real-world effects.

A substantial proportion of the New Zealand fleet is second hand Japanese domestic vehicles, which are manufactured to Japanese vehicle emission standards. VEPM does not include specific Japanese emission factors, because a comprehensive Japanese emissions model is not readily available. An equivalent European emission factor is assumed in VEPM for each Japanese vehicle category, emission standard and pollutant based on a detailed comparison of emission factors from European and Japanese emission models. This approach has been used internationally[4].

1.2 Purpose of VEPM

VEPM has been developed to quantify vehicle emissions and predict how these are likely to change over time. The model can estimate the effect that new technology and improved fuel will have on emissions from New Zealand's vehicle fleet. An important feature of the model is the ability to estimate changes to vehicle emissions in future years (from 2001 to 2050).

VEPM provides estimates that are suitable for air quality assessments, greenhouse gas assessments and emissions inventories. VEPM has been successfully used around New Zealand to estimate vehicle emissions in air quality and greenhouse gas assessments for road projects. The model provides vehicle emission factors, which are used in conjunction with traffic models and air dispersion models to predict air pollutant concentrations downwind of the road.

VEPM emission factors are used in NZTA project evaluation tools and methods including, for example the monetised benefits and costs manual (MCBM) and the Air quality screening model[5], which is a simple online tool to assist with undertaking preliminary or screening assessments. VEPM is also used in more detailed assessments. A schematic of the detailed assessment process using VEPM is shown in Figure 1. The NZTA guide to assessing air quality impacts from state highway projects[6] provides specific guidance

[4] For example, the developers of COPERT used a similar process to develop emission factors for Cyprus where the fleet is dominated by Japanese used imports.
[5] Air quality screening model (nzta.govt.nz)
[6] Air quality assessment guide - October 2019 (nzta.govt.nz)

for using VEPM to assess potential air quality effects associated with state highway asset improvement projects.

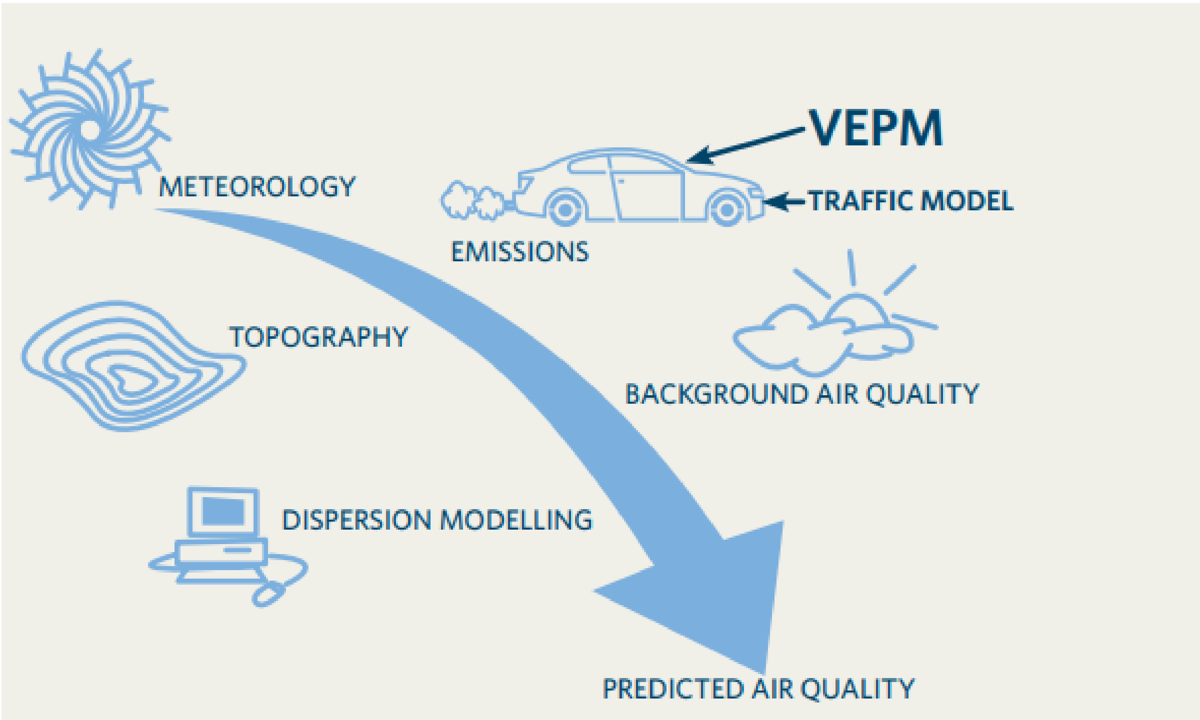

Figure 1: VEPM and the air quality assessment process

1.3 VEPM 7.1

Changes in VEPM 7.1 compared to VEPM 7.0 are described in Chapter 6 of this report and include:

- Updated default fleet data with outputs from the latest version of the Ministry of Transport Vehicle Fleet Model (VFM)[7]
- Updated exhaust particulate (PM) factors for Euro 5/6 and V/VI vehicles.
- Updated calculation of brake and tyre wear emission factors. VEPM 7.1 now includes different brake and tyre wear factors for light duty hybrid, plug in hybrid, electric and internal combustion engine vehicles.
- New emission factors for plug-in hybrid vehicles and for different categories of hybrid and plug in hybrid vehicles.
- Updated cold start methodology for Euro 6 vehicles and implementation of some corrections in the cold start methodology for other light duty vehicle categories.
- Updated emission degradation methodology for light duty and heavy duty vehicles.
- A separate degradation calculation for buses.
- Updated fuel density and calorific values based on real fuel data.

[7] VFM Version 202405 outputs were provided in June 2024

- Updated emission factors and assumptions for calculation of fuel consumption and CO_2. In previous versions of VEPM these were incorrectly based on gross calorific values of fuels.
- Updated assumptions for assigning Japanese equivalencies for articulated to be equivalent with assumptions for rigid trucks.

The overall effect of these updates on predicted emission factors is summarised in Section 6.4 of this report, which compares emission factors from VEPM 7.0 and 7.1.

1.4 Purpose and scope of this report

The purpose of this report is to provide technical information for VEPM users, including a detailed description of the assumptions and methodologies for calculating emission factors in VEPM 7.1.

The overall methodology, assumptions and emission factors in VEPM 7.1 are similar to VEPM 7.0. However, there are a number of significant updates in the detailed methodology, so this technical report has been updated in its entirety to provide a detailed description of all assumptions and methodologies for calculating emission factors in VEPM 7.1.

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. Each update is typically accompanied by a technical report describing changes to assumptions and methodologies. This VEPM 7.1 report generally supersedes previous technical reports, however, previous reports are referred to for further detail where appropriate.

1.5 Structure of this report

Chapter 2 of this report provides technical background information for VEPM users, including discussion of the limitations and uncertainty of VEPM. User defined model inputs are also described. Subsequent sections provide information on the methodology and assumptions used to calculate fleet weighted emission factors as follows:

- Chapter 3 provides an overview of the methodology for calculating fleet weighted emissions factors in VEPM.
- Chapter 4 describes the methodology and assumptions to develop default fleet profiles for all years from 2001 to 2050.
- Chapter 5 describes the methodology and assumptions for calculation of fuel consumption and emission factors for each vehicle sub-category.
- Chapter 6 summarises the changes in VEPM 7.1 compared with VEPM 7.0.
- Chapter 7 summarises recommendations for future updates.

2. Information for VEPM users

This chapter provides technical background information for VEPM users, including discussion of the limitations and appropriate application of VEPM and a description of user defined model inputs. Additional information about particulate emissions, idle emission rates and the history of VEPM is also provided.

2.1 Limitations and appropriate application of VEPM

VEPM is an average-speed model which is comparatively easy to use, and there is a reasonably close correspondence between the required model inputs and the data generally available to users. However, average speed models do have limitations.

A review of the limitations and appropriate application of VEPM (Metcalfe & Boulter 2022) concluded that average-speed models are considered valid over a network of roads within an urban area larger than approximately a half square kilometre. However, they can only predict one emission rate for a given average speed. This means that, at a local scale (e.g. for an individual intersection or road link) VEPM might significantly underestimate or overestimate emissions, but on average VEPM emission estimates are expected to be valid. The review considered alternative models and concluded that, although different modelling approaches can theoretically provide more detail and accuracy compared with average-speed models such as VEPM, these models have their own limitations and may not improve the accuracy of assessments compared with an average-speed model. Overall, the review concluded that VEPM continues to be the most appropriate tool for greenhouse gas emission and air quality assessments in New Zealand due to reasons of practicality, cost, and consistency.

Specific recommendations from the review (Metcalfe & Boulter 2022) for VEPM users include:

Using VEPM for local scale assessment (spatial resolution)

- It is recommended that VEPM continue to be used to estimate vehicle emissions for GHG and air quality assessments in New Zealand, including local scale assessments.
- For local scale air quality assessments, where the spatial resolution of emissions can be of more relevance (compared with a greenhouse gas assessment), it is particularly important that users understand the limitations of VEPM.

Temporal resolution of speed data for assessments with VEPM

- 24-hour or 1-hour resolution speed data are appropriate for estimation of GHG emissions with VEPM. The most appropriate option will depend on the nature and scale of the project and the availability of good quality data. In general, it is recommended that 1-hour temporal resolution data should be used if good quality 1-hour data are available.
- Using VEPM with higher resolution speed data (i.e. less than 1 hour) is generally not recommended.

Using VEPM to assess impacts of speed limit changes

- It is appropriate to use VEPM to estimate the impact of speed limit changes on GHG emissions for speed limits above 60 km/h.

- VEPM can also be used to assess impacts of speed limit changes at speeds below 60 km/h, although:
    - the limitations of the model predictions should be made clear, and
    - the limitations of the model should be considered in any conclusions or recommendations based on the assessment.

VEPM can account for variation in the fleet composition (e.g. the proportion of heavy duty vehicles), road gradient and heavy vehicle load. Emission estimates are sensitive to these variables, so local data should be used where possible.

2.2 Uncertainty of VEPM

All emission models have an inherent uncertainty and evaluating this is a complex task. In the case of VEPM, this is compounded by the fact that the emission factors are based on test data from European vehicles. Research has found that real world emissions from New Zealand vehicles are comparable with real world emissions from European vehicles (Kuschel et al 2019), which supports the continued use of European emission factors in VEPM. However, at a fleet average level, we know that there are differences between the European and New Zealand vehicle fleets (Metcalfe, Kuschel & Gimson 2020).

Understanding the uncertainty of VEPM emission factors and validating emission estimates with real-world information is an area of ongoing research (Smit et al. 2022).

2.3 Model inputs

Emission factor calculations in VEPM are affected by user defined model inputs, which are briefly described in this section. Instructions for using the model are provided in the VEPM User Guide.

2.3.1 Year

The analysis year, between 2001 and 2050, is selected by users in the VEPM Year & Speed tab (as shown in Figure 2). The default fleet profile is based on the user selected year.

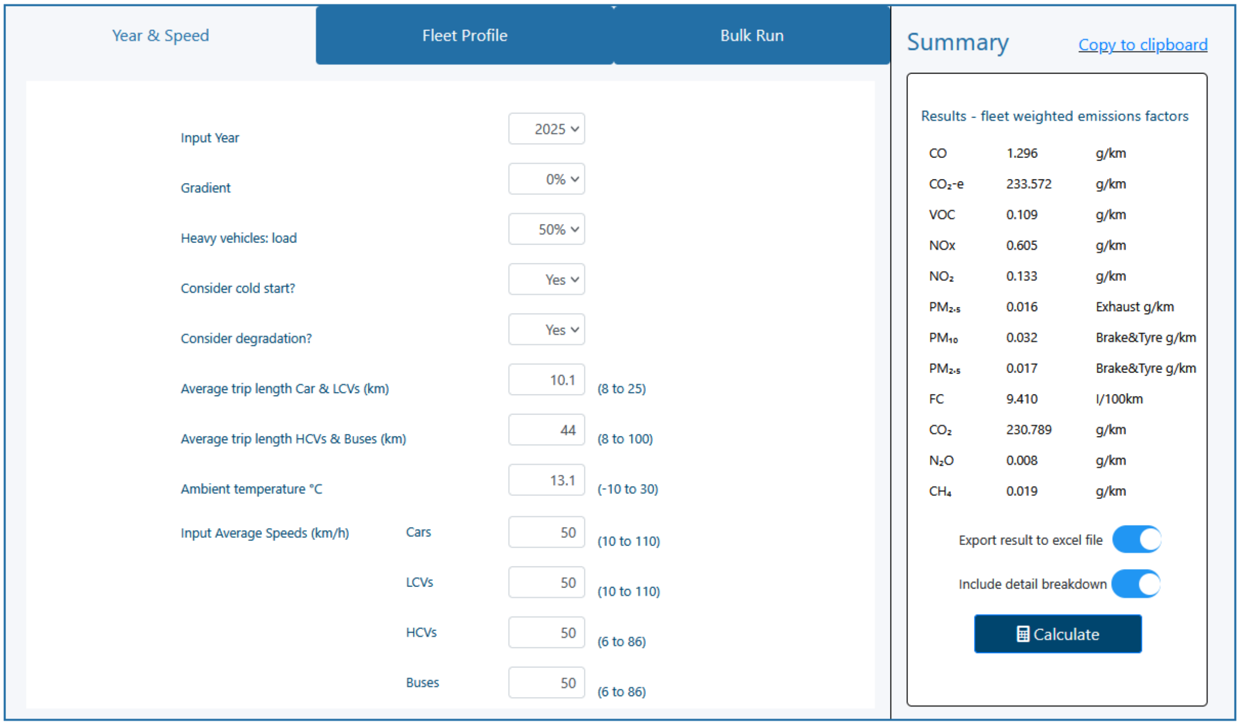

Figure 2: VEPM Year & Speed tab

2.3.2 Speed

Average speed is selected by users in the VEPM Year and Speed tab (as shown in Figure 2).

For light duty vehicles, average speed must be between 10 and 110km/h. For heavy duty vehicles the valid speed range depends on the vehicle size, the gradient and load.

Average speed emission factors are intended to represent emissions as a function of mean vehicle speed over a complete driving cycle of several kilometres.

Average speed data are often derived from traffic models. **24-hour or 1-hour resolution speed data are appropriate for estimation of emissions with VEPM**. The most appropriate option will depend on the nature and scale of the project, the pollutant being assessed, and the availability of good quality data. In general, it is recommended that 1-hour temporal resolution data should be used if good quality 1-hour data are available. However, using VEPM with higher resolution speed data (i.e. finer than 1 hour) is generally not recommended.

2.3.3 Gradient

Gradient is an optional input, which can be selected by users in the VEPM Year and Speed tab (as shown in Figure 2). The default gradient is 0%. Road gradients between -6% and +6% can be selected in 2% increments for both light and heavy duty vehicles.

Vehicle emissions can be significantly affected by road gradient. **It is recommended that site-specific data should be used wherever possible, and that gradient should be carefully considered in defining road segments for calculation of emissions.**

Users should be aware that depending on the gradient and the pollutant being considered, the increase in emissions uphill tends to be significantly greater than the corresponding reduction in emissions going downhill. This means, it cannot be assumed that the increase in emissions due to uphill sections will be cancelled out by the effects of the corresponding downhill sections if the region over which emissions are being assessed has a net zero change in elevation.

2.3.4 Heavy vehicle load

Heavy vehicle emissions are higher when the vehicle is fully loaded. Loading factors for heavy vehicles of 0%, 50% and 100% can be selected. The default load is 50%.

2.3.5 Consider cold start?

When a vehicle is started from cold, emissions are substantially higher, until the engine and catalyst warm up. Cold start effects are included in the emissions calculation by default.

Calculation of cold start is optional in VEPM. **To avoid overestimation of cold start emissions, users should omit cold start for calculation of emission factors outside urban areas**.

2.3.6 Consider degradation?

The model includes some allowance for degradation of emissions over time. This option allows the user to ignore degradation effects.

2.3.7 Average trip length

The model allows the user to define average trip lengths. Trip length is used to calculate cold start emissions. o, for example, a shorter average trip length will result in higher average emissions because the proportion of the trip in cold start conditions is higher. The default value in VEPM 7.1 is 10.1 km for light duty vehicles and 44 km for heavy duty vehicles.

2.3.8 Ambient temperature

Ambient temperature must be between -10 and 30°C. Ambient temperature affects cold start emissions, with higher emissions at lower temperatures. The default is set at 13.1°C to reflect an average winter temperature in Auckland. For specific times, or other locations, this variable can be adjusted.

2.3.9 Fleet profile

Users can adjust the percentage of VKT that is assigned to each vehicle category (shown in Table 2) in the VEPM Fleet Profile tab (as shown in Figure 3). If the user defines the fleet profile, the default fleet (percentage of VKT for each vehicle sub-category) is adjusted proportionally.

Fleet weighted emission factors are sensitive to the **proportion of heavy commercial vehicles** in the fleet, so **it is recommended that site-specific or local data should be used wherever possible**.

It is important to note that:

- The user defined fleet must add up to 100%.
- Users cannot allocate %VKT to vehicle categories that are not included in the default fleet for the analysis year. For example, in 2001 there were no plug-in hybrid vehicles in the fleet so the user cannot include these in the fleet.

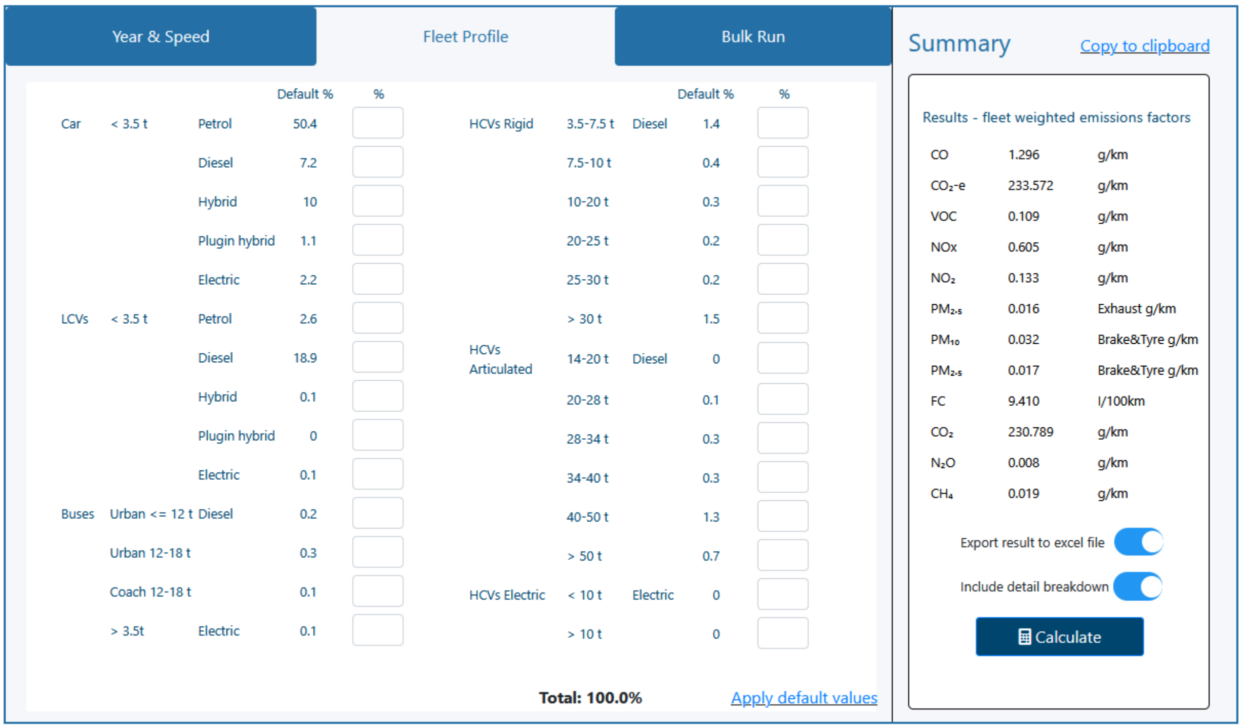

Figure 3: VEPM Fleet Profile tab

2.4 Particulate

VEPM includes emission factors for particulate matter from vehicle exhaust as well as brake and tyre wear.

In VEPM exhaust particulate is denoted as $PM_{2.5}$. However, almost all particulate matter from both petrol and diesel exhaust is less than 1 micron, with the majority being in the 10-100 nanometre range.

PM from tyre and brake wear are substantially larger with around 40% being above 10 micrometres. VEPM provides estimated brake and tyre wear factors for PM_{10} and $PM_{2.5}$. These factors are based on the methodology described in the European EMEP/EEA Air pollution emission inventory guidebook (EEA 2024b).

VEPM does not include road surface wear emission factors. However, it is recommended that road surface wear emissions should be included in emissions inventories and assessments of air quality impacts. T hese can be estimated based on Tier 1 emission factors provided in the EMEP/EEA guidebook (EEA 2024b).

2.5 Idle emission rates

VEPM does not provide idle emission rates. This means that intersection delays need to be accounted for in average speed calculations. The NZTA Traffic Model Emissions Tool allows users to easily apply VEPM emission factors to “link and turn” (intersection) outputs from traffic models so that idle emission rates are generally not required.

In cases where idle emission rates are required, an approximation of idle emission rates could be obtained from VEPM as follows:

- Calculate emissions rates in grams/hour based on the VEPM emission factor (in g/km) and the corresponding speed at 10km/hour, 15km/hour and 20km/hour
- Extrapolate back to zero km/hour to estimate the emission rate in g/hour

A hypothetical example for carbon monoxide emissions is shown in Table 1.

Table 1: CO emission factors and rates at low speeds for a hypothetical example

Speed (km/hour)	Emission factor (g/km)	Emission rate (g/hour)
25	6.11	153
20	7.01	140
15	8.46	127
10	11.32	113

These emission rates are plotted in Figure 4. Extrapolating the line back to the (zero speed) y axis gives an approximate value for the idle rate of 85g/hour.

