Vehicle Fleet Emissions Model

(Version 3.2)

June 2022

Short name

'VFEM3' or 'Fleet Model'

Purpose of the model

This model projects the makeup of the future vehicle fleet and their travel, energy (fuel and electricity) use and greenhouse gas (GHG) emissions.

Software used

☐ **Excel**

☐ **Tableau**

☑ **SAS**

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Vehicle Fleet Emissions Model

1. At a high-level, what does this model do?

This model projects the makeup of future vehicle fleets and their kilometres travelled, energy (fuel and electricity) use and greenhouse gas (GHG) emissions.

The original version of Ministry of Transport's Vehicle Fleet Emissions Model (VFEM) was a spreadsheet model. We then have revised the model to enhance its performance and changed its operation environment to the SAS platform. Moreover, we have recently updated the model's base cases after considering the latest data and information. The current version is referred to as VFEM3.2. The methodology for estimating GHG emissions from domestic transport has been revised in the latest GHG inventory[1]. Changes have been made in this version of VFEM to align its projections to the latest GHG inventory data. It consists of a number of SAS files and needs to read a number of huge datasets. It is therefore not easily used by external people. We recommend that those interested contact the Ministry of Transport for possible arrangements.

The model estimates data for historic years (since 2001) and projected years (up to 2055). The data is broken out by:

- vehicle type
- vehicle age
- NZ new or used import (that is, import status)
- engine size bracket (light vehicles) or gross vehicle mass bracket (trucks and buses)
- fuel type.

The model results includes:

- number of vehicles
- vehicle travel (vehicle kilometres travelled, or VKT)
- fuel use
- GHG emissions.

The vehicle types and fuel types included in the model are described in Tables 1 and 2 below.

Table 1: Vehicle types and sizes in VFEM

Code	Vehicle type	Size bands				
1	Cars and SUVS	0-1349cc	1350-1599cc	1600-1999cc	2000-2999cc	3000+cc
2	Vans and utes	0-1349cc	1350-1599cc	1600-1999cc	2000-2999cc	3000+cc
3	Shared use cars and SUVs	0-1349cc	1350-1599cc	1600-1999cc	2000-2999cc	3000+cc
4	Shared use vans and utes	0-1349cc	1350-1599cc	1600-1999cc	2000-2999cc	3000+cc
5	Mopeds and motorcycles	<60cc	60+cc			
6	Light trucks	3500kg < GVM < 5000kg	<7500kg	<10000kg		
7	Heavy trucks		<25000kg	<30000kg	30000+kg	
8	Buses	3500kg < GVM <7500kg	<12000kg	12000+kg		

Notes: cc (cubic centimetres) refers to engine size; GVM = gross vehicle mass.

[1] New Zealand's Greenhouse Gas Inventory 1990-2020 (new-zealands-greenhouse-gas-inventory-1990-2020).

Table 2: Fuel types in VFEM

Fuel type for vehicles	Code
Petrol	1
Diesel	2
Petrol hybrid	3
Diesel hybrid	4
Electric	5
Petrol plugin hybrid – fuel and electricity	6
Diesel plugin hybrid – fuel and electricity	7
LPG/CNG	8
Other	9

2. Where do I find the model results?

This time we have updated the baseline projections of VFEM for three scenarios - base, fast EV uptake, and slow EV uptake. The model results can be found in a summary spreadsheet file, which is published alongside this document. The results include total GHG emissions (CO2-e), vehicle numbers in the fleet, and vehicle kilometres travelled. They are also broken down by vehicle type and fuel type. The total GHG emissions are the sum of tailpipe emissions and the emissions resulted from electricity generation of the electricity used by electric vehicles. Projections of future vehicle registrations (that is, vehicles entering the fleet) can be found in the "Registration projections" sheet. Furthermore, the "Raw data" sheet contains detailed results. Users can do more customised analyses on the data (for example, by using the Pivot Table tool).

3. What are the inputs to this model and where do they come from?

There are many inputs to VFEM. The structure of the key data files is presented in the Appendix:

- historic fleet mix by vehicle type, size, age, fuel type, and engine technology
- historic annual vehicle travel
- historic scrappage pattern
- historic vehicle registrations (that is, vehicles entering the fleet) breakdown
- historic GHG emissions from road transport[2]
- historic fuel use by road transport[3]
- energy (fuel and electricity) use per 100 km travelled by vehicle
- future vehicle registration mixes
- future fleet size generated by the separately-documented VKT/Vehicle Numbers Model
- future fleet travel generated by the VKT/Vehicle Numbers Model
- Future and historic amounts of GHG produced for each kilowatt hour of electricity used. These factors drop over time, as more electricity will be generated from renewable sources.

The first four data inputs, including the historic fleet mix and vehicle travel data, are obtained from analysis of the Motor Vehicle Register (MVR) database, which is administered by the Waka Kotahi NZ Transport Agency. The data on future and historic amounts of GHG produced for each kilowatt hour

[2] Sourced from New Zealand's GHG inventory (new-zealands-greenhouse-gas-inventory-1990-2020)
[3] Sourced from MBIE's oil statistics (NZ oil stats), with rail diesel use provided by MBIE

of electricity used are provided by the Ministry of Business, Innovation and Employment (MBIE). Energy economy factors for different vehicle categories are obtained in a research project conducted by Emission Impossible[4].