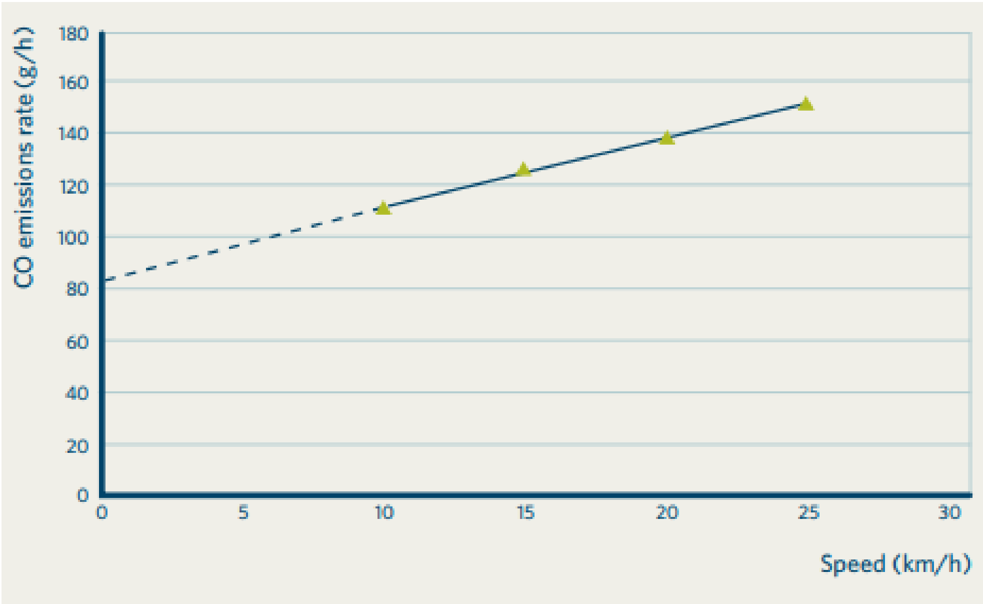

Figure 4: CO emission rates at low speeds for estimation of idle emission rates for a hypothetical example

2.6 Development of VEPM

VEPM was originally developed for the Auckland Council in 2008 (EFRU 2008). At time of preparation (pre-2008), it was recognised that there was insufficient emissions test data from New Zealand domiciled vehicles to develop VEPM using New Zealand data. The New Zealand fleet includes vehicles that have been manufactured to various emission standards including Japanese, European and Australian. These different jurisdictions have introduced different emission requirements at different times and have used different emission measurement techniques. This inconsistency means that international emission models are not directly applicable to the New Zealand fleet. VEPM was therefore developed using New Zealand fleet data and emissions data from a range of international models. Given the makeup of the New Zealand fleet, and other emissions models in use around the world, emissions data from Japan, USA, Australia and Europe were investigated for the development of VEPM.

The majority of New Zealand new passenger car and light commercial fleet is manufactured to European emission standards. For vehicles manufactured to European emission standards, the UK National Atmospheric Emissions Inventory (NAEI) was selected as the most appropriate source of emission factors for development of VEPM. The NAEI model was supplemented with emissions data from other sources, including the available New Zealand data, where practicable. It also incorporated features from other models, e.g. emission factors for heavy duty vehicles and cold start emissions factors from the European Computer Model to Calculate Emissions from Road Transport (COPERT).

Since the development of VEPM, the NAEI has been updated many times and has now been replaced with emissions factors based on the COPERT model. Therefore, emission factors in VEPM have been updated based on those from the COPERT model for all vehicles manufactured to European emission standards.

A substantial proportion of the passenger car and light commercial fleet is second hand Japanese domestic vehicles, which are manufactured to Japanese vehicle emission standards. Japanese vehicle emissions factors would have been ideal for these vehicles. However, a comprehensive Japanese emissions model is not readily available. For these vehicles, detailed comparison was undertaken to assign the closest equivalent European emission factor for each Japanese vehicle class and each pollutant as described in the technical report (EFRU 2008). This approach has also been used internationally[8].

VEPM has been regularly updated since its release in 2008 to ensure its predictions reflect the changing emissions profile of the New Zealand fleet. Updates have incorporated updated New Zealand fleet data and the latest internationally available emission factors. Key updates to VEPM in each public release are summarised as follows:

- 2008 VEPM 3.0 based on emissions measurements in the United Kingdom National Atmospheric Emissions Inventory (UK NAEI) database from the 1990s and early 2000s. To estimate emissions from the Japanese vehicle fleet, a detailed comparison of Japanese and European emission factors was undertaken.
- 2011 VEPM 5.0 based on updated emissions measurements from the UK NAEI database (2009) and the European COPERT 4, version 8, 2011 database. VEPM 5.0 included emissions from hybrid vehicles, the effects of gradient, $PM_{2.5}$ as output and updated (2010) fleet profile data for New Zealand vehicles. Extensive work was undertaken to calibrate VEPM 5.0 against all available emissions data from New Zealand.
- 2012 VEPM 5.1 incorporated emission factors for light duty vehicles at different road gradients from the World Road Association.
- 2017 VEPM 5.3 included an updated fleet profile, country of origin and date of emission standard introduction. VEPM 5.3 incorporated emission factors based on COPERT for Euro 5, Euro 6 and Euro V, and the addition of Euro VI and includes emission factors for NO_2.
- 2019 VEPM 6.0 included an updated fleet profile, separate categories for hybrid, plug in hybrid and electric vehicles, including electric buses and trucks. VEPM 6.0 includes updated New Zealand fleet profile data and all emission factors in VEPM 6.0 were aligned and updated with the latest version of COPERT.
- 2020 VEPM 6.1 incorporated emission factors for buses and articulated trucks. Real world fuel consumption factors for light duty diesel vehicles were incorporated. All COPERT emission factors were updated.
- 2021 VEPM 6.2 incorporated an updated fleet profile, added emission factors for methane, nitrous oxide and carbon dioxide equivalent. Light duty vehicle degradation correction factors and gradient correction factors were updated and all COPERT emission factors were updated.
- 2022 VEPM 6.3 incorporated an updated fleet profile, revised assumed emission factors for Japanese used vehicles from 2010 and revised the assumed date of introduction of Euro 6/VI standards in New Zealand.
- 2023 VEPM 7.0 replaced the VEPM 6.3 spreadsheet with a web-based database application. The methodology, assumptions and emission factors in VEPM 7.0 were identical to VEPM 6.3.

Details of each update are provided in the corresponding technical report. These are available on the NZTA website.

[8] The developers of COPERT used a similar process to develop emission factors for Cyprus where the vehicle fleet is also dominated by Japanese used imports.

3. Fleet weighted emission factor calculations in VEPM

This chapter outlines the overall methodology for calculating fleet weighted emissions factors in VEPM.

3.1 Overall methodology: calculation of fleet weighted emission factors

Fleet weighted emissions are calculated in VEPM by multiplying emissions factors in g/km for defined vehicle sub-categories by the proportion of vehicle kilometres travelled (VKT) for those sub-categories. The calculation of fleet weighted emission factors is shown schematically in Figure 5 and is described briefly in the following sections.

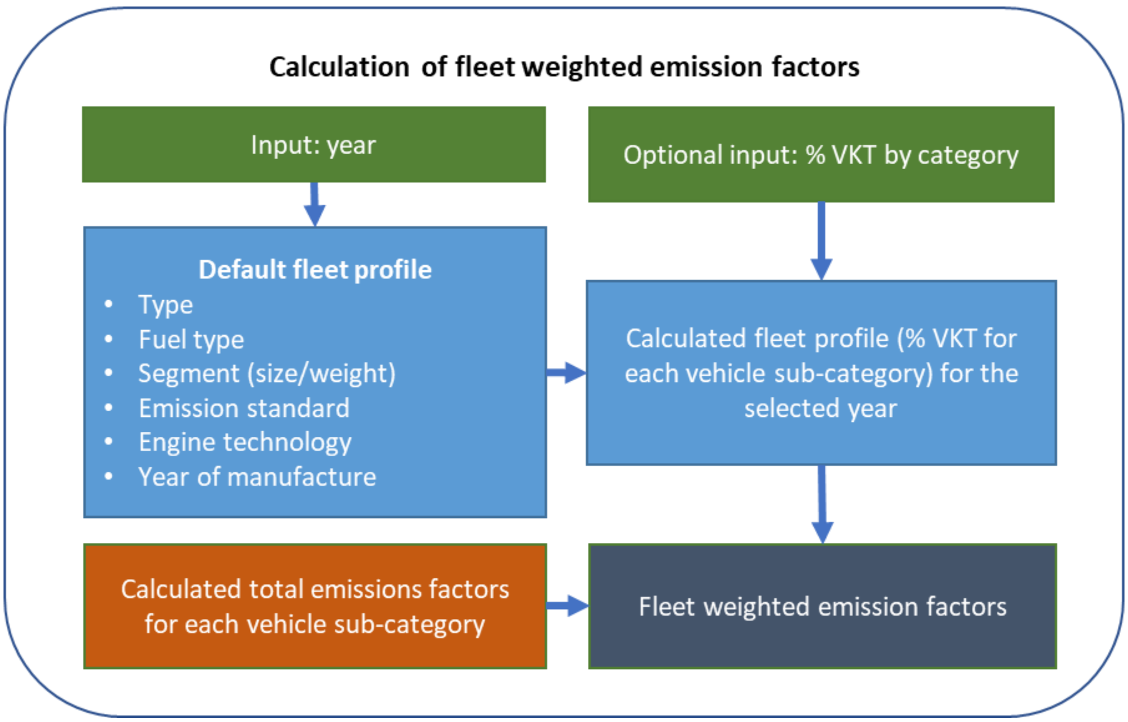

Figure 5: Calculation of fleet weighted emission factors in VEPM.

3.1.1 Pollutants

VEPM calculates New Zealand fleet weighted emission factors for:

- Exhaust emission factors for harmful pollutants:
    - Particulate matter ($PM_{2.5}$[9])
    - Nitrogen oxides (NO_X)
    - Nitrogen dioxide (NO_2)
    - Volatile organic compounds (VOC)
    - Carbon monoxide (CO)

[9] Exhaust PM is denoted as $PM_{2.5}$ in VEPM, however almost all PM from vehicle exhaust is less than 1 micron (PM_1), with the majority being in the 10-100 nanometre range.

- Exhaust emission factors for greenhouse gases:
    - Carbon dioxide (CO_2)
    - Methane (CH_4)
    - Nitrous oxide (N_2O)
    - Carbon dioxide equivalent (CO_2e), which is calculated from CO_2, CH_4 and N_2O factors
- Brake and tyre wear factors for particulate matter smaller than 10 µm (PM_{10}) or smaller than 2.5 µm ($PM_{2.5}$)

VEPM also calculates New Zealand fleet weighted fuel consumption.

3.2 VKT

3.2.1 Vehicle categories

VEPM calculates emission factors for the vehicle categories shown in Table 2.

The vehicle categories in Table 2 are further broken down into sub-categories within VEPM so that specific emission factors can be assigned. Sub-categories include:

- Engine size
    - Petrol, petrol hybrid and petrol plug-in hybrid cars:
        - <1350
        - ≥1350-1999cc
        - ≥2000cc
    - Diesel cars:
        - <2000cc
        - ≥2000cc
- Emission standard that the vehicle was manufactured to (e.g. Euro 5 or Euro 6), which is assigned based on the vehicle year of manufacture and country of manufacture.
- Some emission standard sub-categories are further broken down by engine technology type (for example, there are different Euro V emission factors for vehicles equipped with EGR or SCR emission control systems).

Table 2: Vehicle categories in VEPM 7.1

Type	Fuel	Segment
Cars	Petrol	<3.5t
	Diesel	<3.5t
	Petrol hybrid	<3.5t
	Petrol plug-in hybrid	<3.5t
	Electric	<3.5t
Light commercial vehicles (LCVs)	Petrol	<3.5t
	Diesel	<3.5t
	Petrol hybrid	<3.5t
	Petrol plug-in hybrid	<3.5t
	Electric	<3.5t
Buses	Diesel	Urban <=12 t Urban 12-18 t Coach 12-18 t
	Electric	>3.5 t
Heavy commercial vehicles (HCVs)	Diesel	Rigid <=7.5 t Rigid 7.5 - 10 t Rigid 10 - 20 t Rigid 20 - 25 t Rigid 25 - 30 t Rigid >30 t Articulated 14 - 20 t Articulated 20 - 28 t Articulated 28 - 34 t Articulated 34 - 40 t Articulated 40 - 50 t Articulated 50 - 60 t
	Electric	<10 t >10t

3.2.2 Default fleet profile

Default fleet profiles are based on outputs from the Ministry of Transport Te Manatū Waka (MoT) Vehicle Fleet Model (VFM)[10].

Default fleet data (percentage of VKT for each vehicle sub-category) is included in VEPM for all years between 2001 and 2050. The percentage of VKT for each vehicle sub-category is calculated in VEPM based on the user selected analysis year.

Vehicle sub-categories in Ministry of Transport VFM are not consistent with sub-categories in the European emission factor database. This means that a series of assumptions are required to derive a default New Zealand fleet profile for each year. These assumptions are described in chapter 4.

[10] VFM outputs were provided by Ministry of Transport in July 2024 (VFM version 202405)

3.3 Emission factors

VEPM is based on emission factors from the European COPERT model, which are published by EMEP/EEA in a spreadsheet (EEA 2024a). The EMEP/EEA spreadsheet provides speed-based exhaust emission factors and energy consumption factors for vehicles broken down by type (passenger car, light commercial vehicle, etc), fuel, segment (size or vehicle weight), the emission legislation with which they are compliant[11] and in some cases, engine technology type.

Emission factors are calculated in VEPM for each vehicle sub-category (defined by type, fuel, size/weight segment and emission legislation/engine technology type) and each pollutant based on user defined speed and a range of optional inputs, which are described in Section 2. The emission factors for each vehicle sub-category are combined with fleet data to calculate fleet weighted average emission factors for vehicle categories (shown in Table 2) and for the total fleet.

The methodology and assumptions for calculation of total emission factors for all vehicle sub-categories and pollutants are described in chapter 5.

[11] Some vehicle categories are further broken down by engine technology (for example EGR or SCR specifies the type of NOx emission control system).

4. Default fleet

This chapter describes the methodology and assumptions to develop default fleet profiles for all years from 2001 to 2050.

4.1 Overall methodology: calculation of default fleet profiles

Default fleet profiles (the default percentage of VKT travelled for each vehicle sub-category in VEPM) are included in VEPM for all years between 2001 and 2050. The percentage of VKT for each vehicle sub-category (defined by type, fuel, size/weight segment and emission legislation/engine technology type) is calculated in VEPM based on the user selected analysis year.

Default fleet profiles are based on outputs from the Ministry of Transport Te Manatū Waka (MoT) Vehicle Fleet Model (VFM)[12]. Vehicle sub-categories in Ministry of Transport model are not consistent with sub-categories in the European emission factor database. This means that a series of assumptions are required to derive a default New Zealand fleet profile for each year.

The methodology for deriving default fleet profiles is shown schematically in Figure 6 and is described in the following sections.

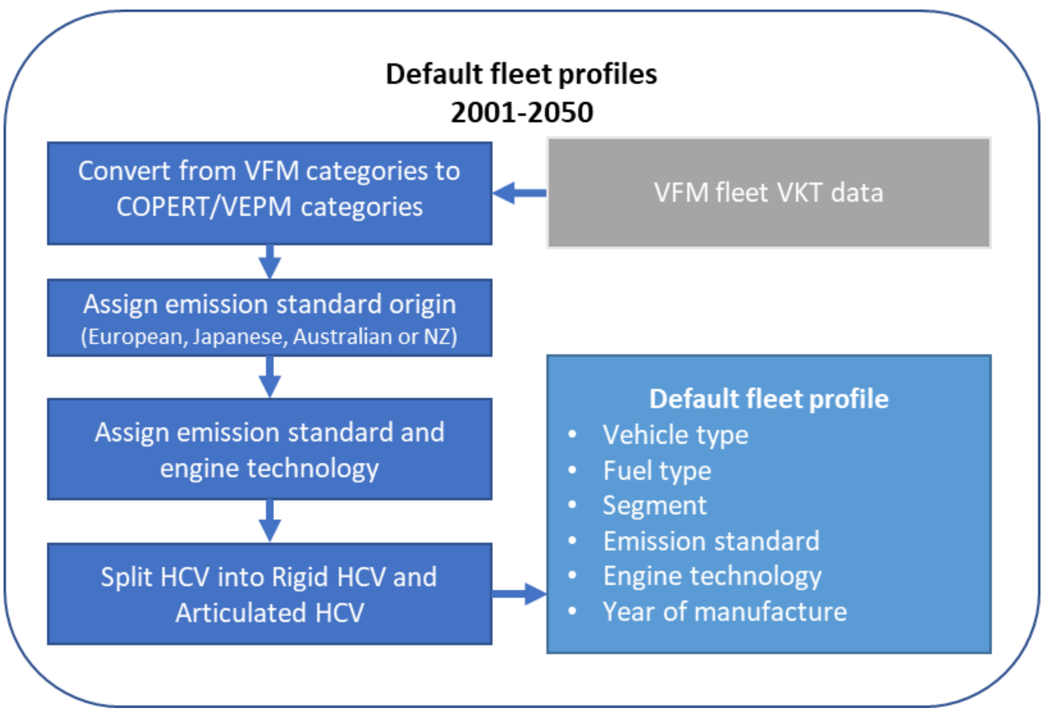

Figure 6: Calculation of default fleet profile in VEPM.

[12] VFM outputs were provided by Ministry of Transport in July 2024 (VFM202405)

4.2 VFM fleet VKT data

VKT data from VFM is provided by MoT for all years from 2001 to 2050 broken down by:

- vehicle type
- fuel type (petrol, diesel, hybrid, plugin hybrid, electric, etc[13])
- engine capacity (light duty vehicles) or vehicle mass (heavy vehicles)
- year of manufacture
- import status (whether the vehicle was sold new in New Zealand or was a used import).

Vehicle types include[14]:

- 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): Light trucks and heavy trucks with GVM > 3.5 tonnes
  - Buses > 3.5 tonnes

Fleet data in VEPM are regularly updated when VFM is updated.

4.2.1 VFM fleet data in VEPM 7.1

Fleet data in VEPM 7.1 are based on VKT values from VFM for the *base case with existing measures scenario*.

At the time of writing, MoT staff consider this to be the most realistic scenario as it accounts for existing policy measures at July 2024. These existing policy measures are described in Table 3.

Table 3: Policy measures accounted for in VEPM 7.1 fleet projections

Mitigation measure	Short description
Clean Car Discount Scheme	The Clean Car Discount encouraged buyer demand for low-emission vehicles by providing rebates for zero- and low-emission light vehicles, and required a fee to be paid for high-emission vehicles registered in New Zealand for the first time. It was repealed on 31 December 2023.
Clean Car Standard	The Clean Car Standard requires vehicle importers to achieve annually stricter CO_2 targets from 2023 or otherwise face financial charges. The Standard has been reviewed and the revised settings will be applied from 2025.
Road User Charges exemptions for electric vehicles	A Road User Charges exemption on light electric vehicles commenced in 2009 and ran until 1 April 2024. A Road User Charges exemption for heavy electric vehicles was introduced in 2017 and will run until 1 January 2026.

[13] VFM includes data for some fuel types that are not currently included in VEPM. These are diesel hybrid, diesel plug-in hybrid, LPG/CNG and hydrogen/other.
[14] Mopeds and motorcycles are included in VFM data but are not currently included in VEPM.

Mitigation measure	Short description
Public transport bus decarbonisation	The Government will require only zero-emission public transport buses to be purchased by 1 July 2025 and is targeting full decarbonisation of the bus fleet by 2035. The Government is providing about $44.7 million over the next 4 years to support bus decarbonisation initiatives.
New Zealand Emissions Trading Scheme (NZ ETS)	The Emissions Trading Scheme is a tool for sending price signals to producers, consumers and investors. It puts a price on emissions, by charging certain sectors of the economy for the greenhouse gases they emit.

The fleet data in VEPM 7.1 includes historical fleet and actual travel data to 2022 with projections to 2055.

Table 4 and Figure 7 show the overall default fleet profile in VEPM 7.1.

Table 4: Default fleet (% VKT by vehicle category totals) in VEPM 7.1

	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 hybrid	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%	11.1%	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	61.7%	7.8%	2.2%	0.2%	0.4%	2.9%	17.6%	0.0%	0.0%	0.0%	6.6%	0.6%	0.0%	0.0%
2025	50.5%	7.2%	10.0%	1.1%	2.2%	2.6%	18.9%	0.1%	0.0%	0.1%	6.7%	0.5%	0.0%	0.1%
2030	37.4%	6.4%	19.3%	2.9%	5.4%	2.2%	17.4%	0.2%	0.6%	1.0%	6.6%	0.5%	0.0%	0.2%
2035	25.7%	5.0%	24.4%	4.8%	11.9%	1.9%	14.8%	0.3%	1.3%	2.7%	6.4%	0.4%	0.2%	0.2%
2040	15.9%	3.5%	22.0%	5.4%	25.9%	1.5%	11.0%	0.3%	1.5%	6.1%	5.9%	0.3%	0.5%	0.3%
2045	8.9%	2.2%	14.8%	4.5%	42.6%	1.1%	7.6%	0.3%	1.3%	9.8%	5.4%	0.3%	0.8%	0.3%
2050	5.1%	1.4%	8.8%	3.5%	54.5%	0.8%	5.1%	0.3%	1.1%	12.8%	4.8%	0.3%	1.2%	0.4%

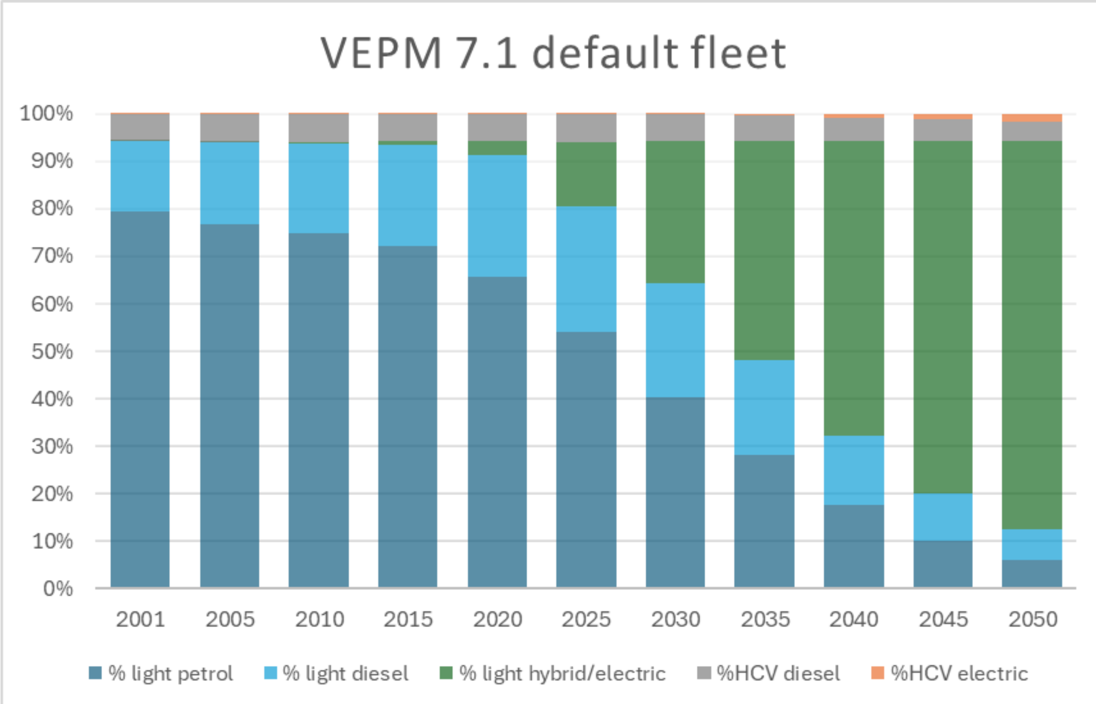

Figure 7: Default fleet (%VKT by vehicle category totals) in VEPM 7.1. **Note**: %HCV includes buses.

4.3 Equivalent EMEP/EEA vehicle categories assumed for VFM vehicle categories

Vehicle classifications in the EMEP/EEA emission factors spreadsheet (EEA 2024a) do not match classifications in the New Zealand fleet data from VFM. This means that a series of assumptions are required as summarised in Table 5. Assumptions for light commercial vehicles, and buses are described in more detail in the following subsections. Assumptions for splitting heavy vehicle VKT between rigid and articulated sub-categories are described in Section 4.7.

4.3.1 Light commercial vehicle category

All light commercial vehicles are classified as N1-III in VEPM on the basis that the average light commercial vehicle mass in New Zealand is roughly equivalent to the EMEP/EEA N1-III category (Metcalfe & Sridhar 2019).

The EMEP/EEA spreadsheet (EEA 2024a) does not include emission factors for hybrid or plugin hybrid light commercial vehicles, so Large-SUV-Executive passenger car factors are assumed in VEPM for hybrid and plugin hybrid LCVs.

4.3.2 Bus and coach split

The default fleet breakdown assumes that 80% of buses > 12 tonnes are urban buses standard and 20% are coaches. There are no data to support this assumption. Further investigation is recommended to confirm whether the bus and coach split is realistic.

4.3.3 Vehicle categories not included in VEPM

There are vehicle categories in the EMEP/EEA spreadsheet which are not currently included in VEPM (e.g. motorcycles and additional engine size categories for passenger cars). Further work is recommended to consider whether any of these additional categories warrant inclusion in future versions of VEPM.

Table 5: EMEP/EEA vehicle classifications assumed in VEPM7.1

Vehicle fuel and type	NZ VFM fleet data segment	EMEP/EEA vehicle size segment used
Petrol, petrol hybrid & petrol plugin hybrid passenger cars	Cars and SUVs ○ <1350 ○ 1350-1599cc ○ 1600-1999cc ○ 2000-2999cc ○ >=3000cc	Passenger cars ○ Small ○ Medium ○ Medium ○ Large-SUV-Executive ○ Large-SUV-Executive
Diesel passenger cars	Cars and SUVs ○ <1350cc ○ 1350-1599cc ○ 1600-1999cc ○ 2000-2999cc ○ >=3000cc	Passenger cars ○ Medium ○ Medium ○ Medium ○ Large-SUV-Executive ○ Large-SUV-Executive
Petrol and diesel light commercial vehicles	Vans and Utes. All engine sizes	Light commercial vehicles N1-III class (reference mass > 1760kg)
Petrol hybrid light commercial vehicle	Vans and Utes. All engine sizes	Petrol hybrid Large-SUV-Executive passenger car
Petrol plugin hybrid light commercial vehicle	Vans and Utes. All engine sizes	Petrol plugin hybrid Large-SUV-Executive passenger car
Buses	3.5 – 7.5t 7.5 – 12t	Urban buses midi <= 15t
	>12t	Split between urban Buses standard 15-18t & coaches standard <= 18t
Heavy commercial vehicles	3.5 – 5.0t (light truck) 5.0 – 7.5t (light truck)	Rigid 3.5 – 7.5t
	7.5 – 10t (light truck)	Split between rigid 7.5 – 12t & articulated
	10 – 20t (heavy truck)	Split between rigid 14 – 20t & articulated
	20 – 25t (heavy truck)	Split between rigid 20 – 26t & articulated
	25 – 30t (heavy truck)	Split between rigid 26 – 28t & articulated
	>30t (heavy truck)	Split between rigid >32t & articulated

4.4 Assigning emission standard origin

VEPM emission factors for each vehicle category (type, fuel, size segment) are broken down by emission standards (Euro 1, Euro 2 etc).

New Zealand fleet data from VFM does not include vehicle emissions standards. This means that a series of assumptions are required to further breakdown VKT by emission standards depending on vehicle country of manufacture and year of manufacture. Appendix 1 shows the emission standard that is assigned in VEPM for each vehicle category (type, fuel, segment) by emission standard origin (European, Australian, New Zealand and Japanese) and year of manufacture.

The New Zealand fleet includes vehicles that have been manufactured to emission standards from various regions including Europe, Australia and Japan as well as vehicles manufactured in New Zealand before emission standards were introduced.

The emission standard origin is particularly important for estimating emissions from vehicles manufactured from the 70s to the late 90s when there was considerable variation between the emissions standards of vehicles from different parts of the world. For more recent vehicle imports, we know that the vast majority of vehicles entering the fleet are manufactured to European standards (new vehicles) or Japanese standards (used vehicles) (Metcalfe & Sridhar 2017)[15]. VFM vehicle data does not include a breakdown by country of manufacture or emission standards.

As shown in Table 6, VKT is assigned to either European, Japanese, Australian or New Zealand emissions standard origin in VEPM based on year of manufacture, import status, as well as country of manufacture for older (up to 2009) vehicles.

Table 6: Emissions standard origin assumed in VEPM based on vehicle country of origin and import status

Year of manufacture	Country of manufacture	Import status	Emission standards origin assumed
Up to 2009	Europe	New and used	European
	Australia	New and used	Australian
	New Zealand	N/A	New Zealand
	Japan	New	European
	Japan	Used	Japanese
2010 onwards	All	New	European
2010 onwards	All	Used	Japanese

The methodology is summarised as follows, with the detailed methodology and assumptions fully described in Section 4.4.1.

[15] Statistics on the emission standards of new vehicles are available at: Fleet statistics | Ministry of Transport

- For vehicles up to year of manufacture 2009, emission standard origin is based on a detailed country of manufacture and import status breakdown of the fleet that was developed for VEPM 5.3 after analysing fleet data up to 2014[16]. It was assumed that:
    - Vehicles manufactured in Europe, Australia and New Zealand are manufactured to European, Australian and New Zealand emission standards respectively
    - Vehicles manufactured in Japan and first sold in New Zealand (new import status) are manufactured to European standards
    - Used import vehicles from Japan are manufactured to Japanese standards
- For vehicles from year of manufacture 2010 onwards, all new vehicles are assumed to be manufactured to European emission standards and all used vehicles manufactured to Japanese emission standards.

The breakdown by emission standards origin (European, Australian, New Zealand, Japanese) for vehicles up to year of manufacture 2009 has not been updated since it was developed based on analysis of 2014 fleet data. It is recommended that update of this data should be considered as part of future fleet updates. Investigating whether vehicle import status from VFM could be used to assign emission standards to vehicles manufactured before 2009 is also recommended.

4.4.1 Detailed emission standard origin methodology in VEPM

Emission standard origin is assigned using detailed historical data (from VEPM 5.3) for years of manufacture up to 2009 and based on import status (new or used) from VFM for year of manufacture 2010 onwards. The detailed methodology depends on the fleet year as described in the following subsections.

VEPM fleets from 2001-2009

For VEPM fleets from 2001 to 2009 detailed emission standard 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:** The VEPM 5.3 breakdown was calculated as follows:

Light duty vehicles:

- Country of manufacture data for the entire fleet were extracted from the motor vehicle register for all years between 2001 and 2014. This information included the vehicle import status.
- The proportion of vehicles from each country (New Zealand, Australia, Japan and Europe) was calculated for each year of manufacture for each vehicle category (type, fuel, size segment and import status).
- Emission standard origin (New Zealand, Australian, Japanese and European) was then assigned based on the assumptions shown in Table 6.

Heavy duty vehicles:

- Country of manufacture 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.

[16] This country of origin breakdown was developed in 2016 for incorporation into VEPM 5.3.

- The proportion of vehicles from each country of manufacture (Europe, Japan, Australia and New Zealand) was calculated for each year of manufacture for each vehicle category (type, fuel, size segment).
- The country of manufacture proportions were applied to VKT for each year of manufacture for each vehicle category to calculate VKT broken down by country of manufacture, year of manufacture and vehicle category (type, fuel, size segment).
- Import status (new or used) was not available for heavy duty vehicles. For Japanese manufactured vehicles, VKT were split between new and used vehicles 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[17]. All used vehicles were assumed to be of 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 heavy duty Japanese vehicles for years of manufacture up to 2010 was assumed to be the same for all fleet years.
- Emission standard origin (New Zealand, Australian, Japanese and European) was then assigned based on the assumptions shown in Table 6.

VEPM fleets from 2001-2009

For VEPM fleets from 2010 to 2014 emission standard origin is assigned as follows in VEPM 7.1:

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

VEPM fleets from 2015 onwards

For VEPM fleets from 2015 onwards emission standard origin is assigned as follows in VEPM 7.1:

- For years of manufacture 1968-2009, the detailed emission standard 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 emission standard origin is based on import status (new or used) from VFM. All NZ New vehicles are assumed to be manufactured to European emission standards and all used imports are manufactured to Japanese emission standards.

[17] This information was taken from Ministry of Transport 2015 annual fleet statistics spreadsheet (sheet 2.5a to 2.8a)

4.5 Assigning emission standards

Appendix 1 shows the emission standard assigned in VEPM for each vehicle category (type, fuel, segment) by emission standard origin (European, Australian, New Zealand or Japanese) and year of manufacture.

4.5.1 European

Vehicles assigned European emission standard origin are assumed to be manufactured to European emission standards. However, there is a delay between implementation of standards in Europe and the introduction of these standards in New Zealand. As shown in Table 7 and Table 8, three to five years elapsed between introduction of Euro 4/5/IV/V emission standards in Europe and the introduction of these standards in New Zealand. For Euro 6/VI, the lag will be more than 10 years.

The date of introduction of European emission standards in VEPM 7.1 is based on the following assumptions:

- For emission standards that are specified in New Zealand legislation, it is assumed that 100% of new vehicles comply with the European emission standard required by New Zealand legislation at the year of manufacture. This is a conservative because some vehicles being imported into New Zealand will comply with European standards before they are required in New Zealand.
- For historical emission standards which are not specified in New Zealand legislation, a four to five year delay is assumed for compliance with European emission standards in New Zealand.
- It is assumed that Euro 6 d/e standards will be implemented in 2028 and Euro VI-C standards will be implemented in 2025.

Table 7: Light duty emission standard introduction dates for Europe and New Zealand

Standard	Europe[18]		New Zealand[19],[20]			
	Light duty		Light duty petrol		Light duty diesel	
	New models	All models	New models	All models	New models	All models
Euro 1	Jul-92	Jan-93				
Euro 2	Jan-96	Jan-97				
Euro 3	Jan-00	Jan-01				
Euro 4	Jan-05	Jan-06	Jan-08	Jan-09	Jan-08	Jan-08
Euro 5	Sep-09	Jan-11	Nov-13	Nov-16	Jan-14	Nov-16
Euro 6	Sep-14	Sep-15	July-27	Jul-28	Jul-27	Jul-28

[18] TransportPolicy.net, available at http://transportpolicy.net/index.php?title=EU:_Light-duty:_Emissions
[19] NZ Transport Agency available at https://www.nzta.govt.nz/vehicles/vehicle-types/vehicle-classes-and-standards/environmental-standards/
[20] 2023 amendment available at: https://www.nzta.govt.nz/assets/resources/rules/docs/vehicle-exhaust-emissions-amendment-2023.pdf

Table 8: Heavy duty diesel emission standard introduction dates for Europe and New Zealand

Standard	Europe[21]	New Zealand	
	New models	New models	All models
Euro I	92		
Euro II	Oct-96		
Euro III	Jan-00		
Euro IV	Oct-05	Jan-08	Jan-09
Euro V	Oct-08	Jan-12	Jan-12
Euro VI	Jan-13	Nov-24	Nov-25

The emission standards assumed for European (New Zealand new) vehicles based on year of manufacture are shown in Table 38, Appendix 1.

4.5.2 Australian

Australian Design rules are generally based on European standards with delayed implementation. Australian vehicles are assigned to the equivalent European standard adopted in Australia based on year of manufacture as shown in Table 39, Appendix 1.

4.5.3 New Zealand Manufactured

There has been no significant manufacture of vehicles in New Zealand since the 1990s, so there are very few New Zealand manufactured vehicles in today's fleet. However, VEPM calculates emission factors from 2001, so emission factors for these vehicles are still required in the database.

New Zealand manufactured light duty vehicles are assigned to emission factors for New Zealand manufactured vehicles based on year of manufacture as shown in Table 40, Appendix 1. The emission factors are described in Section 5.12.

Any heavy commercial vehicles manufactured in New Zealand are assumed to be equivalent to Australian manufactured vehicles for the same year of manufacture.

4.5.4 Japanese

A substantial proportion of the New Zealand fleet is second hand Japanese domestic vehicles, which are manufactured to Japanese emission standards.

Japanese used vehicles are assumed to comply with the Japanese emission standard required by Japanese legislation at the year of manufacture. Japanese emission standards assumed by year of manufacture are summarised in Table 41, Appendix 1. Emissions are estimated based on the closest

[21] TransportPolicy.net, available at http://transportpolicy.net/index.php?title=EU:_Heavy-duty:_Emissions

equivalent European emission standard for each vehicle sub-category and pollutant, as described in chapter 5. Appendix 2 summarises the equivalent European emission standards assumed for each vehicle sub-category and pollutant.

4.6 Assigning engine technology

Emission factors are assigned in COPERT according to the emission standard that vehicles are manufactured to. Some emission factors are further broken down by engine technology type . For example, there are different Euro V emission factors for vehicles equipped with EGR or SCR emission control systems.

4.6.1 Heavy commercial vehicle engine technology splits

The EMEP/EEA spreadsheet (EEA 2024a) provides separate emission factors for exhaust gas recirculation (EGR) and selective catalytic reduction (SCR) heavy commercial Euro V vehicles. For European member states, it is estimated that approximately 75% of Euro V vehicles are equipped with SCR, with the rest being equipped with EGR (EEA 2024). There are no specific data for New Zealand (Metcalfe & Sridhar 2017) therefore the same assumption has been made for VEPM.

The EMEP/EEA spreadsheet also provides separate EGR and SCR factors for Euro IV vehicles. However, the emission factors are identical so a nominal choice of SCR technology is made in VEPM.

4.6.2 Light duty engine technology splits

The EMEP/EEA spreadsheet specifies emission control technology (in addition to emission standard) for some light duty vehicle categories as follows:

- Gasoline direct injection (GDI) or port fuel injection (PFI) engine technology for some petrol vehicle emission standards. Euro 6 standards also include a gasoline particulate filter option (GPF). However, the emission factors are identical for different technologies.
- Diesel particulate filter (DPF) is specified for Euro 3 to Euro 5 light duty diesel, however no alternative option is provided.
- In addition to DPF, Euro 6 diesel options include DPF combined with selective catalytic reduction (SCR) and DPF combined with a lean NOx trap (LNT). However, the emission factors are identical for different combinations of technologies. At this stage a nominal default choice of DPF technology has been adopted in VEPM.

At this stage a nominal choice of technology has been adopted in VEPM (PFI for petrol vehicles, GDI for hybrid and plugin hybrid and DPF for diesel vehicles).

In some cases, the EMEP/EEA spreadsheet has different emission factors for different technologies. It is recommended that the significance of technology choices and the availability of any data on likely technology splits should be reviewed and confirmed.

4.7 Splitting rigid and articulated truck VKT

Heavy duty vehicle VKT data from the MoT VFM 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 VFM to indicate whether vehicles have trailers or not.

Emission factors are provided in the EMEP/EEA spreadsheet 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 in VEPM, VKT undertaken by trucks towing a trailer is estimated based on road user charges (RUC) data (Metcalfe et al 2021). All VKT undertaken by trucks towing a trailer is assigned to an articulated truck category in VEPM. This means that the "articulated" truck category in VEPM includes articulated trucks as well as rigid trucks towing a trailer.

All remaining truck VKT is assigned to the rigid truck category in VEPM based on the GVM in VFEM.

Table 9 to Table 12 provide estimates for:

1. The overall proportion of heavy duty VKT travelled by trucks towing a **trailer**
2. The proportion of VKT travelled by trucks towing a trailer that is taken from each GVM category in VFM (with the remainder being assigned to the corresponding **rigid** truck category in VEPM)
3. The proportion of VKT for trucks towing a trailer from each GVM category in VFM that is assigned to each **articulated** truck GCM category.

The assumptions and methodology for deriving these estimates are described in (Metcalfe et al 2021). The estimates are based on data available in 2021. It is recommended that the articulated truck splits should be updated periodically.

This following section describes how these data are applied in VEPM to split VKT between rigid and articulated truck categories.

Table 9: Proportion of heavy duty VKT assigned to trucks towing a trailer derived from RUC data

Year	RUC Truck VKT (millions)	RUC Trailer VKT (millions)	RUC Leading Trailer VKT (millions)	RUC Trucks with Trailers VKT (millions)	**% of heavy duty VKT assigned to trucks towing a trailer**
2001	2,229	988	0	988	44%
2002	2,353	1,042	0	1,042	44%
2003	2,436	1,078	0	1,078	44%
2004	2,601	1,148	0	1,148	44%
2005	2,652	1,146	0	1,146	43%
2006	2,652	1,149	0	1,149	43%
2007	2,753	1,185	0	1,185	43%
2008	2,734	1,194	0	1,194	44%

Year	RUC Truck VKT (millions)	RUC Trailer VKT (millions)	RUC Leading Trailer VKT (millions)	RUC Trucks with Trailers VKT (millions)	**% of heavy duty VKT assigned to trucks towing a trailer**
2009	2,591	1,098	0	1,098	42%
2010	2,653	1,175	0	1,175	44%
2011	2,675	1,222	0	1,222	46%
2012	2,738	1,247	38	1,209	44%
2013	2,665	1,238	94	1,144	43%
2014	2,831	1,309	99	1,210	43%
2015	2,787	1,275	100	1,175	42%
2016	2,809	1,284	104	1,180	42%
2017	2,982	1,383	119	1,264	42%
2018	3,079	1,384	119	1,265	41%

Table 10: Estimated proportion of VKT travelled by trucks towing a trailer taken from each heavy duty GVM category

Year	**% of trucks towing trailer VKT from each VEPM heavy duty GVM category**					
	3.5-7.5t	**7.5-10t**	**10-20t**	**20-25t**	**25-30t**	**>30t**
2001	0%	1%	27%	38%	30%	4%
2002	0%	1%	26%	38%	31%	4%
2003	0%	1%	26%	39%	31%	3%
2004	0%	1%	26%	38%	32%	3%
2005	0%	1%	25%	38%	33%	4%
2006	0%	1%	24%	37%	33%	5%
2007	0%	1%	24%	37%	33%	5%
2008	0%	1%	23%	36%	33%	7%
2009	0%	1%	23%	34%	34%	8%
2010	0%	1%	23%	34%	34%	9%
2011	0%	1%	22%	34%	34%	9%
2012	0%	1%	22%	32%	35%	10%
2013	0%	1%	22%	31%	34%	12%
2014	0%	1%	22%	30%	35%	13%
2015	0%	1%	22%	29%	35%	13%
2016	0%	1%	23%	27%	35%	14%
2017	0%	1%	22%	26%	36%	15%
2018	0%	1%	22%	25%	37%	16%
2019	0%	1%	21%	23%	38%	17%
2020	0%	1%	21%	22%	39%	17%

Table 11: Assumed proportion of VKT for trucks towing a trailer from each GVM category that is assigned to each articulated truck GCM category for 2019 and onwards

Truck GVM	Assumed proportion of VKT for trucks towing a trailer assigned to each articulated truck GCM category						
	14-20t	20-28t	28-34t	34-40t	40-50t	50-60t	Grand Total
07.5-10.0t	100%	0%	0%	0%	0%	0%	100%
10.0-20.0t	0%	10%	58%	21%	9%	2%	100%
20.0-25.0t	0%	0%	0%	29%	60%	12%	100%
25.0-30.0t	0%	0%	0%	1%	66%	34%	100%
30.0-99.0t	0%	0%	0%	0%	50%	50%	100%

Table 12: Assumed proportion of VKT for trucks towing a trailer from each GVM category that is assigned to each articulated truck GCM category up to and including 2012

Truck GVM	Assumed proportion of VKT for trucks towing a trailer assigned to each articulated truck GCM category						
	14-20t	20-28t	28-34t	34-40t	40-50t	50-60t	Grand Total
07.5-10.0t	100%	0%	0%	0%	0%	0%	100%
10.0-20.0t	0%	10%	58%	21%	11%	0%	100%
20.0-25.0t	0%	0%	0%	29%	72%	0%	100%
25.0-30.0t	0%	0%	0%	1%	99%	0%	100%
30.0-99.0t	0%	0%	0%	0%	100%	0%	100%

4.7.1 Detailed methodology to split rigid and articulated truck VKT in VEPM

To account for trailer travel in VEPM the total VKT that is undertaken by trucks towing a trailer is estimated based on the overall proportion of VKT travelled by trucks towing a trailer (from Table 9) as follows:

$$VKT_{TTT} = VKT \times P_{TTT} \qquad \text{Equation 1}$$

Where:

VKT_{TTT}= VKT for trucks towing a trailer (total across all vehicle size categories)

VKT = VKT for heavy duty vehicles (total across all vehicle size categories from VFM)

P_{TTT} = the proportion of heavy duty vehicle travel that is undertaken by trucks towing a trailer (shown in Table 9).

The VKT that is assigned to trucks towing a trailer **from each GVM category** is then estimated (with the remainder being assigned to the corresponding rigid truck category in VEPM), based on the proportions from Table 10 as follows:

$$VKT_{TTT,GVM} = VKT_{TTT} \times P_{TTT,GVM} \qquad \text{Equation 2}$$

Where:

$VKT_{TTT,GVM}$ = VKT that are assigned to trucks towing trailer(s) from the GVM category

VKT_{TTT} is the total VKT for heavy duty vehicles heavy duty trucks towing trailer(s) (Equation 1)

$P_{TTT,GVM}$ is the proportion of VKT for trucks towing trailers that is taken from each GVM category (shown in Table 10)

VKT is then assigned to articulated truck categories in VEPM based on the estimated gross combined mass of the truck and trailer(s) based on the proportions shown in Table 11 and Table 12 as follows:

$$VKT_{ARTIC,GCM} = \sum_{GVM} VKT_{TTT,GVM} \times P_{ARTIC,GCM,GVM} \qquad \text{Equation 3}$$

Where:

$VKT_{ARTIC,GCM}$ is the VKT for each articulated truck GCM category in VEPM

$VKT_{TTT,GVM}$ is the VKT for trucks towing trailer(s) in each GVM category

$P_{ARTIC,GCM,GVM}$ is the proportion of VKT for trucks towing a trailer from each GVM category that is assigned to each articulated truck GCM category. (**Note**: The proportion is shown in Table 11 for all years from 2019 and in Table 12 for all years up to 2012. Between 2012 and 2019 the values are interpolated).

The remaining heavy vehicle VKT for each GVM size category is allocated to the corresponding rigid truck category in VEPM as follows:

$$VKT_{RIGID,GVM} = VKT_{GVM} - VKT_{TTT,GVM} \qquad \text{Equation 4}$$

Where:

$VKT_{RIGID,GVM}$ = VKT for rigid heavy duty vehicles in the GVM category

VKT_{GVM} = total VKT for heavy duty vehicles in the GVM category (from VFEM3)

$VKT_{TTT,GVM}$ = VKT that are assigned to trucks towing trailer(s) from the GVM category (Equation 2)

5. Calculation of emission factors

This Chapter describes the methodology and assumptions to calculate emission factors for each vehicle category and emission standard for each pollutant.

5.1 Overall methodology: exhaust emission factors and energy consumption

The calculations are described for vehicles manufactured to European and Japanese emission standards. The proportion of vehicles manufactured to these emission standards is estimated based on the methodology outlined in Chapter 4.

The overall methodology for calculation of total emission factors is shown schematically in Figure 8.

Exhaust emissions are calculated according to Equation 5 as the sum of hot emissions (when the engine is at its 'hot' stabilised operating temperature) and emissions during the transient warming up phase (cold start). Emission factors are adjusted to account for vehicle degradation, fuel and gradient effects.

$$E_{TOTAL} = E_{HOT} \times s(m) \times g \times f + E_{COLD} \times f$$ Equation 5

Where:

E_{TOTAL} = Total emission factor

E_{HOT} = Hot emission factor

s(m) = Degradation correction factor for a given accumulated vehicle mileage (m)

g = gradient correction factor[22]

f = fuel correction factor

E_{COLD} = Cold emission contribution (function of trip length and ambient temperature)

Exhaust emission factors and correction factors are calculated generally in accordance with the Tier 3 methodology described in the EMEP/EEA air pollutant emission inventory guidebook (EEA 2024). However, some additional information and data sources are used, including a real-world fuel consumption adjustment factor, which is applied to light duty diesel vehicles as described in Section 4.7.

The calculation of energy consumption factors follows the same methodology.

The information and data sources for calculation of emission factors in VEPM 7.1 are summarised in Appendix 3.

The calculations and assumptions are described in detail in the following sections.

[22] Note: Heavy duty hot emission factors are adjusted for load as well as gradient.

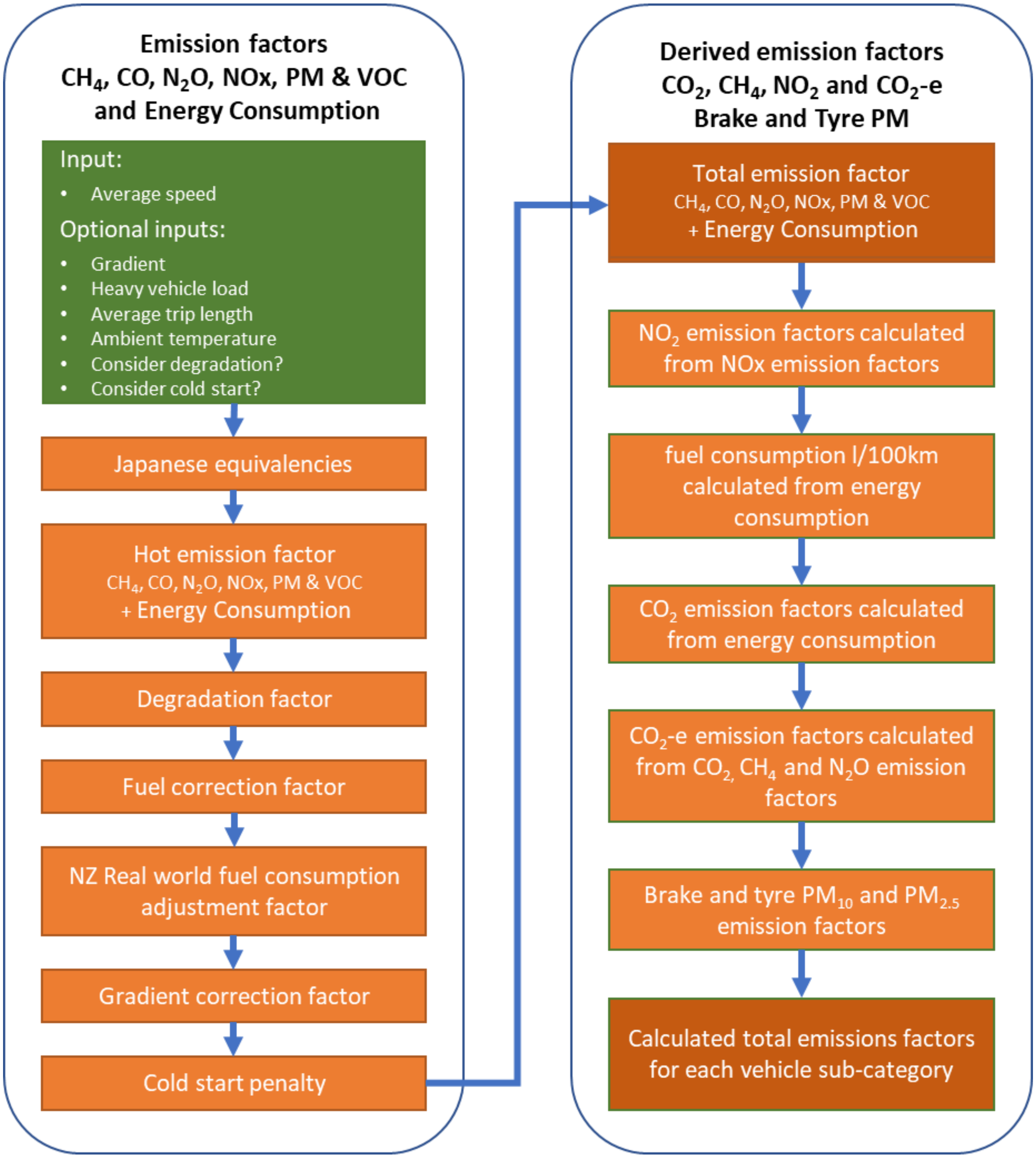

Figure 8: Calculation of total emissions factors by vehicle category in VEPM

5.2 Hot emission factors

5.2.1 Hot emission factors: CO, NOx, VOC, PM, CH_4, N_2O and energy consumption

All hot emission factors (for CO, NOx, VOC, PM CH_4, N_2O and energy consumption) are the latest available COPERT emission factors from the EMEP/EEA spreadsheet (EEA 2024a).

5.2.2 Assumed driving mode for assigning hot emission factors: CH_4 and N_2O and PM from some petrol vehicles

The EMEP/EEA spreadsheet (EEA 2024a) provides emission factors for urban, rural and highway driving modes (unlike other emission factors, which are calculated based on average speed) for the following pollutants:

- CH_4
- N_2O for heavy vehicles
- Exhaust PM for pre-Euro 5 petrol cars and LCVs, Euro V and Euro VI heavy vehicles

Hot emission factors are assigned in VEPM based on the speeds that are considered representative for each EMEP/EEA driving mode as shown in Table 13.

Table 13: Assumed driving mode for assigning CH_4, N_2O and PM emission factors based on speed

Min Speed (km/h)	Max Speed (km/h)	Driving mode	
		PM, CH_4 & N_2O Heavy vehicle	**N_2O light vehicle**
0	34	Urban peak	Urban hot
35	54	Urban off peak	Urban hot
55	79	Rural	Rural
80	140	Highway	Highway

5.2.3 Calculation of N_2O hot emission factors

N_2O emissions are particularly important for light vehicles equipped with catalysts and are dependent on catalyst temperature and aging. Furthermore, catalyst aging is dependent on fuel sulphur level. The EEA guidebook provides parameters to calculate N_2O emission factors for light duty vehicles based on cumulative mileage and fuel sulphur content as follows:

$$EF_{N2O} = [a \times Mileage + b] \times EF_{base} \quad \text{Equation 6}$$

Where:

EF_{N2O} is the N_2O emission factor

a and b are parameters defined in the EMEP/EEA guidebook by vehicle category, emission standard and fuel sulphur content

EF_{base} is the base emission factor from the EMEP/EEA guidebook for the vehicle category, emission standard and fuel sulphur content

Mileage is the mean mileage of the vehicle category

Equation 6 is used to calculate N_2O emission factors for each light duty vehicle category in VEPM based on the average cumulative mileage for each vehicle category at the assessment year[23] and the fuel sulphur content at the assessment year.

5.2.4 Hybrid and plug-in hybrid vehicles

The EMEP/EEA spreadsheet provides plug in hybrid electric vehicle (PHEV) emission factors for charge depleting mode (electric) and charge sustaining mode (combustion engine). To estimate emissions, it is necessary to apply a utility factor which quantifies the share of vehicle kilometres travelled in charge sustaining/combustion engine mode.

Specific New Zealand factors are not available. At this stage we have assumed the same utility factors that are used in COPERT Australia. This assumes that passenger vehicles operate in electric mode 40% of the time and that commercial vehicles operate in electric mode 20% of the time (Smit 2023).

Hybrid and PHEV LCVs are assigned the emission factors for Large SUV/executive passenger cars in VEPM (because the EMEP/EEA spreadsheet does not include emission factors for hybrid or PHEV LCVs).

PHEV emission factors are only available for Euro 6 or newer technology. In VEPM 7.1 it is assumed that all PHEV are Euro 6d.

5.2.5 Japanese vehicles: CO, VOC, NOx and PM and energy consumption

VEPM does not include specific Japanese emission factors, because a comprehensive Japanese emissions model is not readily available. An equivalent European emission factor is assumed in VEPM for each Japanese vehicle category, emission standard and pollutant.

The equivalent European emission factor that is assumed for each Japanese vehicle category, emission standard and pollutant is provided in Appendix 3.

For vehicles manufactured up to 2010, a detailed comparison of emission factors from European and Japanese emission models was undertaken to assign the closest equivalent European emission factor for each Japanese vehicle category and each pollutant. The detailed comparison is described in the technical report (EFRU 2008). This approach has been used internationally[24].

Harmonisation of international emissions standards means that emissions from modern European and Japanese vehicles are similar. For vehicles manufactured from 2010 onwards a simplified approach was used to assign equivalence. A comparison of Japanese and European emission standards was undertaken to identify the closest equivalent standard (Metcalfe & Peeters 2022). For vehicles manufactured from 2010 onwards, Japanese vehicles are assigned the emission factors of the closest equivalent European emission standard (for all pollutants) based on the date of introduction of Japanese emissions standards.

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[23] Cumulative mileage is estimated in VEPM based on vehicle age for calculation of degradation factors.
[24] For example, the developers of COPERT used a similar process to develop emission factors for Cyprus where the fleet is dominated by Japanese used imports.

Articulated trucks

For articulated trucks, the European emission standard is assigned based on the emission standard assigned to the closest equivalent rigid truck category (by weight) as shown in Table 14.

Table 14: Assumed closest equivalent rigid truck category (by weight)

Articulated heavy vehicle	Rigid heavy vehicle
Articulated 14-20t	Rigid 10-20t
Articulated 20-28t	Rigid 20-25t
Articulated 28-34t	Rigid 25-30t
Articulated 34-40t	Rigid >30t
Articulated 40-50t	Rigid >30t
Articulated >50t	Rigid >30t

5.2.6 Japanese vehicles: CH_4 and N_2O

For all years of manufacture:

- Japanese/European emission factor equivalencies for CH_4 are assumed to be the same as VOC
- Japanese/European emission factor equivalencies for N_2O are assumed to be the same as NOx.

5.3 Cold emissions contribution

Engine emissions are higher during the warming up phase (cold start). Cold start emissions are calculated as an extra emission over the emissions that would be expected if all vehicles were only operated with hot engines and warmed-up catalysts.

Although cold start emissions occur in all vehicle categories, they are most significant in petrol vehicles.

Several updates and corrections have been applied to the calculation of cold start penalties in VEPM 7.1. The changes compared to VEPM 7.0 are described in Section 6.2.

5.3.1 Light duty CO, NOx, HC, PM and energy consumption cold start penalty factors

Cold start emissions are estimated for light duty vehicles in VEPM based on the methodology described in the EMEP/EEA guidebook as follows:

$$E_{cold} = \beta \times e_{hot} \times (\rho - 1) \qquad \text{Equation 7}$$

Where:

E_{cold} is the cold start penalty which is added to the hot emission factor if cold start is applied

β is the fraction of mileage driven under cold start conditions

e_{hot} is the hot running emission factor[25]

ρ is the ratio of cold start to hot running emissions (e_{cold}/e_{hot})

VEPM uses algorithms from the EMEP/EEA guidebook to calculate the ρ ratio and β fraction for different vehicle categories and pollutants (and energy consumption). The ρ ratio and β fraction depend on the ambient temperature. The β fraction also depends on trip length and the ρ ratio depends on speed.

For post Euro 1 vehicles, a β reduction fraction is also applied (depending on the Euro standard). The β reduction fraction accounts for improvements in vehicle technology, which have progressively reduced the distance driven in cold conditions.

The EMEP/EEA equations for calculating ρ ratio are valid up to a speed of 45 km/h. The guidebook states that this should correspond to the mean trip speed – not the instantaneous speed (EEA 2024). Cold start emissions can still be calculated in VEPM at speeds above 45 km/h. This is because, in urban areas it is likely that trip segments might exceed 45 km/h, whereas overall mean trip speeds are likely to be less than 45 km/h. However, if the user specified speed is higher than 45 km/h the ρ ratio is calculated based on the maximum valid speed of 45 km/h.

Calculation of cold start is optional in VEPM. To avoid overestimation of cold start emissions, users should omit cold start for emission factors outside urban areas (where the mean trip speed is likely to exceed 45 km/h).

5.3.2 Light duty CH_4 and N_2O cold start penalty factors

The EMEP/EEA guidebook provides urban hot and urban cold driving mode emission factors for N_2O and CH_4 for all vehicle categories. T his differs to other emission factors, where the ρ ratio is provided. Equation 7 is rearranged for calculation of the cold start penalty in VEPM as follows:

$$E_{cold} = \beta \times e_{hot} \times \left(\frac{e_{cold}}{e_{hot}} - 1\right) \qquad \text{Equation 8}$$

So:

$$E_{cold} = \beta \times (e_{cold} - e_{hot}) \qquad \text{Equation 9}$$

The guidebook does not provide β fractions for these pollutants so we assume:

$$\beta = 0.6474 - 0.02545 \times L_{trip} - (0.00974 - 0.000385 \times L_{trip}) \times ta \qquad \text{Equation 10}$$

[25] For Euro 2 to Euro 5 petrol vehicles this is the Euro 1 hot running emission factor.

5.3.3 Hybrid and plug-in hybrid vehicles

The EMEP/EEA guidebook (EEA 2024) does not provide a methodology for calculating cold start emissions from hybrid or plug-in hybrid vehicles, so it is assumed that there is no cold start penalty.

5.3.4 Heavy duty vehicles

Cold start emission factors for CO, VOC and NOx from heavy duty vehicles have been incorporated into VEPM 7.1 based on the methodology described in the EMEP/EEA guidebook (EEA 2024a).

$$E_{cold} = \beta \times e^{cold}$$ Equation 11

Where:

E_{cold} is the cold start penalty which is added to the hot emission factor if cold start is applied

β is the fraction of mileage driven under cold start conditions

e^{cold} is the cold emission factor

β is calculated according to Equation 12 as a function of trip length, with the assumption that heavy vehicles operate in cold conditions for 8.25km.

$$\beta = \frac{8.25}{L_{trip}}$$ Equation 12

Where:

L_{trip} is the trip length. The default value for heavy duty trip length in VEPM is 44km which is the same as the assumption in COPERT for Europe.

The cold emission factor is calculated according to equation Equation 13.

$$e^{cold} = A \times V \times B \times t_a + C$$ Equation 13

Where:

e^{cold} is the cold emission factor

A, V, B and C are constants which are provided in the EMEP/EEA spreadsheet (EEA 2024b)

t_a is the ambient temperature (**Note**: If $t_a > 0$°C then B=0. This means ambient temperature does not affect cold start emissions from heavy duty vehicles except below 0°C)

The EMEP/EEA guidebook methodology estimates cold start emissions based on measurement data from Euro V and Euro VI vehicles. The data were fitted into the existing COPERT methodology for passenger cars in a simplified approach.

The New Zealand fleet includes a significant proportion of vehicles older than Euro V and VI. Although there is no cold start measurement data available for pre- Euro V vehicles, we apply the EMEP/EEA guidebook methodology to all Euro I – Euro VI vehicles in VEPM. We assume that this is reasonable because the EMEP/EEA guidebook assumes that cold start emissions are the same for Euro 1 to Euro 5 light duty diesel vehicles on the basis that:

> *Excess cold-start emissions from diesel vehicles are not very significant compared with those from petrol vehicles. Therefore, no distinction is made between the different diesel vehicle types.*

5.3.5 Japanese vehicles

The method for estimating cold start emissions for Japanese vehicles in VEPM is the same as the method for European vehicles. Japanese vehicle emission standard equivalencies for cold emissions are assumed to be the same as hot emission factor equivalencies.

5.4 Degradation factors

Degradation factors are applied to hot emission factors in VEPM to account for performance deterioration due to vehicle age. The EMEP/EEA guidebook does not include degradation factors for all vehicle categories and pollutants, so VEPM uses factors from several published literature sources to estimate degradation effects.

The sources of degradation factors in VEPM 7.1 are summarised in Table 15 and are described in more detail in the following sections.

Table 15: Sources of emission degradation factors in VEPM 7.1

Vehicle type	Fuel	Region of origin	Emission standard/YOM	Source VEPM 7.1
Car and LCV	Petrol	Europe	Pre-Euro 1	FORS (1996)*
			Euro 1 to 6	EEA (2024)
		Japan	Up to YOM 1974	FORS (1996)*
			YOM 1975 to 2009	JCAP (2001)
			From 2010 onwards	EEA (2024)
	Diesel	All	Euro 1 to 6	EEA (2024) for CO, NOx and VOC. Ubanwa *et al* (2003) for PM.
		All	Pre Euro assumed to be the same as Euro 1	
Heavy duty	Diesel	All	All	USEPA (2022)

5.4.1 Cumulative VKT in VEPM

Degradation factors are calculated in VEPM based on cumulative VKT (which is commonly referred to as vehicle mileage).

Degradation is calculated in VEPM based on average cumulative VKT for each vehicle category. Cumulative VKT is calculated for the user selected assessment year, based on VKT data from the Ministry of Transport VFM model. As described in Section 4.2, VFM provides annual VKT for all vehicle categories by year of manufacture for each year from 2001 to 2050.

As illustrated in Figure 9, it is assumed that:

- degradation factors are 1 (i.e. no degradation) up to a specified cumulative VKT where degradation starts, then
- emissions increase linearly with cumulative VKT, and
- emissions reach a maximum at a specified stabilisation cumulative VKT

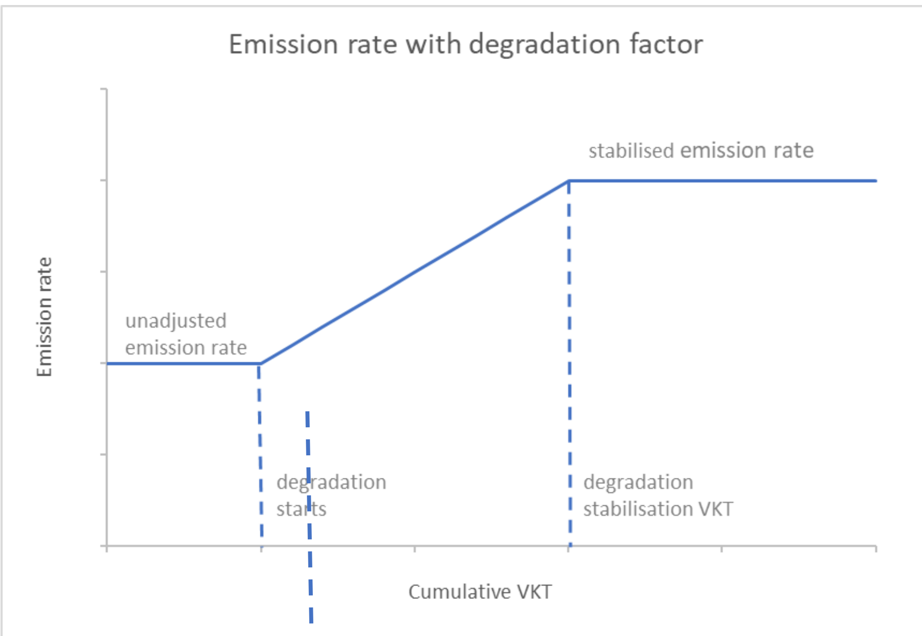

Figure 9: Illustration of degradation in VEPM

5.4.2 Light duty CO, NOx and VOC degradation factors

VEPM 7.1 uses degradation functions from the EMEP/EEA guidebook (EEA 2024) for light duty petrol and diesel vehicles from Euro 1 to Euro 6.

Degradation factors are calculated and applied based on the equations and factors provided in the guidebook[26]. The calculated stabilised degradation factors are shown in Table 16. Based on the assumptions specified in the EMEP/EEA guidebook, it is assumed that:

- Degradation starts at 50,000 km
- Degradation stabilises at 200,000 km

[26] Degradation ccorrection factors are calculated based on Equation 23 and coefficients provided in Tables 3-92 and 3-93 of the EMEP/EEA guidebook (EEA 2022)

Table 16: CO, NOx and VOC degradation factors assumed in VEPM 7.1 for specified vehicle categories. Source: calculated from equation 23 of the EMEP/EEA guidebook (EEA 2024).

Vehicle type	Emission standard	Stabilised degradation factor at 200,000 km		
		CO	NO_x	VOC
Petrol car and LCV	Euro 1	2.275	3.325	1.739
	Euro 2	1.750	3.025	1.739
	Euro 3	2.500	2.905	1.122
	Euro 4	1.750	1.750	1.122
	Euro 5	2.050	3.250	1.579
	Euro 6	1.192	1.312	1.579
Diesel car and LCV	Euro 1	1.000	1.000	2.068
	Euro 2	1.375	1.375	2.068
	Euro 3	1.225	1.225	2.068
	Euro 4	1.045	1.045	2.068
	Euro 5	1.045	1.045	2.068
	Euro 6	4.480	1.273	2.068

For pre-Euro petrol vehicles, stabilised degradation factors are based on an Australian study (FORS 1996). Stabilised degradation factors at 400,000 km are assumed to be 1.39 for VOC, 1.25 for CO, and 1.0 for NOx. These were derived from Figures 2-15 to 2-17 of FORS (1996).

5.4.3 Light duty PM degradation factors

There are no degradation factors for PM emissions from petrol vehicles in VEPM.

The stabilised degradation factor for diesel vehicle PM in VEPM is unchanged from the original VEPM technical report (EFRU 2008). Degradation is assumed to start at zero km and is assumed to be 2 at 80,000 km (i.e. it is assumed that PM emissions double from 0 to 80,000 km and then remain stable). This factor is from Ubanwa *et al* (2003), which is relatively old and is based on testing of American vehicles. Updated degradation factors are not readily available (Metcalfe *et al* 2021) so PM degradation factors have not been comprehensively updated. However, published remote sensing data from Europe suggests that particulate emissions from Euro 5 and Euro 6 diesel vehicles do not significantly increase with mileage (Davidson *et al* 2022). Therefore, we recommend that the PM degradation factor is set at 1 (i.e. no degradation) for light duty Euro 5 and Euro 6 diesel vehicles in the next VEPM update.

5.4.4 Light duty N_2O degradation factors

As discussed in Section 5.2.2, the effect of mileage is already accounted for in the calculation of light duty N_2O emission factors. No additional degradation factor is applied to N_2O.

5.4.5 Light duty CH_4 degradation factors

The degradation factor for CH_4 is assumed to be the same as the VOC degradation factor.

5.4.6 Heavy duty vehicle degradation

Degradation factors for heavy duty vehicles in previous versions of VEPM were based on USEPA factors which have been superseded. T his means that heavy duty degradation factors in VEPM need to be updated.

It is not ideal to apply degradation factors which have been developed for vehicles manufactured to US standards in VEPM. However, there is relatively little information available on emissions degradation from heavy vehicles, which means that options are limited. At the time of writing, the two options for updating heavy duty degradation factors in VEPM are to either, exclude degradation factors for heavy duty vehicles altogether (which would be consistent with COPERT) or update the USEPA factors (Boulter 2023).

To maintain consistency with previous versions of VEPM, our preferred approach is to update the USEPA degradation functions. Independent peer review has confirmed that this is appropriate for VEPM (Boulter 2023).

The applicability of MOVES 3 in the New Zealand context is briefly discussed in the following section.

Applicability of MOVES 3 Heavy vehicle degradation factors

The USEPA MOVES 3 model estimates a tampering and mal-maintenance (T&M) factor to represent fleet wide average increases in emissions as the fleet ages.

Emission factors in VEPM are based on European COPERT emission factors. These factors are based on tests on engines and vehicles with different mileages, so it could be assumed that degradation effects are included in COPERT emission factors.

However, in laboratory testing, properly maintained heavy duty engines often yield very small emission increases over time (USEPA 2022). The MOVES 3 model assumes that in the real world, emissions deterioration of heavy duty vehicles is dominated by the effects of tampering and mal-maintenance. Mal-maintenance includes issues such as emission control equipment malfunctions that are not repaired, and tampering includes issues such as deliberate removal of after treatment devices. USEPA has developed estimates of frequencies and emission impacts of specific emission control equipment malfunctions based on surveys and studies. These are then aggregated to estimate the overall T&M factor for each pollutant across the fleet. USEPA assumes that the T&M factors include any emission increases due to general vehicle ageing and deterioration.

Although the USEPA T&M factors were developed for vehicles manufactured to United States emission standards, vehicle emission control technology is broadly similar in all jurisdictions. It is reasonable to assume that the potential for tampering and mal maintenance is at least as significant in New Zealand compared with the United States because New Zealand has limited in service emissions requirements. Research to investigate the incidence of tampering in the New Zealand fleet has previously been recommended (Metcalfe *et al* 2021). Ideally, this further work would enable development of New Zealand specific factors or, at the very least, to confirm the applicability of these USEPA factors in New Zealand.

The MOVES 3 model assumes that there is no emission degradation due to tampering and mal maintenance until the end of the vehicle warranty period. Once the warranty period ends, the emission rate increases linearly until the vehicle reaches the end of its useful life. At the end of the useful life, emissions are assumed to remain constant. Default values for vehicle warranty periods and useful life are provided in MOVES 3.

T&M adjustment factors are provided for NOx (oxides of nitrogen), $PM_{2.5}$ (particulate), CO (carbon monoxide) and THC (total hydrocarbons).

Development of degradation factors for VEPM 7.1

We have used the default vehicle warranty period, useful life and T&M factors from USEPA MOVES 3 model (USEPA 2022) to develop degradation factors for VEPM 7.1. The assumptions made to assign USEPA factors to VEPM vehicle categories are described in this section.

MOVES 3 provides degradation rates for 5 heavy vehicle categories. The assumed equivalent vehicle segments in VEPM are shown in Table 17.

Table 17: Equivalent vehicle categories assumed to derive heavy duty degradation factors from MOVES 3

VEPM segment	MOVES 3 regulatory class	MOVES 3 gross vehicle weight range in pounds (lbs)	MOVES 3 approximate gross vehicle weight range in metric tonnes (t)
Rigid <=7.5 t	LHD2b3	8,500-14,000 lbs	3.9-6.4 t
Rigid 7.5 -10 t	MHD	19,500-33,000 lbs	8.8-15 t
All rigid and articulated HCV >10t	HHD	>33,000 lbs	>15 t
All bus and coach categories	Urban bus	-	-

Degradation rates from MOVES 3 are assigned to the closest equivalent European vehicle category, as shown in Table 18.

Up to USEPA model year group 2003-2006, these are the same as equivalencies assumed in previous versions of VEPM. It is assumed that USEPA model year group 2007-2009 is equivalent to Euro V based on comparison of emission requirements in the New Zealand vehicle exhaust emissions land transport rule[27]. For year of manufacture 2013 onwards, it is assumed that US vehicles are equivalent to Euro VI[28].

Table 18: USEPA and Euro equivalencies assumed to derive heavy duty degradation factors from MOVES 3

MOVES 3 'model year group'	Assumed Euro equivalence
Pre-1998	Euro II
1998-2002	Euro III
2003-2006	Euro IV
2007-2009	Euro V
2010-2012	not assigned
2013+	Euro VI

Heavy duty degradation factors assumed in VEPM 7.1

In accordance with the MOVES 3 methodology, the relevant MOVES 3 adjustment factor is applied in VEPM assuming that:

- Degradation starts at the MOVES 3 warranty mileage for the equivalent vehicle category
- Degradation stabilises at the MOVES 3 useful mileage for the equivalent vehicle category

Table 19 shows the warranty mileage, and useful mileage from MOVES 3 that are assumed for each vehicle category along with the equivalent VKT that is assumed in VEPM. Table 20 shows the stabilised degradation factors that are assumed in VEPM.

Table 19: Cumulative VKT assumed for degradation start and stabilisation in VEPM 7.1. Source: MOVES 3 Table B-1 (USEPA 2022)

VEPM category	MOVES 3		VEPM cumulative VKT	
	Warranty mileage	Useful mileage	Degradation starts VKT	Degradation stabilisation VKT
<=7.5 t	50,000	110,000	80,467	177,027
7.5-10 t	100,000	185,000	160,934	297,728
>10 t	100,000	435,000	160,934	700,063
Buses	100,000	435,000	160,934	700,063

[27] Vehicle Exhaust Emissions 2007 (as at 1 April 2021) (nzta.govt.nz)
[28] Transportpolicy.net states that US 2010 standards were fully phased-in by 2014, and that the fully phased-in standards are roughly equivalent in terms of stringency and emission control technology to Euro VI US: Heavy-duty: Emissions | Transport Policy

Table 20: Stabilised degradation factors assumed in VEPM 7.1 for $PM_{2.5}$, NOx, THC and CO. Source: MOVES 3 Table 2-9, Table 2-19, Table 2-22 (values converted from percentage increase to a multiplication factor). (USEPA 2022).

Emission standard	Exhaust PM	NOx	VOC and CO
	Stabilised degradation factor		
Euro II	1.85	1.00	4.0
Euro III	1.74	1.00	4.0
Euro IV	1.48	1.00	2.5
Euro V	2.00	1.00 (1.04 for <7.5 t rigid)	2.5
Euro VI	1.67	1.58 (1.56 for <7.5 t rigid)	1.22

The MOVES 3 T&M factors are the best available information to represent emission degradation for heavy duty vehicles at the time of writing. However, it is recommended that heavy duty degradation factors in VEPM should be reviewed if suitable European factors become available.

Further work to investigate whether the assumed rates of "mal maintenance" and tampering are applicable in New Zealand is recommended. Depending on the outcome of this work, New Zealand specific factors could be developed.

5.4.7 Heavy duty degradation factors for CH_4

Degradation factors for CH_4 are assumed to be the same as the VOC degradation factor.

5.4.8 Japanese vehicles

For light duty petrol vehicles manufactured up to 2010 VEPM uses Japanese degradation factors for CO, VOC and NOx (JCAP 2001) as described in the VEPM development report (EFRU 2008).

For all other vehicle categories, the degradation factors are the same as degradation factors for European vehicles. The Japanese vehicle emission standard equivalencies for degradation are assumed to be the same as hot emission factor equivalencies.

5.4.9 Energy consumption degradation factors

A degradation factor of 1 is assumed for energy consumption for all vehicle categories (i.e. no degradation).

5.5 Gradient and load

5.5.1 Light duty vehicle gradient correction factors for CO, NOx and PM

Light duty vehicle gradient correction factors in VEPM are derived from PIARC guidance because correction factors are not included in the EMEP/EEA spreadsheet (EEA 2024a). Gradient adjustment factors are based on factors from PIARC guidance (PIARC 2019).

Gradient factors for petrol cars, diesel cars, petrol LCVs and diesel LCVs are derived from PIARC emission factors (PIARC 2019[29]) for three pollutants: CO, NO_X and PM. There is a PIARC emission factor for each European emissions standard, for 0, ±2, ±4 and ±6% gradient, based on speed but with no distinction for engine size. PIARC tabulates the factors by speed, with the emissions factors expressed in grams per hour. There is a separate table for each combination of vehicle type, fuel type and pollutant. For example, Table 21 shows CO emission factors for Euro 3 petrol cars.

Table 21: PIARC CO emission factors for Euro 3 petrol cars in g/km, for speeds from 0 to 130 km/h (PIARC 2019)

Gradient	Speed (km/h)													
	0	10	20	30	40	50	60	70	80	90	100	110	120	130
-6%	1	5	9	4	4	4	4	7	4	6	10	15	24	42
-4%	1	5	13	7	7	7	6	11	6	9	16	29	52	91
-2%	1	7	19	9	10	10	9	14	12	17	33	57	89	148
0%	1	9	25	13	17	15	21	25	32	44	61	104	157	300
2%	1	12	47	22	30	24	36	46	63	100	133	234	416	885
4%	1	15	68	35	48	38	55	97	130	211	281	620	1,317	2,399
6%	1	18	103	51	79	65	90	161	271	466	730	1,599	2,742	3,431

Emission ratios from these tables were used to develop gradient adjustment factors. The emission ratio for a particular gradient and speed is the ratio of the emission factor for that gradient and speed divided by the corresponding 0% gradient emission factor at the same speed.

For example, Table 22 shows the CO emission ratios for Euro 3 petrol cars.

[29] At section 11.1.2 pages 38 to 56 of PIARC 2019

Table 22: CO emission ratios relative to 0% gradient for Euro 3 petrol cars, from 0 to 130 km/h

Gradient	Speed (km/h)													
	0	10	20	30	40	50	60	70	80	90	100	110	120	130
-6%	1.00	0.50	0.34	0.33	0.25	0.26	0.19	0.26	0.13	0.14	0.16	0.14	0.15	0.14
-4%	1.00	0.58	0.50	0.50	0.39	0.46	0.29	0.43	0.19	0.21	0.26	0.28	0.33	0.30
-2%	1.00	0.74	0.73	0.69	0.60	0.69	0.41	0.57	0.36	0.38	0.54	0.55	0.57	0.49
0%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2%	1.00	1.24	1.84	1.71	1.78	1.59	1.70	1.84	1.95	2.30	2.19	2.26	2.65	2.95
4%	1.00	1.59	2.68	2.69	2.84	2.53	2.60	3.86	4.01	4.86	4.62	5.98	8.40	7.99
6%	1.00	1.97	4.06	3.89	4.68	4.33	4.30	6.42	8.38	10.71	12.02	15.43	17.48	11.42

These emission ratios, for each of the non-zero gradients, were then plotted and fitted with 4th degree polynomials to enable interpolation between the discrete speeds. For example, Figure 10 shows the fitted polynomial curve for CO emissions from Euro 3 petrol cars.

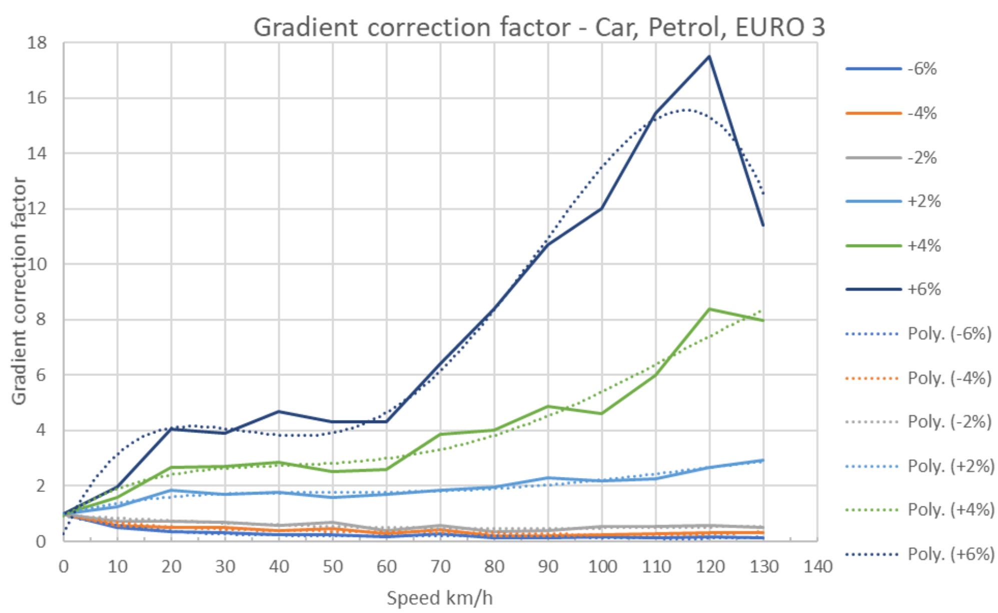

Figure 10: Fitted polynomial curves to derive gradient correction factors for CO from Euro 3 petrol cars

These equations are used in VEPM to calculate gradient correction factors based on actual speed and gradient. The gradient correction factors are applied as a multiplier to scale hot emission factors.

5.5.2 N_2O and CH_4 gradient correction factors

The gradient correction factor for N_2O is assumed to be 1 (i.e. no correction is applied)

The following assumptions are applied for CH_4:

- No gradient correction factor is applied to light duty emission factors (this is consistent with the assumption for VOC).
- For heavy duty vehicles, a gradient correction factor is derived from the hot emission factor for VOC at the corresponding gradient divided by the hot emission factor for VOC at zero percent gradient for each vehicle category.

5.5.3 Heavy duty gradient and load

Heavy duty vehicle hot emission factors and energy consumption factors are corrected for gradient and load in the EMEP/EEA spreadsheet (EEA 2024a). These factors are adopted in VEPM 7.1.

5.5.4 Japanese vehicles

Japanese vehicle emission standard equivalencies for gradient adjustment factors are assumed to be the same as hot emission factor equivalencies.

5.6 Fuel properties

The properties of fuels assumed in VEPM are shown in Table 23 and Table 24. These fuel properties are used in the calculation of fuel correction factors as well as fuel consumption and CO_2 emission factors.

The fuel type in VEPM is automatically selected for the assessment year based on the type of fuel that was available in New Zealand at the time. Fuel density and net calorific values are based on actual fuel properties reported by MBIE[30]. Average density and calorific values are calculated for each fuel type over the applicable date range for that fuel type. All other fuel properties are based on the fuel specifications in the regulations at the time.

Table 23: Properties of petrol fuel in VEPM, based on fuel specifications

Type	Date range	Sulphur (ppm)	Density (kg/m^3)	Aromatics (% by vol)	Oxygenates (% by wt)	Olefins (% by vol)	E100 (%)	E150 (%)	Net CV (MJ/kg)
0	Base fuel	165	-	39	0.4	10	52	86	-
1	Pre-Sep 2002	500	740	48	0.1	8.2	56	89	44.0
2	Sep 2002-Dec 2003	350	743	42	1	8.2	57.5	89	43.9
3	Jan 2004-Dec 2005	350	743	42	1	25	57.5	75	43.9
4	Jan 2006-Dec 2007	150	742	42	1	18	57.5	75	43.9
5	Jan 2008-Dec 2011	50	745	42	1	18	57.5	75	43.9
6	Jan 2012-Jun 2018	50	746	42	2.7	18	57.5	75	43.9
7	Jul 2018 onwards	10	747	42	2.7	18	57.5	75	43.9

[30] Ministry of Business Innovation and Employment (MBIE) data tables for oil: downloaded on 13 April 2023 from www.mbie.govt.nz

Table 24: Properties of diesel fuel in VEPM, based on fuel specifications

Type	Date range	Sulphur (ppm)	Density (kg/m^3)	PAHs (% by wt)	Cetane Number	T95 (°C)	Net CV (MJ/kg)
10	Base fuel	400	840	9	51	350	-
11	Pre-Sep 2002	3,000	840	11	45	370	42.8
12	Sep 2002-Dec 2003	1,561	841	11	47	370	42.8
13	Jan 2004-Dec 2005	500	835	11	49	370	42.8
14	Jan 2006-Dec 2008	50	836	11	51	360	42.9
15	Jan 2009 onwards	10	841	11	51	360	42.9

The base fuel properties shown in Table 23 and Table 24 are default values from the EMEP/EEA guidebook. These base fuel properties are used to calculate fuel correction factors which account for differences in fuel specifications for fuel available in New Zealand versus base fuels used in the emissions testing.

5.7 Fuel correction factors

Emission factors in VEPM are based on measurements from in-service vehicles operating with typical production fuels. Studies have shown that changes in fuel properties result in changes in emissions from vehicles, regardless of their technology and make.

Fuel effects are modelled in VEPM to account for:

- Differences in fuel specifications for fuel available in New Zealand versus base or reference fuels used in the emissions testing
- Introduction of new and improved specification fuels.

VEPM uses algorithms from the EMEP/EEA Guidebook (EEA 2024) to compensate for fuel effects except that the algorithms for PM for pre-2004 diesel are adjusted to account for the high sulphur content of New Zealand diesel.

The base emissions factor (E_{base}) is adjusted by the ratio of the fuel correction factor of the actual fuel ($FCorr_{actual}$) to the fuel correction factor of the base fuel ($FCorr_{base}$) as shown below:

$$E_{hot} = E_{base} \times \left(\frac{FCorr_{actual}}{FCorr_{base}}\right) = E_{base} \times FCorr$$ Equation 14

Where:

E_{hot} is the base emissions factors after fuel correction

E_{base} is the base emission factor (essentially E_{hot} without fuel corrections applied)

$FCorr_{actual}$ is the fuel correction of the actual fuel

$FCorr_{base}$ is the fuel correction of the base fuel

FCorr is the fuel correction factor

5.7.1 Fuel correction algorithms

Table 25, Table 26 and Table 27 outline the fuel correction factors applied to different passenger cars, light commercial vehicles and heavy duty diesel vehicles used in VEPM 7.1. These are the same as EMEP/EEA (EEA 2024) algorithms except for the PM correction factors for pre-2004 diesel.

Fuel correction algorithms for pre 2004 diesel

The sulphur content of New Zealand diesel was significantly higher than the European base fuel up to 2004.

The PM fuel correction algorithms were adjusted to take this into account by applying a scaling factor. For light duty vehicles the scaling factor was based on an UK data that a 2.4% reduction in PM was achieved by switching from 2,000ppm to 500ppm sulphur diesel (EFRU 2008). For heavy duty vehicles, the scaling factor was based on UK data that a 13% reduction in PM was achieved by switching from 2,000ppm to 500ppm sulphur fuel.

The adjusted algorithms are shown in Table 25, Table 26 and Table 27.

VEPM utilises the fuel properties shown in Table 23 and Table 24 to calculate the fuel correction factors.

Table 25: Fuel correction factors for petrol passenger cars and light duty commercial vehicles

Pollutant	Correction factor equation
CO	FCorr = [2.459 – 0.05513 x (E100) + 0.0005343 x $(E100)^2$ + 0.009226 x (ARO)-0.0003101 x (97-S)] x [1-0.037 x (OXY – 1.75)] x [1-0.008 x (E150 – 90.2)]
VOC	FCorr = [0.1347 + 0.0005489 x (ARO) + 25.7 x (ARO) x $e^{(-0.2642\ (E100))}$ – 0.0000406 x (97-S)] x [1-0.004 x (OLE – 4.97)] x [1-0.022 x (OXY – 1.75)] x [1-0.01 x (E150 – 90.2)]
NO_X	FCorr = [0.1884 – 0.001438 x (ARO) + 0.00001959 x (ARO) x (E100) – 0.00005302 x (97 – S)] x [1+0.004 x (OLE – 4.97)] x [1+0.001 x (OXY – 1.75)] x [1+0.008 x (E150 – 90.2)]
PM CO_2 EC	FCorr = 1

Note: ARO = aromatic content in %, E100 = mid range volatility in %, E150 = tail end volatility in %, OLE = olefin content in %, OXY = oxygenates in %, S = sulphur content in ppm

Table 26: Fuel correction factors for diesel passenger cars and light duty commercial vehicles

Pollutant	Correction factor equation
CO	FCorr=-1.3250726 + 0.003037 x DEN – 0.0025643 x PAH – 0.015856 x CN + 0.0001706 x T95
VOC	FCorr =-0.293192 + 0.0006759 x DEN – 0.0007306 x PAH – 0.0032733 x CN – 0.000038 x T95
NO_X	FCorr = 1.0039726 – 0.0003113 x DEN + 0.0027263 x PAH – 0.0000883 x CN – 0.0005805 x T95
PM	Pre 2004 diesel (fuel types 11 and 12): FCorr = (-0.3879873 + 0.0004677 x DEN + 0.0004488 x PAH + 0.0004098 x CN + 0.0000788 x T95) x [1 – 0.015 x (450 – 500)/100]/[1-2.4% x (S-500)/(2000-500)] Fuel types 13, 14 and 15: FCorr = (-0.3879873 + 0.0004677 x DEN + 0.0004488 x PAH + 0.0004098 x CN + 0.0000788 x T95) x [1 – 0.015 x (450 – S)/100]
CO_2 EC	FCorr = 1

Note: CN = cetane number, DEN = density at 15°C in kg/m^3, PAH = polycyclic aromatic hydrocarbon content in %, S = sulphur content in ppm, T95 = back-end distillation in °C

Table 27: Fuel correction factors for diesel heavy duty commercial vehicles

Pollutant	Correction factor equation
CO	FCorr = 2.24407 – 0.0011 x DEN + 0.00007 x PAH – 0.00768 x CN – 0.00087 x T95
VOC	FCorr = 1.61466 – 0.00123 x DEN + 0.00133 x PAH – 0.00181 x CN – 0.00068 x T95
NO_X	FCorr = -1.75444 + 0.00906 x DEN – 0.0163 x PAH + 0.00493 x CN + 0.00266 x T95
PM	Pre 2004 diesel (fuel types 11 and 12): FCorr = [0.06959 + 0.00006 x DEN + 0.00065 x PAH – 0.00001 x CN] x [1-0.0086 x (450 – 500)/100]/[1-13% x (S-500)/(2000-500)] Fuel types 13, 14 and 15: FCorr = [0.06959 + 0.00006 x DEN + 0.00065 x PAH – 0.00001 x CN] x [1-0.0086 x (450 – S)/100]
CO_2 EC	FCorr = 1

Note: CN = cetane number, DEN = density at 15°C in kg/m^3, PAH = polycyclic aromatic hydrocarbon content in %, S = sulphur content in ppm, T95 = back-end distillation in °C

The base fuels and the available improved fuel qualities assumed in VEPM 7.1 for each vehicle emission standard are shown in Table 28 (for petrol) and Table 29 (for diesel). The fuel correction factors are calculated relative to the applicable base fuel for the vehicle technology.

Fuel correction factors are applied to hot emission factors and the cold emission penalty in VEPM (in accordance with the EMEP/EEA methodology (EEA 2024).

Table 28: Base fuels used to correct petrol fuel quality for each vehicle technology category 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 29: Base fuels used to correct diesel fuel quality for each vehicle technology category in VEPM

Vehicle Technology	Base Fuel	Available Improved Fuel Qualities
Pre-Euro 3	Base (diesel type 10)	Diesel types 11-15
Euro 3	Jan 2004 (diesel type 13)	Diesel types 14-15
Euro 4	Jan 2006 (diesel type 14)	Diesel type 15
Euro 5 and later	Jan 2009 (diesel type 15)	-

Smit *et al* (2022) note that actual fuel properties can differ appreciably from the fuel specifications and thereby influence the correction factors. A preliminary assessment of the potential impact of using actual fuel properties found that using actual fuel properties would slightly reduce hot emissions factors for CO, HC and PM and would slightly increase NOx (Metcalfe *et al* 2021). Changing fuel corrections from being based on specifications to actual fuel properties warrants further investigation.

5.8 Fuel consumption and greenhouse gas emission factors

5.8.1 Fuel consumption

Fuel consumption is calculated in VEPM from total energy consumption factors based on the fuel properties shown in Table X and Table X.

Fuel consumption is calculated as follows:

$$FC = (EC \times 100) \times \frac{1}{CV} \times \frac{1000}{\rho} \qquad \text{Equation 15}$$

Where:

FC = fuel consumption (l/100km)

EC = energy consumption (MJ/km)

CV = net calorific value (Mj/kg)

ρ = density kg/m^3

5.8.2 Exhaust CO_2 and CO_2-e emission factors

CO_2 emissions are calculated from estimated total energy consumption factors.

Energy consumption factors are calculated in VEPM based on the net calorific value of fuel. This means that it is necessary to convert New Zealand CO_2 emission factors, which are based on gross calorific values.

We use the assumption adopted in the New Zealand Greenhouse Gas inventory:

$$\text{Net calorific value} = 0.95 \times \text{gross calorific value} \qquad \text{Equation 16}$$

Emission factors are reported as tonnes CO_2 per TJ of energy, so gross emission factors are converted to net emission factors based on equation 17:

$$\text{Net emission factor} = \text{gross emission factor} \div 0.95 \qquad \text{Equation 17}$$

Gross CO_2 emission factors for regular petrol and diesel are from the 1990-2020 New Zealand greenhouse gas inventory (MfE 2019)[31] as follows:

- Petrol[32] 66.80 tCO_2/TJ
- Diesel 69.45 tCO_2/TJ

Note: tCO_2/TJ is equivalent to gCO_2/MJ.

Equation 17 is used to convert these gross emission factors to net CO_2 emission factors for VEPM as follows:

- **Petrol 70.3 gCO_2/MJ** (net emission factor used in VEPM)
- **Diesel 73.1 gCO_2/MJ** (net emission factor used in VEPM)

CO_2 emission factors are calculated directly from total energy consumption factors as follows:

$$CO_2 = [EC \times EF] \qquad \text{Equation 18}$$

Where:

CO_2 = emission factor (g/km)

EC = energy consumption estimated by VEPM (MJ/km)

[31] Updated gross CO_2 emission factors are now available in the latest greenhouse gas inventory (1990-2022). These will be implemented in the next release of VEPM. **Note:** Gross CO_2 emission factors typically vary by less than 10% year on year, if at all.
[32] This is the weighted average gross emission factor for regular and premium petrol calculated based on MBIE consumption figures for 2020.

EF = net emission factor (g CO_2/MJ)

CO_2-equivalent (CO_2-e) emission factors are calculated in VEPM as follows:

$$CO_{2-e} = CO_2 + (298 \times N_2O) + (25 \times CH_4) \quad \text{Equation 19}$$

Equation 19 uses the global warming potentials (GWPs) are from the measuring emission guidance produced by the Ministry for the Environment (MfE 2020). These are based on the IPCC Fourth Assessment Report (AR4) [33].

5.8.3 CO_2 from lubrication and additives

The EMEP/EEA guidebook (EEA 2024) provides a methodology for estimating CO_2 emissions from lubricant oil and exhaust additives (urea solutions such as AdBlue). These are not included VEPM 7.1.

Investigation of data requirements, data availability and potential significance of these emissions is recommended.

5.9 New Zealand real world fuel consumption adjustment factors

5.9.1 Light duty real world fuel consumption adjustment factors

New Zealand real world fuel consumption correction factors are applied to light duty diesel vehicles in VEPM 7.1 as shown in Table 30.

The adjustment factors are applied in VEPM 7.1 to adjust fuel consumption predictions (and consequently CO_2 emission predictions) for diesel cars and LCVs for all years of manufacture.

Table 30: New Zealand real world fuel consumption adjustment factors applied in VEPM 7.1

Vehicle type	Engine size category in VEPM	Real world fuel consumption adjustment factor
Diesel car	<2000cc	**1.26**
	≥2000cc	**1.11**
Diesel LCV	N/A	**1.06**

The fuel consumption adjustment factors were estimated based on MoT real world fuel consumption factors. MoT has developed factors for diesel and petrol vehicles in New Zealand using fuel consumption and travel data from a large data set of fuel card transactions (Wang *et al* 2015). Previous work found that

[33] The Ministry for the Environment has now moved to reporting CO_2e calculated using the GWPs from the IPCC Fifth Assessment Report (AR5). These will be implemented in the next release of VEPM. **Note:** For motor vehicle exhaust GHG emissions, the impact of basing the GWP calculations on AR5 rather than AR4 is minor as the bulk of the GHG emissions are from CO_2.

there was good agreement between VEPM and these real-world fuel consumption for light duty petrol vehicles. However, light duty diesel fuel consumption was found to be underestimated by VEPM (Kuschel *et al* 2019). New Zealand real world adjustment factors were developed so that light duty diesel fuel consumption estimates from VEPM are more realistic. The factors shown in in Table 30 have been updated based on outputs from VEPM 7.1 to account for changes in fuel properties. The methodology and assumptions for derivation of the factors are otherwise unchanged from Metcalfe *et al* (2020).

Real world fuel consumption factors by year of manufacture for petrol and diesel light duty vehicles have been proposed (Metcalfe *et al* 2021), however these have not yet been implemented in VEPM. Further work is recommended to update, validate and implement real world fuel consumption factors.

5.9.2 Heavy duty real-world fuel consumption

Real world fuel consumption of heavy duty vehicles was investigated for the VEPM 6.1 update (Metcalfe *et al* 2020) and resulted in the incorporation of EMEP/EEA emission factors for articulated trucks. The VEPM 6.2 update improved the split between rigid and articulated trucks (Metcalfe *et al* 2021). Further work is recommended to compare estimated fuel consumption for heavy duty vehicles in VEPM with real world fuel consumption estimates and to develop and implement real world fuel consumption factors, if appropriate.

5.10 NO_2 emission factors

The EMEP/EEA Air pollutant emission inventory guidebook includes factors for the proportion of NO_2 in NOx (f-NO_2) according to vehicle type, fuel used and the Euro emission standard.

Table 31,

Table 32, and Table 33 show the factors that are assumed in VEPM 7.1, which are from the EMEP guidebook (EEA,2024).

Table 31: Fraction of NO_2 emissions by petrol cars and LCVs assumed in VEPM 7.1

Emission standard	**f-NO_2**
Pre-Euro	0.04
Euro 1	0.04
Euro 2	0.04
Euro 3	0.03
Euro 4	0.03
Euro 5	0.03
Euro 6	0.02

Table 32: Fraction of NO_2 emissions by diesel cars and LCVs assumed in VEPM 7.1

Emission standard	**f-NO_2**
Pre-Euro	0.11
Euro 1	0.11
Euro 2	0.11
Euro 3	0.25
Euro 4	0.55
Euro 5	0.40
Euro 6 a/b/c	0.30
Euro 6d	0.20

Table 33: Fraction of NO_2 emissions by diesel heavy vehicles assumed in VEPM 7.1

Emission standard	**f-NO_2**
Pre-Euro	0.11
Euro I	0.11
Euro II	0.11
Euro III	0.14
Euro IV	0.14
Euro V	0.10
Euro VI	0.10

5.11 Brake and tyre wear emission factors

Brake and tyre wear emission factors in VEPM 7.1 are calculated in accordance with the Tier 2 methodology described in the latest version of the EMEP/EEA guidebook (EEA 2024b). The guidebook was updated in 2024 to include different brake and tyre wear factors for hybrid, plug in hybrid, electric vehicles and conventional passenger cars.

The emission factor calculation takes speed into account. For heavy duty vehicles, the load and vehicle size (based on the number of axles) are also taken into account.

The default number of axles for heavy duty vehicles in VEPM 7.1 is shown in Table 34. These were derived from information provided by NZTA on the requirements of the Vehicle Dimensions and Mass Rule (as reported in Metcalfe & Sridhar 2019).

Table 34: Default number of axles assumed in VEPM 7.1 for calculation of tyre wear emission factors

Vehicle type	Vehicle category	Default number of axles
Light vehicles		2 axles
Rigid HCV Diesel	3.5 – 7 t	2 axles
	7.5 – 10 t	2 axles
	10 – 20t	3 axles
	20 – 25t	4 axles
	25 – 30t	5 axles
	>30t	6 axles
Articulated HCV Diesel	14 – 20 t	5 axles
	20 – 28 t	6 axles
	28 – 34t	6 axles
	34 – 40t	7 axles
	40 – 50t	8 axles
	>50t	9 axles
Electric HCV	<10t	2 axles
	>10t	3 axles
Bus Diesel	<12t	2 axles
	>12t	3 axles
Bus Electric		3 axles

5.12 New Zealand manufactured vehicle emission factors

New Zealand vehicles were not built to meet any emission standard until an emissions rule was implemented in 2005. Emission factors for New Zealand manufactured light duty vehicles were derived based on testing of New Zealand vehicles undertaken for Ministry of Transport in 2005. The VEPM development report shows that petrol cars manufactured in New Zealand were broadly equivalent to vehicles manufactured to pre-Euro (ECE 15/02) and Euro 1 standards. The proportion of New Zealand manufactured vehicles manufactured to these standards was estimated as shown in Table 35.

In VEPM 7.1 emission factors for New Zealand manufactured vehicles are calculated from total emission factors for ECE 15/02 and Euro 1 emission factors, based on the proportions shown in Table 35.

Table 35: New Zealand manufactured passenger car equivalent emissions standards assumed in VEPM 7.1 based on year of manufacture

Year of manufacture	% of ECE 15/02 cars in the fleet	% of Euro 1 cars in the fleet
<=1987	100%	0%
1988-1992	80%	20%
1993-1997	40%	60%
1998-2002	10%	90%
>=2003	0%	100%

6. Summary of changes compared to VEPM 7.0

This section summarises the changes in VEPM compared with the previous version (VEPM 7.0).

6.1 Fleet update

As described in Section 4.2.1, the default fleet profile has been updated in VEPM 7.1 based on outputs from the Ministry of Transport VFM.

Historical fleet data up to 2019 has not changed, however projections are somewhat different in VEPM 7.1 compared to VEPM 7.0 as shown in Table 36 and Table 37. The key difference is a lower proportion of petrol cars, and a higher proportion of hybrid cars in the VEPM 7.1 future fleet compared to VEPM 7.0.

Table 36: Default fleet (% VKT by vehicle category totals) in VEPM 7.1

	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 hybrid	LCV electric	Diesel HCV	Diesel buses	Electric HCV	Electric buses
2020	61.7%	7.8%	2.2%	0.2%	0.4%	2.9%	17.6%	0.0%	0.0%	0.0%	6.60%	0.6%	0.0%	0.0%
2025	50.5%	7.2%	10.0%	1.1%	2.2%	2.6%	18.9%	0.1%	0.0%	0.1%	6.70%	0.5%	0.0%	0.1%
2030	37.4%	6.4%	19.3%	2.9%	5.4%	2.2%	17.4%	0.2%	0.6%	1.0%	6.60%	0.5%	0.0%	0.2%
2035	25.7%	5.0%	24.4%	4.8%	11.9%	1.9%	14.8%	0.3%	1.3%	2.7%	6.40%	0.4%	0.2%	0.2%
2040	15.9%	3.5%	22.0%	5.4%	25.9%	1.5%	11.0%	0.3%	1.5%	6.1%	5.90%	0.3%	0.5%	0.3%
2045	8.9%	2.2%	14.8%	4.5%	42.6%	1.1%	7.6%	0.3%	1.3%	9.8%	5.40%	0.3%	0.8%	0.3%
2050	5.1%	1.4%	8.8%	3.5%	54.5%	0.8%	5.1%	0.3%	1.1%	12.8%	4.80%	0.3%	1.2%	0.4%

Table 37: Default fleet (% VKT by vehicle category totals) in VEPM 7.0

	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 hybrid	LCV electric	Diesel HCV	Diesel buses	Electric HCV	Electric buses
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%

6.2 Implementation of Euro 6 and Euro VI

Dates for implementation of Euro 6 and Euro VI emission standards (for new vehicles manufactured to European standards) have been updated in VEPM 7.1 to reflect confirmed implementation dates for New Zealand. As described in Section 4.5.1 it is assumed that Euro 6d standards will be implemented in 2028 and Euro VI-C standards will be implemented in 2025.

In VEPM 7.0 it was assumed that Euro 6 and Euro VI emission standards would be implemented in 2030.

6.3 Emission factor updates

6.3.1 Hybrid and plug-in hybrid

VEPM 7.1 includes emission factors for all petrol hybrid and petrol plug-in hybrid categories that are available in the EMEP/EEA guidebook, as described in Section 5.2.4. Plug in hybrid emissions are calculated based on plug in hybrid emission factors available in the EMEP/EEA guidebook with an assumed utility factor of 40% for passenger cars and 20% for light commercial vehicles as described in Section 5.2.4.

In VEPM 7.0 all petrol hybrid vehicles were assigned the EMEP/EEA hot emission factor for Euro 4 medium petrol hybrid (GDI) vehicles (EEA 2021). For plug-in hybrid vehicles, it was assumed that all tail pipe emission factors were 48% of hybrid vehicle emission factors in VEPM 6.3.

6.3.2 Articulated truck Japanese equivalency

In VEPM 7.1, European emission standards are assigned to Japanese articulated trucks based on the rigid truck equivalencies for each pollutant as described in Section 5.2.5.

In VEPM 7.0, a simplified approach was taken for assigning emissions standards to Japanese used articulated trucks. For these vehicles, the emission standard was assigned based on the emission standard assumed in VEPM for HCVs for CO based on year of manufacture for Japanese used vehicles[34].

6.3.3 PM emission factors for Euro 5/6 and Euro V/VI

PM exhaust emission factors for Euro 5/6 petrol vehicles and Euro V/VI heavy duty vehicles have been updated in this version of VEPM. The methodology is described in Section 5.3.2.

In VEPM 7.0 PM exhaust emission factors for Euro 5/6 petrol vehicles and Euro V/VI heavy duty vehicles were based on a previous version of the EMEP spreadsheet (EEA 2020)

6.3.4 Calculation of cold emissions contribution

The following updates and corrections have been applied to the calculation of cold start in VEPM 7.1 compared to VEPM 7.0:

- The updated EMEP/EEA guidebook (EEA 2024) includes a methodology for calculating cold start over emissions from Euro V and Euro VI heavy duty vehicles. This methodology has been implemented in VEPM 7.1 as described in Section 5.3.4. Cold start over emissions for heavy duty vehicles were not estimated in previous versions of VEPM.
- The updated EMEP/EEA guidebook (EEA 2024) includes an updated methodology for calculating cold start emissions from Euro 6 petrol and diesel passenger cars. These updates have been implemented in VEPM 7.1
- The guidebook specifies lower bounds for the ρ ratio which were not implemented in previous versions of VEPM. Lower bounds have been specified in VEPM 7.1 in accordance with the guidebook as follows:
    - for light duty petrol vehicles from Euro 1 to Euro 6 and Euro 6 light duty diesel vehicles:
        - if the calculated ρ ratio is less than 1, a value of 1 is used
    - for Pre-Euro 6 light duty diesel vehicles:
        - ρ ratio = 0.5 for VOC if temperature exceeds 29°C and
        - ρ ratio = 0.5 for PM if temperature exceeds 26°C.
- In VEPM 7.1, the cold start penalty for Euro 2 to Euro 5 vehicles is calculated based on Euro 1 hot emission factors as described in the EMEP/EEA guidebook (EEA 2024). In previous versions of VEPM, the cold start penalty for Euro 2 to Euro 5 petrol vehicles was incorrectly calculated based on the category hot emission factor (i.e. the cold start penalty for Euro 2 vehicles was calculated based on the Euro 2 hot emissions factors)

[34] 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).

- Cold start emission equations are valid up to a mean trip speed of 45 km/h. VEPM is sometimes used for short trip segments which may include segments over and under 45 km/h. To ensure that equations are valid:
    - when speed is above 45 km/h, cold start over emissions are calculated in VEPM 7.1 based on a speed of 45 km/h and
    - it is recommended that cold start emissions are only applied in urban areas where overall average speeds tend to be less than 45 km/h.

In previous versions of VEPM cold start emissions were calculated based on the specified average speed (which could be above 45 km/h).

6.3.5 Calculation of cumulative VKT.

Calculation of mileage in VEPM is described in Section 5.4.1. The methodology been updated in VEPM 7.1.

In previous versions of VEPM, average cumulative mileage for vehicles by year of manufacture and by vehicle type was calculated based on VKT estimates from VFM for 2009 and cumulative VKT for buses was assumed to be the same as HCVs.

6.3.6 Degradation factors

In VEPM 7.1, degradation factors have been updated for light duty vehicles based on EEA (2024) and for heavy duty based on USEPA (2022) as described in Section 5.4. Separate degradation factors for buses have been implemented based on USEPA (2022).

6.3.7 Fuel properties, fuel consumption and greenhouse gas emissions

Energy consumption factors are calculated in VEPM based on the net calorific value of fuel.

In previous versions of VEPM, the gross calorific value was incorrectly used to calculate fuel consumption from estimated energy consumption. The calorific value of fuel has been updated based on net calorific values reported by MBIE as described in Section 5.6.

Values for density have also been updated in this version of VEPM to reflect actual fuel properties reported by MBIE as described in Section 5.6.

In previous versions of VEPM, unadjusted MfE emission factors for CO_2 from petrol and diesel were used to calculated CO_2 emissions. These factors are based on the gross calorific value of fuels. The emission factors have been adjusted in this version of VEPM as described in Section 5.8.2.

6.3.8 New Zealand real world fuel consumption factors

Light duty real world fuel consumption adjustment factors have been updated in VEPM 7.1 to account for changes in fuel properties as described in Section 5.9.1.

6.3.9 NO_2 emission factors

As described in Section 5.10, the fraction of NO_2 in NOx (f-NO_2) is specified in the EMEP/EEA Air pollutant emission inventory guidebook. VEPM 7.1 is based on factors from the latest guidebook, which included updated factors for light duty diesel vehicles (EEA,2024).

6.3.10 Brake and tyre wear factors

Brake and tyre wear emission factors in VEPM 7.1 are calculated in accordance with the Tier 2 methodology described in the latest version of the EMEP/EEA guidebook (EEA 2024b).

Brake and tyre wear factors in VEPM 7.0 were based on the Tier 2 methodology from the previous version of the guidebook.

In VEPM 7.1, 2-axle heavy vehicles are calculated in the same way as other heavy vehicles. In VEPM 7.0 these vehicles were assumed to be light commercial vehicles.

In VEPM 7.1, the default number of axles on battery electric buses was changed from 2 (in VEPM 7.0) to 3 to reflect the most common electric buses on our roads.

6.4 VEPM 7.1 compared to VEPM 7.0

This section compares key fleet weighted emissions factors now predicted by VEPM 7.1 with those from the previous version 7.0 to show the effect of changes in assumptions and methodology.

6.4.1 Effect on fleet weighted factors

Figure 11 through to Figure 15 compare the fleet weighted emissions factors for carbon monoxide (CO), volatile organic compounds (VOC), fuel consumption, nitrogen oxides (NOx), nitrogen dioxide (NO_2) exhaust particulate ($PM_{2.5}$ exhaust) and brake and tyre wear particulate (PM_{10} brake and tyre).

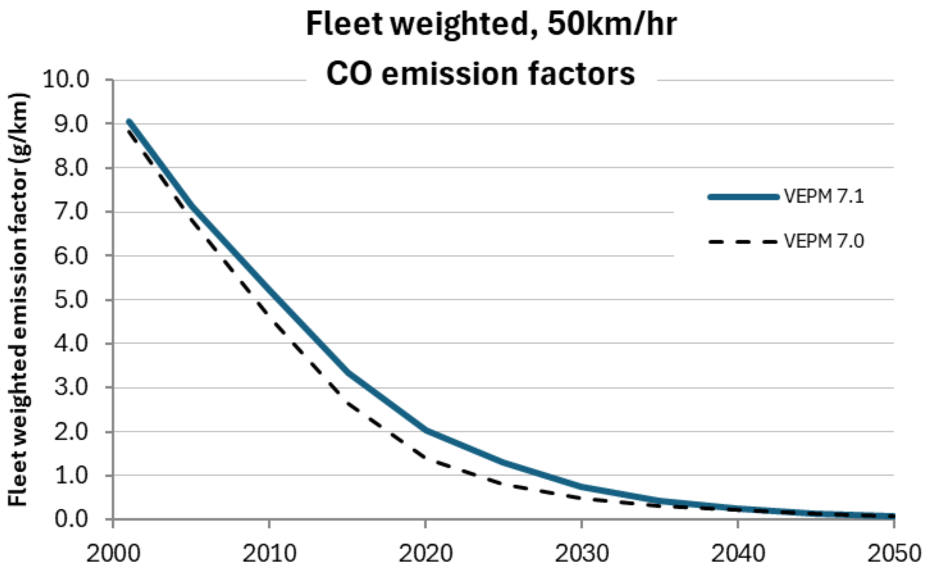

Figure 11: Comparison of CO emission factors from VEPM 7.1 and VEPM 7.0

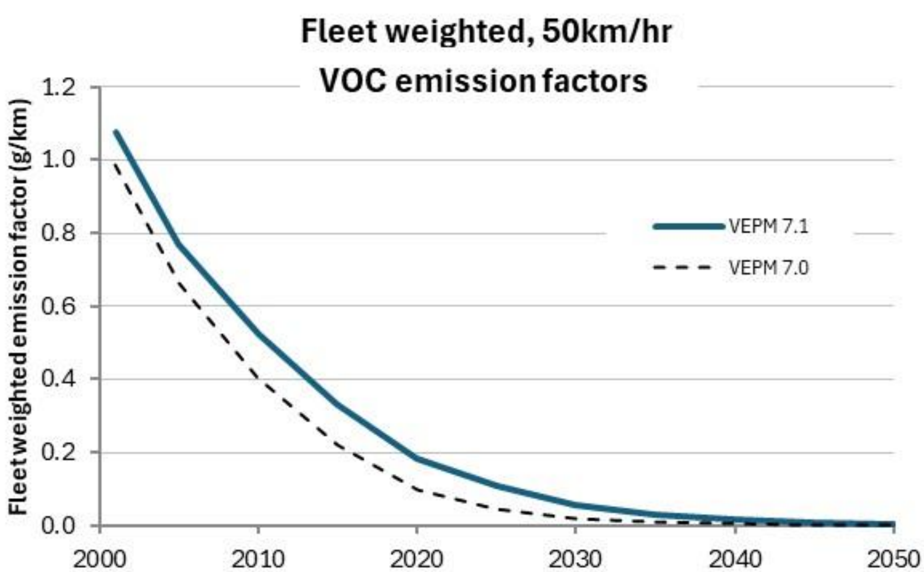

Figure 12: Comparison of VOC emission factors from VEPM 7.1 and VEPM 7.0

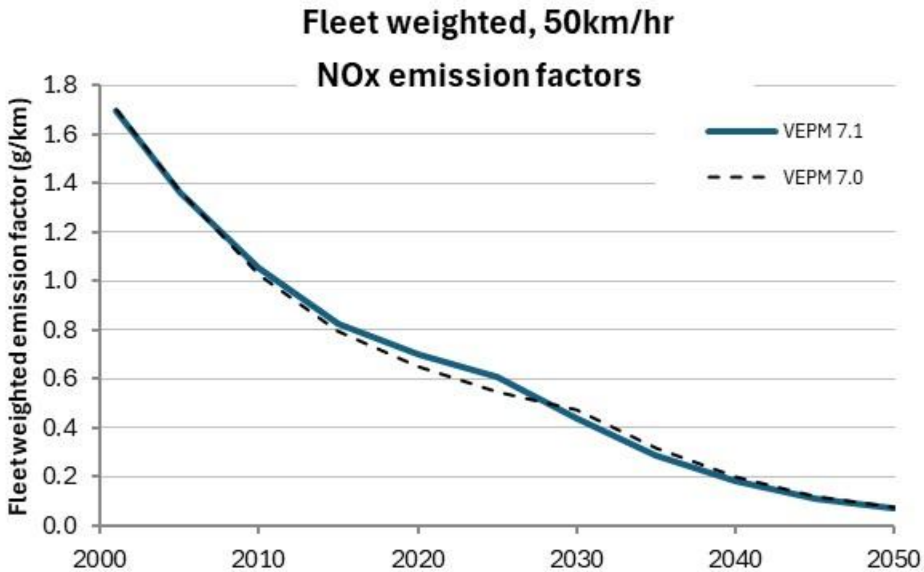

Figure 13: Comparison of NOx emission factors from VEPM 7.1 and VEPM 7.0

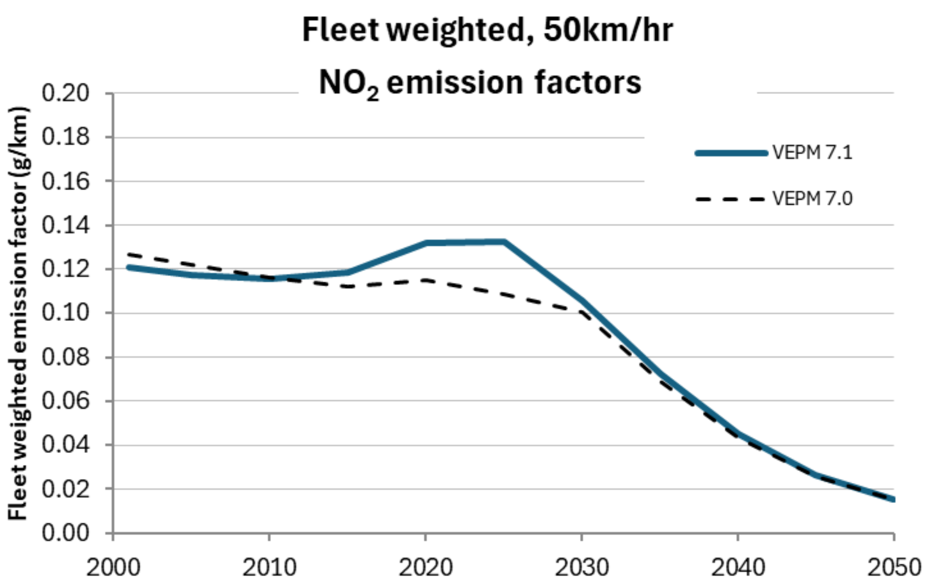

Figure 14: Comparison of NO_2 emission factors from VEPM 7.1 and VEPM 7.0

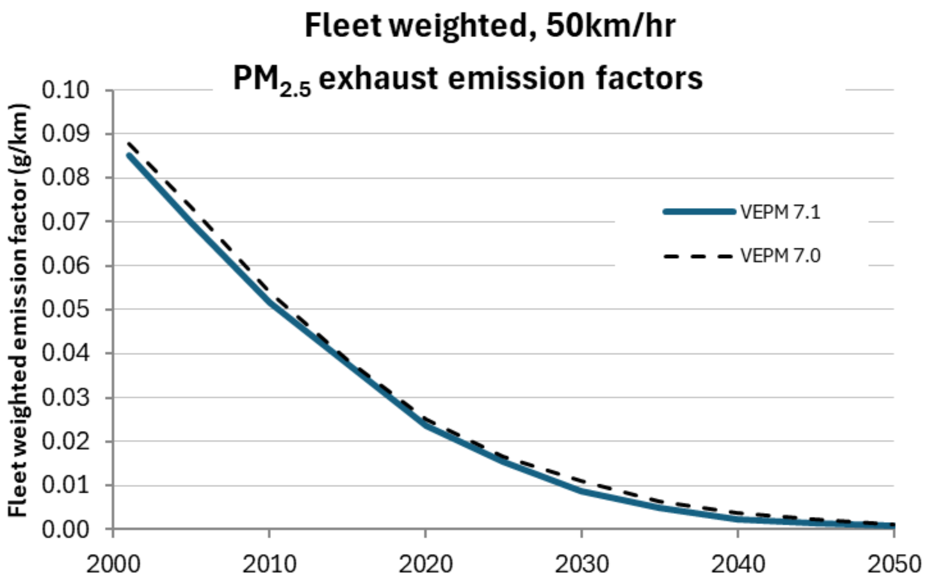

Figure 15: Comparison of $PM_{2.5}$ exhaust emission factors from VEPM 7.1 and VEPM 7.0

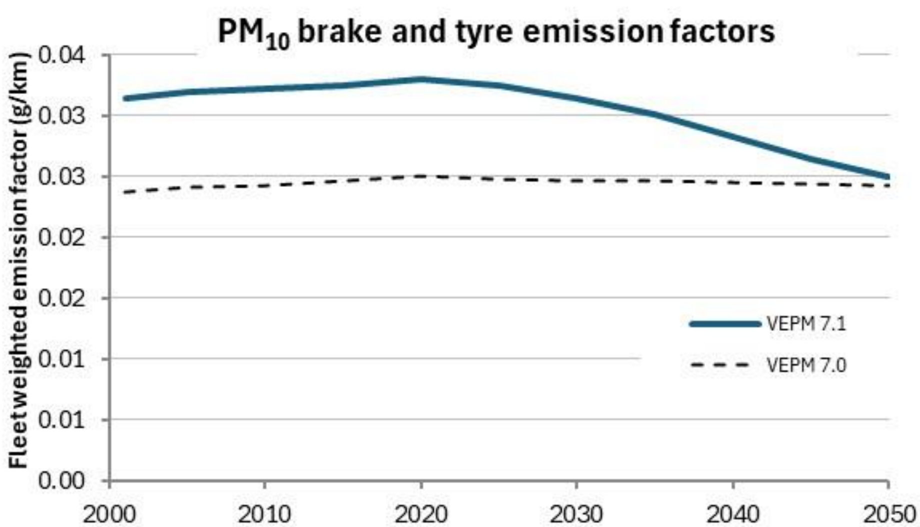

Figure 16: Comparison of PM_{10} brake and tyre wear emission factors from VEPM 7.1 and VEPM 7.0

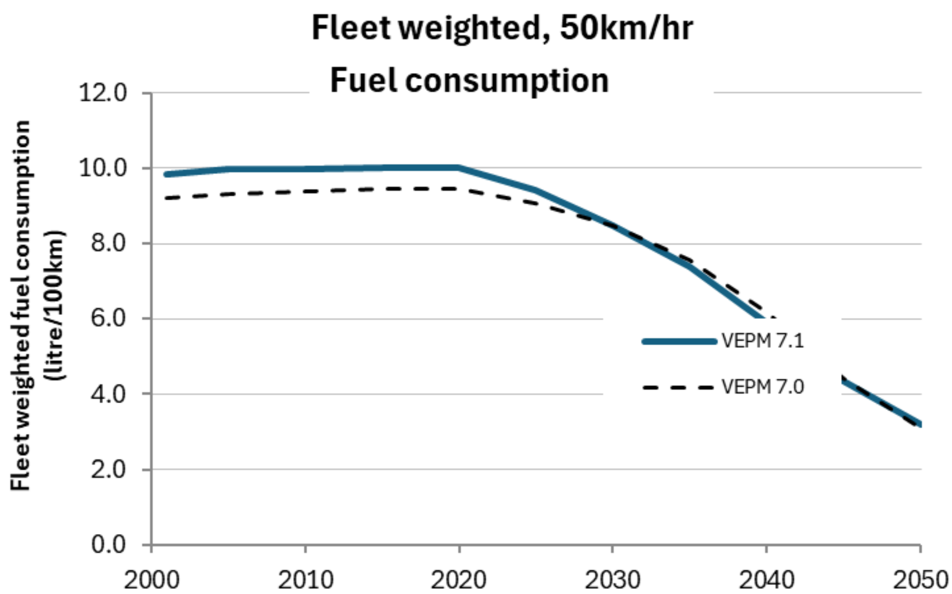

Figure 17: Comparison of fuel consumption factors from VEPM 7.1 and VEPM 7.0

6.4.2 Discussion of differences between VEPM 7.1 and VEPM 7.0

Key differences between VEPM 7.1 and VEPM 7.0 are:

- **CO**, **VOC** and **NOx** emission factors are slightly higher in VEPM 7.1 compared with VEPM 7.0 (see Figure 11 to Figure 13). This is primarily due to changes in the calculation of cold start emission factors. This includes correction of cold start algorithms for light duty vehicles and the addition of cold start emission factors for heavy duty diesel vehicles.
- **NO_2** emission factors are higher in VEPM 7.1 from 2015 to 2035 due to an increase in the f-NO_2 factor (the assumed fraction of NO_2 in NOx emissions) for Euro 4 diesel cars and LCVs.
- **PM_{10} brake and tyre wear** factors are higher in VEPM 7.1 compared to VEPM 7.0 and gradually decrease from 2020 onwards, whereas the factors were steady in VEPM 7.0. This is due to the inclusion of new emission factors for different vehicle categories. The change in VEPM 7.1 factors over time is due to the increasing proportion of battery electric vehicles, which have substantially lower brake wear factors compared to conventional vehicles.
- Fleet weighted **fuel consumption** (and consequently CO_2 emissions) are higher in VEPM 7.1 compared to VEPM 7.0 up to 2020 (see Figure 17). For future years, the values are similar. This change is due to a combination of:
  - Correction of the calorific values for fuel in VEPM 7.1, which has increased overall fuel consumption estimates compared to VEPM 7.0.
  - Changes in the VEPM 7.1 fleet projection compared to VEPM 7.0 based on updated outputs from the Ministry of Transport VFM, as discussed in Section 6.1.

7. Recommendations

Improvement of VEPM is an area of ongoing research. Recommendations from research reports are not repeated here.

Specific recommendations from the previous sections of this report for future VEPM updates are as follows:

- The Ministry of Transport VFM provides fleet projections to 2055. For consistency, extending VEPM to 2055 could be considered.
- The EMEP/EEA spreadsheet provides **electricity consumption factors** for some vehicle categories. Further work is recommended to consider whether electricity consumption factors warrant inclusion in future versions of VEPM.
- Emission factors for **Euro 7 and Euro VII** vehicles are available in the EMEP/EEA spreadsheet. These factors should be incorporated into future versions of VEPM.
- **Real world fuel consumption factors** by year of manufacture for petrol and diesel light duty vehicles have been proposed (Metcalfe *et al* 2021), however these have not yet been implemented in VEPM. Further work is recommended to update, validate and implement real world fuel consumption factors for light duty vehicles.
- Further work is recommended to investigate how real world **fuel consumption of heavy duty vehicles** compares with VEPM estimates and to develop and implement real world fuel consumption factors if appropriate.
- Further investigation is recommended to confirm whether the percentage split of bus VKT between **bus and coach** is realistic.
- The **emission standards split for vehicles up to year of manufacture 2009** has not been updated since it was developed based on analysis of 2014 fleet data. It is recommended that update of this data should be considered as part of future fleet updates, including investigation of whether vehicle import status data from VFM could be used.
- There are vehicle categories in the EMEP/EEA spreadsheet which are not currently included in VEPM (e.g. motorcycles and additional engine size categories for passenger cars). Further work is recommended to consider whether any of these **additional vehicle categories** warrant inclusion in future versions of VEPM.
- The assumptions and for splitting articulated and rigid truck VKT are based on data available in 2021. It is recommended that the **articulated truck VKT splits** should be updated periodically.
- For some vehicle categories and emission standards, EMEP/EEA emission factors are further broken down by emission control **technology.** It is recommended that the significance of technology assumptions, and the availability of any data on likely technology in the NZ fleet should be reviewed and confirmed.

- It is recommended that fuel properties (gross calorific value and density) and **gross CO_2** emission factors for petrol and diesel should be updated regularly in future versions of VEPM. Developing a checklist of parameters to be reviewed would be helpful. In addition, updating VEPM to calculate fuel consumption based on the CO_2 emission factor for the specific assessment year (i.e. including the official CO_2 factor reported for each year covered) could also be considered.
- Investigation of data requirements, data availability and potential significance of **CO_2 emissions from lubricants and additives** is recommended.

In general, we recommend updating VEPM whenever the EMEP/EEA spreadsheet is updated. The default fleet profile should also be updated whenever VFEM is updated.

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Appendix 1: emission standards assumed by emission standard origin and year of manufacture

Vehicles are assigned to an emission standard origin (European, Australian, New Zealand, Japanese) based on the assumptions outlined in Section 4.4. **Note:** From 2010 all used vehicle imports are assigned to Japanese and all new vehicle imports are assigned to European.

European

Table 38: Emission standards assumed by year of manufacture for vehicles assigned **European emission standard origin** (includes New Zealand new European and Japanese vehicles up to year of manufacture 2009 and all New Zealand new vehicles from 2010 onwards)

Category	Fuel Type	Year of Manufacture	EMEP Standard	EMEP Technology
Passenger Cars	Petrol	<1972	PRE ECE	-
Passenger Cars	Petrol	1972-1977	ECE 15/00-01	-
Passenger Cars	Petrol	1978-1980	ECE 15/02	-
Passenger Cars	Petrol	1981-1984	ECE 15/03	-
Passenger Cars	Petrol	1985-1995	ECE 15/04	-
Passenger Cars	Petrol	1996-1999	Euro 1	-
Passenger Cars	Petrol	2000-2003	Euro 2	-
Passenger Cars	Petrol	2004-2008	Euro 3	PFI
Passenger Cars	Petrol	2009-2015	Euro 4	PFI
Passenger Cars	Petrol	2016-2027	Euro 5	PFI
Passenger Cars	Petrol	>=2028	Euro 6 d	PFI
Passenger Cars	Petrol hybrid	<=2015	Euro 4	GDI
Passenger Cars	Petrol hybrid	2016-2027	Euro 5	GDI
Passenger Cars	Petrol hybrid	>=2028	Euro 6 d	GDI
Passenger Cars	Petrol PHEV	All years	Euro 6 d	GDI
Passenger Cars	Diesel	<1996	Conventional	-
Passenger Cars	Diesel	1996-1999	Euro 1	-
Passenger Cars	Diesel	2000-2003	Euro 2	-
Passenger Cars	Diesel	2004-2007	Euro 3	DPF
Passenger Cars	Diesel	2008-2015	Euro 4	DPF
Passenger Cars	Diesel	2016-2027	Euro 5	DPF
Passenger Cars	Diesel	>=2028	Euro 6 d	DPF
Light Commercial Vehicles	Petrol	<1996	Conventional	-
Light Commercial Vehicles	Petrol	1996-1999	Euro 1	-
Light Commercial Vehicles	Petrol	2000-2003	Euro 2	-
Light Commercial Vehicles	Petrol	2004-2008	Euro 3	PFI
Light Commercial Vehicles	Petrol	2009-2015	Euro 4	PFI
Light Commercial Vehicles	Petrol	2016-2027	Euro 5	PFI
Light Commercial Vehicles	Petrol	>=2028	Euro 6 d	PFI
Light Commercial Vehicles	Diesel	<1996	Conventional	-
Light Commercial Vehicles	Diesel	1996-1999	Euro 1	-
Light Commercial Vehicles	Diesel	2000-2003	Euro 2	-
Light Commercial Vehicles	Diesel	2004-2007	Euro 3	DPF

Category	Fuel Type	Year of Manufacture	EMEP Standard	EMEP Technology
Light Commercial Vehicles	Diesel	2008-2015	Euro 4	DPF
Light Commercial Vehicles	Diesel	2016-2027	Euro 5	DPF
Light Commercial Vehicles	Diesel	>=2028	Euro 6 d	DPF
Heavy Duty Trucks	Diesel	<1995	Conventional	-
Heavy Duty Trucks	Diesel	1995-1999	Euro I	-
Heavy Duty Trucks	Diesel	2000-2002	Euro II	-
Heavy Duty Trucks	Diesel	2003-2007	Euro III	-
Heavy Duty Trucks	Diesel	2008-2011	Euro IV	SCR
Heavy Duty Trucks	Diesel	2012-2024	Euro V	SCR (75%) EGR (25%)
Heavy Duty Trucks	Diesel	>=2025	Euro VI C	DPF + SCR
Buses	Diesel	<1995	Conventional	-
Buses	Diesel	1995-1999	Euro I	-
Buses	Diesel	2000-2002	Euro II	-
Buses	Diesel	2003-2007	Euro III	-
Buses	Diesel	2008-2011	Euro IV	SCR
Buses	Diesel	2012-2024	Euro V	SCR (75%) EGR (25%)
Buses	Diesel	>=2025	Euro VI C	DPF + SCR

Australian

Table 39: Emission standards assumed by year of manufacture for **Australian manufactured vehicles up to 2009**

Category	Fuel Type	Year of Manufacture	EMEP Standard	EMEP Technology
Passenger Cars	Petrol	<1972	PRE ECE	-
Passenger Cars	Petrol	1972-1977	ECE 15/00-01	-
Passenger Cars	Petrol	1978-1980	ECE 15/02	-
Passenger Cars	Petrol	1981-1984	ECE 15/03	-
Passenger Cars	Petrol	1985-2002	Euro 1	-
Passenger Cars	Petrol	2003-2004	Euro 2	-
Passenger Cars	Petrol	2005-2007	Euro 3	PFI
Passenger Cars	Petrol	2008-2009	Euro 4	PFI
Passenger Cars	Diesel	<1992	Conventional	-
Passenger Cars	Diesel	1992-2002	Euro 1	-
Passenger Cars	Diesel	2003-2006	Euro 2	-
Passenger Cars	Diesel	2007-2009	Euro 4	DPF
Light Commercial Vehicles	Petrol	<1993	Conventional	-
Light Commercial Vehicles	Petrol	1993-2002	Euro 1	-
Light Commercial Vehicles	Petrol	2003-2004	Euro 2	-
Light Commercial Vehicles	Petrol	2005-2007	Euro 3	PFI
Light Commercial Vehicles	Petrol	2008-2009	Euro 4	PFI
Light Commercial Vehicles	Diesel	<1993	Conventional	-
Light Commercial Vehicles	Diesel	1993-2002	Euro 1	-
Light Commercial Vehicles	Diesel	2003-2006	Euro 2	-
Light Commercial Vehicles	Diesel	2007-2009	Euro 4	DPF
Heavy Duty Trucks	Diesel	<1993	Conventional	-
Heavy Duty Trucks	Diesel	1993-2002	Euro I	-
Heavy Duty Trucks	Diesel	2003-2006	Euro III	-
Heavy Duty Trucks	Diesel	2007-2009	Euro IV	SCR
Buses	Diesel	<1993	Conventional	-
Buses	Diesel	1993-2002	Euro I	-
Buses	Diesel	2003-2006	Euro III	-
Buses	Diesel	2007-2009	Euro IV	SCR

New Zealand

Table 40: Emission standards assumed by year of manufacture for **New Zealand manufactured vehicles up to 2009**

Category	Fuel Type	Year of Manufacture	Ratio	EMEP Standard	EMEP Technology
Passenger Cars	Petrol	<1988	100%	ECE 15/02	-
Passenger Cars	Petrol	1988-1992	80%	ECE 15/02	-
Passenger Cars	Petrol	1988-1992	20%	Euro 1	-
Passenger Cars	Petrol	1993-1997	40%	ECE 15/02	-
Passenger Cars	Petrol	1993-1997	60%	Euro 1	-
Passenger Cars	Petrol	1998-2002	10%	ECE 15/02	-
Passenger Cars	Petrol	1998-2002	90%	Euro 1	-
Passenger Cars	Petrol	2003-2009	100%	Euro 1	-
Passenger Cars	Diesel	<1992	100%	Conventional	-
Passenger Cars	Diesel	1992-2002	100%	Euro 1	-
Passenger Cars	Diesel	2003-2006	100%	Euro 2	-
Passenger Cars	Diesel	2007-2009	100%	Euro 4	DPF
Light Commercial Vehicles	Petrol	<1993	100%	Conventional	-
Light Commercial Vehicles	Petrol	1993-2002	100%	Euro 1	-
Light Commercial Vehicles	Petrol	2003-2004	100%	Euro 2	-
Light Commercial Vehicles	Petrol	2005-2007	100%	Euro 3	PFI
Light Commercial Vehicles	Petrol	2008-2009	100%	Euro 4	PFI
Light Commercial Vehicles	Diesel	<1993	100%	Conventional	-
Light Commercial Vehicles	Diesel	1993-2002	100%	Euro 1	-
Light Commercial Vehicles	Diesel	2003-2006	100%	Euro 2	-
Light Commercial Vehicles	Diesel	2007-2009	100%	Euro 4	DPF
Heavy Duty Trucks	Diesel	<1993	100%	Conventional	-
Heavy Duty Trucks	Diesel	1993-2002	100%	Euro I	-
Heavy Duty Trucks	Diesel	2003-2006	100%	Euro III	-
Heavy Duty Trucks	Diesel	2007-2009	100%	Euro IV	SCR
Buses	Diesel	<1993	100%	Conventional	-
Buses	Diesel	1993-2002	100%	Euro I	-
Buses	Diesel	2003-2006	100%	Euro III	-
Buses	Diesel	2007-2009	100%	Euro IV	SCR

Japanese

Table 41: Emission standards assumed by year of manufacture for vehicles assigned **Japanese emission standard origin** (includes Japanese used vehicles, and all used vehicle imports from 2010)

Category	Fuel Type	Year of Manufacture	Standard[35]
Passenger Cars	Petrol	1950-1974	Pre 1973, J73
Passenger Cars	Petrol	1975-1977	J75, J76
Passenger Cars	Petrol	1978-1985	J78
Passenger Cars	Petrol	1986-1999	J78, J88
Passenger Cars	Petrol	2000-2004	J00
Passenger Cars	Petrol	2005-2009	J05
Passenger Cars	Petrol	2010-2017	Euro 5
Passenger Cars	Petrol	2018-2023	Euro 6 a/b/c
Passenger Cars	Petrol	2024-2050	Euro 6 d/e
Passenger Cars	Diesel	1950-1985	Pre 1986
Passenger Cars	Diesel	1986-1991	J86
Passenger Cars	Diesel	1992-1997	J92, J94
Passenger Cars	Diesel	1998-2001	J98
Passenger Cars	Diesel	2002-2004	J02
Passenger Cars	Diesel	2005-2009	J05
Passenger Cars	Diesel	2010-2050	Euro 5
Light Commercial Vehicles	Petrol	1950-1979	J73, J75, J79
Light Commercial Vehicles	Petrol	1980-1987	J79, J81
Light Commercial Vehicles	Petrol	1988-2000	J88
Light Commercial Vehicles	Petrol	2001-2004	J01
Light Commercial Vehicles	Petrol	2005-2009	J05
Light Commercial Vehicles	Petrol	2010-2050	Euro 5
Light Commercial Vehicles	Diesel	1950-1976	Pre 1974, J74
Light Commercial Vehicles	Diesel	1977-1981	J77, J79
Light Commercial Vehicles	Diesel	1982-1987	J82, J83, J87
Light Commercial Vehicles	Diesel	1988-1992	J88
Light Commercial Vehicles	Diesel	1993-1996	J93
Light Commercial Vehicles	Diesel	1997-2004	J97, J03
Light Commercial Vehicles	Diesel	2005-2009	J05
Light Commercial Vehicles	Diesel	2010-2050	Euro 5
Heavy Duty Trucks	Diesel	<1974	Pre 1974
Heavy Duty Trucks	Diesel	1974-1987	J74, J77, J79, J82, J83, J87
Heavy Duty Trucks	Diesel	1988-1993	J88
Heavy Duty Trucks	Diesel	1994-1997	J94, J97
Heavy Duty Trucks	Diesel	1998-2002	J97
Heavy Duty Trucks	Diesel	2003-2004	J03
Heavy Duty Trucks	Diesel	2005-2009	J05
Heavy Duty Trucks	Diesel	2010-2050	Euro VI A/B/C
Buses	Diesel	<1974	Pre 1974

[35] Up to 2010 the standard relates to emission categories in the JCAP Japanese emission model, based on year of manufacture, as described in EFRU 2008. From 2010 the standard refers to the closest equivalent European standard that is assumed based on comparison of emission standards and test requirements (Metcalfe & Peeters 2022)

Category	Fuel Type	Year of Manufacture	Standard[35]
Buses	Diesel	1974-1987	J74, J77, J79, J82, J83, J87
Buses	Diesel	1988-1993	J88
Buses	Diesel	1994-1997	J94, J97
Buses	Diesel	1998-2002	J97
Buses	Diesel	2003-2004	J03
Buses	Diesel	2005-2009	J05
Buses	Diesel	2010-2050	Euro VI A/B/C

Appendix 2: Japanese European equivalence table

Notes:

- Up to 2010 the "Japan Standard" column relates to emission categories in the JCAP Japanese emission model, based on year of manufacture, as described in the VEPM development report (EFRU 2008). From 2010, the "Japan Standard" refers to the closest equivalent European standard that is assumed based on comparison of emission standards and test requirements (Metcalfe & Peeters 2022)
- Articulated trucks are assigned the same standard as the closest equivalent rigid truck based on weight categories shown Table 14.
- For CH_4 and N_2O, equivalences are the same as VOC and NOx respectively.
- The "tech" column shows the technology sub-category, which is specified in the EMEP/EEA emission factors. These are:
    - PFI: port fuel injection
    - GDI: gasoline direct injection
    - DPF: diesel particulate filter – a particulate emission control system
    - EGR: exhaust gas recirculation – a nitrogen oxide emission control system
    - SCR: selective catalytic reduction – a nitrogen oxide emission control system

Category	Fuel Type	Segment	Japan Standard	CO Standard	CO Tech	VOC Standard	VOC Tech	NOx Standard	NOx Tech	PM Standard	PM Tech	EC Standard	EC Tech
CAR	Petrol	Small	Pre 1973, J73	PRE ECE	-	PRE ECE	-	PRE ECE	-	PRE ECE	-	PRE ECE	-
CAR	Petrol	Medium	Pre 1973, J73	PRE ECE	-	PRE ECE	-	PRE ECE	-	PRE ECE	-	PRE ECE	-
CAR	Petrol	Large-SUV-Executive	Pre 1973, J73	PRE ECE	-	PRE ECE	-	PRE ECE	-	PRE ECE	-	PRE ECE	-
CAR	Petrol	Small	J75, J76	Euro 1	-	Euro 1	-	PRE ECE	-	Euro 1	-	Euro 1	-
CAR	Petrol	Medium	J75, J76	Euro 1	-	Euro 1	-	PRE ECE	-	Euro 1	-	Euro 1	-
CAR	Petrol	Large-SUV-Executive	J75, J76	Euro 1	-	Euro 1	-	PRE ECE	-	Euro 1	-	Euro 1	-
CAR	Petrol	Small	J78	Euro 1	-	Euro 1	-	Euro 1	-	Euro 1	-	Euro 1	-
CAR	Petrol	Medium	J78	Euro 1	-	Euro 1	-	Euro 1	-	Euro 1	-	Euro 1	-
CAR	Petrol	Large-SUV-Executive	J78	Euro 1	-	Euro 1	-	Euro 1	-	Euro 1	-	Euro 1	-
CAR	Petrol	Small	J78, J88	Euro 1	-	Euro 2	-	Euro 2	-	Euro 2	-	Euro 2	-
CAR	Petrol	Medium	J78, J88	Euro 1	-	Euro 2	-	Euro 2	-	Euro 2	-	Euro 2	-
CAR	Petrol	Large-SUV-Executive	J78, J88	Euro 1	-	Euro 2	-	Euro 2	-	Euro 2	-	Euro 2	-
CAR	Petrol	Small	J00	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI
CAR	Petrol	Medium	J00	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI
CAR	Petrol	Large-SUV-Executive	J00	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI
CAR	Petrol	Small	J05	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI
CAR	Petrol	Medium	J05	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI
CAR	Petrol	Large-SUV-Executive	J05	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI
CAR	Petrol	Small	Euro 5	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI

Category	Fuel Type	Segment	Japan Standard	CO Standard	CO Tech	VOC Standard	VOC Tech	NOx Standard	NOx Tech	PM Standard	PM Tech	EC Standard	EC Tech
CAR	Petrol	Medium	Euro 5	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI
CAR	Petrol	Large-SUV-Executive	Euro 5	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI
CAR	Petrol	Small	Euro 6 a/b/c	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI
CAR	Petrol	Medium	Euro 6 a/b/c	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI
CAR	Petrol	Large-SUV-Executive	Euro 6 a/b/c	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI	Euro 6 a/b/c	PFI
CAR	Petrol	Small	Euro 6 d/e	Euro 6 d/e	PFI	Euro 6 d/e	PFI	Euro 6 d/e	PFI	Euro 6 d/e	PFI	Euro 6 d/e	PFI
CAR	Petrol	Medium	Euro 6 d/e	Euro 6 d/e	PFI	Euro 6 d/e	PFI	Euro 6 d/e	PFI	Euro 6 d/e	PFI	Euro 6 d/e	PFI
CAR	Petrol	Large-SUV-Executive	Euro 6 d/e	Euro 6 d/e	PFI	Euro 6 d/e	PFI	Euro 6 d/e	PFI	Euro 6 d/e	PFI	Euro 6 d/e	PFI
CAR	Diesel	Medium	Pre 1986	Conventional	-	Conventional	-	Euro 1	-	Conventional	-	Conventional	-
CAR	Diesel	Large-SUV-Executive	Pre 1986	Conventional	-	Conventional	-	Euro 1	-	Conventional	-	Conventional	-
CAR	Diesel	Medium	J86	Euro 1	-	Euro 2	-	Euro 1	-	Conventional	-	Euro 1	-
CAR	Diesel	Large-SUV-Executive	J86	Euro 1	-	Euro 2	-	Euro 1	-	Conventional	-	Euro 1	-
CAR	Diesel	Medium	J92, J94	Euro 1	-	Euro 2	-	Euro 3	DPF	Conventional	-	Euro 1	-
CAR	Diesel	Large-SUV-Executive	J92, J94	Euro 1	-	Euro 2	-	Euro 3	DPF	Conventional	-	Euro 1	-
CAR	Diesel	Medium	J98	Euro 1	-	Euro 2	-	Euro 3	DPF	Euro 1	-	Euro 1	-
CAR	Diesel	Large-SUV-Executive	J98	Euro 1	-	Euro 2	-	Euro 3	DPF	Euro 1	-	Euro 1	-
CAR	Diesel	Medium	J02	Euro 1	-	Euro 2	-	Euro 3	DPF	Euro 3	DPF	Euro 1	-
CAR	Diesel	Large-SUV-Executive	J02	Euro 1	-	Euro 2	-	Euro 3	DPF	Euro 3	DPF	Euro 1	-
CAR	Diesel	Medium	J05	Euro 3	DPF	Euro 4	DPF	Euro 4	DPF	Euro 4	DPF	Euro 3	DPF
CAR	Diesel	Large-SUV-Executive	J05	Euro 3	DPF	Euro 4	DPF	Euro 4	DPF	Euro 4	DPF	Euro 3	DPF
CAR	Diesel	Medium	Euro 5	Euro 5	DPF	Euro 5	DPF	Euro 5	DPF	Euro 5	DPF	Euro 5	DPF
CAR	Diesel	Large-SUV-Executive	Euro 5	Euro 5	DPF	Euro 5	DPF	Euro 5	DPF	Euro 5	DPF	Euro 5	DPF
LCV	Petrol	N1-III	J73, J75, J79	Conventional	-	Conventional	-	Conventional	-	Conventional	-	Conventional	-
LCV	Petrol	N1-III	J79, J81	Euro 1	-	Conventional	-	Euro 1	-	Conventional	-	Conventional	-
LCV	Petrol	N1-III	J88	Euro 1	-	Euro 1	-	Euro 2	-	Euro 1	-	Euro 1	-
LCV	Petrol	N1-III	J01	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI	Euro 3	PFI
LCV	Petrol	N1-III	J05	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI	Euro 4	PFI
LCV	Petrol	N1-III	Euro 5	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI	Euro 5	PFI
LCV	Diesel	N1-III	Pre 1974, J74	Conventional	-	Euro 1	-	Conventional	-	Euro 1	-	Conventional	-
LCV	Diesel	N1-III	J77, J79	Conventional	-	Euro 1	-	Euro 1	-	Euro 1	-	Conventional	-
LCV	Diesel	N1-III	J82, J83, J87	Conventional	-	Euro 1	-	Euro 3	DPF	Euro 1	-	Conventional	-
LCV	Diesel	N1-III	J88	Euro 1	-	Euro 3	DPF	Euro 3	DPF	Euro 1	-	Euro 1	-
LCV	Diesel	N1-III	J93	Euro 1	-	Euro 3	DPF	Euro 3	DPF	Euro 3	DPF	Euro 1	-
LCV	Diesel	N1-III	J97, J03	Euro 1	-	Euro 3	DPF	Euro 4	DPF	Euro 3	DPF	Euro 1	-
LCV	Diesel	N1-III	J05	Euro 3	DPF	Euro 4	DPF	Euro 4	DPF	Euro 4	DPF	Euro 3	DPF
LCV	Diesel	N1-III	Euro 5	Euro 5	DPF	Euro 5	DPF	Euro 5	DPF	Euro 5	DPF	Euro 5	DPF
HCV	Diesel	Rigid <=7,5 t	Pre 1974	Euro I	-	Euro II	-	Conventional	-	Conventional	-	Euro I	-
HCV	Diesel	Rigid 7,5 - 12 t	Pre 1974	Conventional	-	Euro I	-	Conventional	-	Conventional	-	Conventional	-
HCV	Diesel	Rigid 14 - 20 t	Pre 1974	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
HCV	Diesel	Rigid 20 - 26 t	Pre 1974	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
HCV	Diesel	Rigid 26 - 28 t	Pre 1974	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
HCV	Diesel	Rigid >32 t	Pre 1974	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-

Category	Fuel Type	Segment	Japan Standard	CO Standard	CO Tech	VOC Standard	VOC Tech	NOx Standard	NOx Tech	PM Standard	PM Tech	EC Standard	EC Tech
HCV	Diesel	Rigid <=7,5 t	J74, J77, J79, J82, J83, J87	Euro I	-	Euro II	-	Conventional	-	Conventional	-	Euro I	-
HCV	Diesel	Rigid 7,5 - 12 t	J74, J77, J79, J82, J83, J87	Conventional	-	Euro I	-	Euro I	-	Conventional	-	Conventional	-
HCV	Diesel	Rigid 14 - 20 t	J74, J77, J79, J82, J83, J87	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
HCV	Diesel	Rigid 20 - 26 t	J74, J77, J79, J82, J83, J87	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
HCV	Diesel	Rigid 26 - 28 t	J74, J77, J79, J82, J83, J87	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
HCV	Diesel	Rigid >32 t	J74, J77, J79, J82, J83, J87	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
HCV	Diesel	Rigid <=7,5 t	J88	Euro I	-	Euro II	-	Euro I	-	Euro I	-	Euro I	-
HCV	Diesel	Rigid 7,5 - 12 t	J88	Conventional	-	Euro I	-	Euro II	-	Euro II	-	Conventional	-
HCV	Diesel	Rigid 14 - 20 t	J88	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
HCV	Diesel	Rigid 20 - 26 t	J88	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
HCV	Diesel	Rigid 26 - 28 t	J88	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
HCV	Diesel	Rigid >32 t	J88	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
HCV	Diesel	Rigid <=7,5 t	J94, J97	Euro I	-	Euro II	-	Euro II	-	Euro I	-	Euro I	-
HCV	Diesel	Rigid 7,5 - 12 t	J94, J97	Conventional	-	Euro I	-	Euro II	-	Euro II	-	Conventional	-
HCV	Diesel	Rigid 14 - 20 t	J94, J97	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
HCV	Diesel	Rigid 20 - 26 t	J94, J97	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
HCV	Diesel	Rigid 26 - 28 t	J94, J97	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
HCV	Diesel	Rigid >32 t	J94, J97	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
HCV	Diesel	Rigid <=7,5 t	J97	Euro I	-	Euro II	-	Euro III	-	Euro III	-	Euro I	-
HCV	Diesel	Rigid 7,5 - 12 t	J97	Conventional	-	Euro I	-	Euro III	-	Euro III	-	Conventional	-
HCV	Diesel	Rigid 14 - 20 t	J97	Conventional	-	Conventional	-	Euro III	-	Euro III	-	Conventional	-
HCV	Diesel	Rigid 20 - 26 t	J97	Conventional	-	Conventional	-	Euro III	-	Euro III	-	Conventional	-
HCV	Diesel	Rigid 26 - 28 t	J97	Conventional	-	Conventional	-	Euro III	-	Euro III	-	Conventional	-
HCV	Diesel	Rigid >32 t	J97	Conventional	-	Conventional	-	Euro III	-	Euro III	-	Conventional	-
HCV	Diesel	Rigid <=7,5 t	J03	Euro III	-	Euro III	-	Euro IV	SCR	Euro III	-	Euro III	-
HCV	Diesel	Rigid 7,5 - 12 t	J03	Euro III	-	Euro III	-	Euro IV	SCR	Euro III	-	Euro III	-
HCV	Diesel	Rigid 14 - 20 t	J03	Euro III	-	Euro III	-	Euro IV	SCR	Euro III	-	Euro III	-
HCV	Diesel	Rigid 20 - 26 t	J03	Euro III	-	Euro III	-	Euro IV	SCR	Euro III	-	Euro III	-
HCV	Diesel	Rigid 26 - 28 t	J03	Euro III	-	Euro III	-	Euro IV	SCR	Euro III	-	Euro III	-
HCV	Diesel	Rigid >32 t	J03	Euro III	-	Euro III	-	Euro IV	SCR	Euro III	-	Euro III	-
HCV	Diesel	Rigid <=7,5 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	SCR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid <=7,5 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	EGR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid 7,5 - 12 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	SCR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid 7,5 - 12 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	EGR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid 14 - 20 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	SCR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid 14 - 20 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	EGR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid 20 - 26 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	SCR	Euro IV	SCR	Euro IV	SCR

Category	Fuel Type	Segment	Japan Standard	CO Standard	CO Tech	VOC Standard	VOC Tech	NOx Standard	NOx Tech	PM Standard	PM Tech	EC Standard	EC Tech
HCV	Diesel	Rigid 20 - 26 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	EGR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid 26 - 28 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	SCR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid 26 - 28 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	EGR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid >32 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	SCR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid >32 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	EGR	Euro IV	SCR	Euro IV	SCR
HCV	Diesel	Rigid <=7,5 t	Euro VI A/B/C	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR
HCV	Diesel	Rigid 7,5 - 12 t	Euro VI A/B/C	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR
HCV	Diesel	Rigid 14 - 20 t	Euro VI A/B/C	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR
HCV	Diesel	Rigid 20 - 26 t	Euro VI A/B/C	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR
HCV	Diesel	Rigid 26 - 28 t	Euro VI A/B/C	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR
HCV	Diesel	Rigid >32 t	Euro VI A/B/C	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR
BUS	Diesel	Urban Buses Midi <=15 t	Pre 1974	Conventional	-	Euro I	-	Conventional	-	Conventional	-	Conventional	-
BUS	Diesel	Urban Buses Standard 15 - 18 t	Pre 1974	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
BUS	Diesel	Coaches Standard <=18 t	Pre 1974	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
BUS	Diesel	Urban Buses Midi <=15 t	J74, J77, J79, J82, J83, J87	Conventional	-	Euro I	-	Euro I	-	Conventional	-	Conventional	-
BUS	Diesel	Urban Buses Standard 15 - 18 t	J74, J77, J79, J82, J83, J87	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
BUS	Diesel	Coaches Standard <=18 t	J74, J77, J79, J82, J83, J87	Conventional	-	Conventional	-	Euro I	-	Conventional	-	Conventional	-
BUS	Diesel	Urban Buses Midi <=15 t	J88	Conventional	-	Euro I	-	Euro II	-	Euro II	-	Conventional	-
BUS	Diesel	Urban Buses Standard 15 - 18 t	J88	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
BUS	Diesel	Coaches Standard <=18 t	J88	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
BUS	Diesel	Urban Buses Midi <=15 t	J94, J97	Conventional	-	Euro I	-	Euro II	-	Euro II	-	Conventional	-
BUS	Diesel	Urban Buses Standard 15 - 18 t	J94, J97	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
BUS	Diesel	Coaches Standard <=18 t	J94, J97	Conventional	-	Conventional	-	Euro II	-	Euro I	-	Conventional	-
BUS	Diesel	Urban Buses Midi <=15 t	J97	Conventional	-	Euro I	-	Euro III	-	Euro III	-	Conventional	-
BUS	Diesel	Urban Buses Standard 15 - 18 t	J97	Conventional	-	Conventional	-	Euro III	-	Euro III	-	Conventional	-
BUS	Diesel	Coaches Standard <=18 t	J97	Conventional	-	Conventional	-	Euro III	-	Euro III	-	Conventional	-
BUS	Diesel	Urban Buses Midi <=15 t	J03	Euro III	-	Euro III	-	Euro IV	SCR	Euro III	-	Euro III	-

Category	Fuel Type	Segment	Japan Standard	CO Standard	CO Tech	VOC Standard	VOC Tech	NOx Standard	NOx Tech	PM Standard	PM Tech	EC Standard	EC Tech
BUS	Diesel	Urban Buses Standard 15 - 18 t	J03	Euro III	-	Euro III	-	Euro IV	SCR	Euro III	-	Euro III	-
BUS	Diesel	Coaches Standard <=18 t	J03	Euro III	-	Euro III	-	Euro IV	SCR	Euro III	-	Euro III	-
BUS	Diesel	Urban Buses Midi <=15 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	SCR	Euro IV	SCR	Euro IV	SCR
BUS	Diesel	Urban Buses Midi <=15 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	EGR	Euro IV	SCR	Euro IV	SCR
BUS	Diesel	Urban Buses Standard 15 - 18 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	SCR	Euro IV	SCR	Euro IV	SCR
BUS	Diesel	Urban Buses Standard 15 - 18 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	EGR	Euro IV	SCR	Euro IV	SCR
BUS	Diesel	Coaches Standard <=18 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	SCR	Euro IV	SCR	Euro IV	SCR
BUS	Diesel	Coaches Standard <=18 t	J05	Euro IV	SCR	Euro IV	SCR	Euro V	EGR	Euro IV	SCR	Euro IV	SCR
BUS	Diesel	Urban Buses Midi <=15 t	Euro VI A/B/C	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR
BUS	Diesel	Urban Buses Standard 15 - 18 t	Euro VI A/B/C	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR
BUS	Diesel	Coaches Standard <=18 t	Euro VI A/B/C	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR	Euro VI A/B/C	DPF+SCR

Appendix 3: Emission factor and correction factor data sources in VEPM 7.1

Factor	Vehicle category	Reference/source	Comments
Hot running	All vehicle categories	EEA 2024a	All hot emission factors updated to the latest version from EMEP/EEA (EEA 2024a)
Hot running	Japanese domestic imports (light duty) up to YOM 2010	Based on Euro/JCAP equivalent emissions factors	All hot emission factors are from EMEP/EEA (EEA 2024a) and are assigned based on the Japan/Europe equivalencies described in Chapter 5
Cold start	All light duty	EEA 2024	
Fuel correction	All gasoline and diesel	EEA 2024	Based on introduction dates of improved fuels and vehicle technology in New Zealand as described in Chapter 5. Pre 2004 diesel correction factors are adjusted to account for very high sulphur levels in New Zealand fuel.
Degradation	Light duty	Various sources. Refer Table 15, Chapter 5	Light duty CO and NOx and VOC factors from EEA 2024.
Degradation	Heavy duty diesel	USEPA 2022	
Gradient	Light duty	PIARC (2019)	CO, NOx and PM gradient correction factors for light duty vehicles.
Gradient and load	Heavy duty	EEA 2024a	Heavy duty hot emission factors are adjusted for gradient and load in the EMEP/EEA spreadsheet
f-NO_2	All	EEA 2024	
Brake and tyre wear	All	EEA 2024b	
NZ real world fuel consumption	Light duty diesel	Metcalfe, Kuschel and Gimson (2020)	Correction factors based on methodology and assumptions described in Metcalfe, Kuschel and Gimson (2020). Proposed factors have been developed for VEPM 6.2 (Metcalfe *et al* 2021) however they have not been implemented at this stage.