4. How does this model derive its results?

VFEM is essentially a calculator and similar to an average emission factor model. Its modelling process is illustrated schematically in Figure 1.

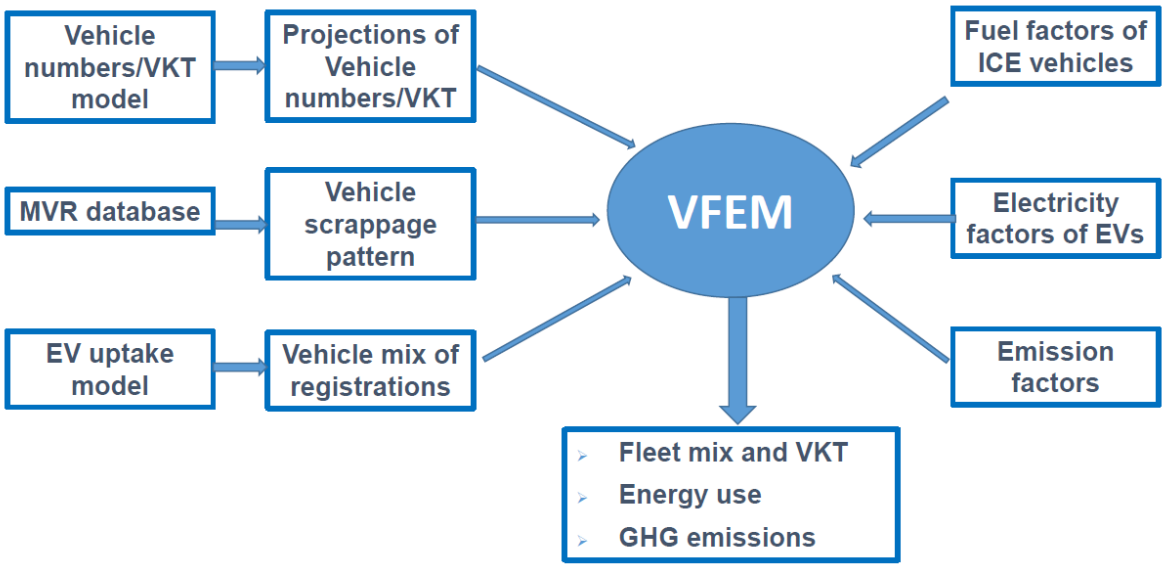

Figure 1: A schematic modelling process of VFEM

To project vehicle fleet mix in future years, it uses the historic vehicle fleet mix as the base data, for example, those for the fleet years from 2001 to 2019. The process works through each projection year to 2055, starting with the most recent, to determine the size and makeup of the future vehicle fleets. The steps the model goes through for each projection year are as follows:

- use the recent levels of vehicle scrappage (the last three years' averages, e.g. 2017-2019 averages for the 2020 projection year) to work out how many existing vehicles survive to the next modelled (projection) year
- use VKT/Vehicle Numbers Model projected vehicle numbers by type (cars/SUVs, vans/utes, shared cars, shared van/utes, motorcycles, trucks, buses) to work out how many vehicles of each type need to be registered into the fleet in the next projection year; the vehicles surviving scrappage plus the new registrations must match the projected vehicle numbers from the VKT/Vehicle Numbers Model
- use the exogenously-specified fleet mixes to determine the mix of vehicles that will be newly registered by their characteristics (age, fuel type, engine size, new/used). The future EV uptake rate is produced by a separate EV uptake projection model.

[4] Metcalf J. and Sridhar S. (2016), Real world energy use projections for VFEM; Report prepared for Ministry of Transport.

Using a similar procedure to that followed for the mix of vehicles, VFEM also takes as input the projected annual travel values from the VKT/Vehicle Numbers Model and splits them across the fleet using the historic travel patterns (based on last three years' averages). It then works out the amount of liquid fuel and electricity required for each specific vehicle category in each specific year using the following formula:

Energy use = Energy factor (energy use / VKT) × Vehicle travel (VKT in a year)

Projections of EV uptake in the future is one of the key components in VFEM modelling process. Both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) are considered. In the EV uptake projection model, a multinomial logit approach is applied to total costs of ownership (TCO)[5] to determine the demand for each type of vehicle. The utility (U) of individual i who selects vehicle option j is given by:

$$U_{ij} = V_j + \varepsilon_{ij}$$

where j is ICEV-P, ICEV-D, BEV, PHEV-P or PHEV-D. ICEV-P refers to a petrol international combustion engine vehicle, and ICEV-D refers to the diesel counterpart. Here V_j is the general utility attached to vehicle option j and ε_{ij} is an idiosyncratic element of utility (or disutility). From the standard multinomial logit model the share of buyers (S) who select option j is given by:

$$S_j = \frac{P_j}{\sum_j P_j} = \frac{e^{V_j}}{\sum_j e^{V_j}}$$

In other words, the ratio of the utility of option j to total utility is the equal to the share of the buying population (P) who choose that option. So the share of buyers choosing any option j is:

$$Ln(S_j) = \alpha_j + \sigma Ln(U_j)$$

Here α is a calibration parameter and σ is the elasticity of the share of buyers choosing option j with respect to the utility associated with that option. By Roy's Identity we can substitute price (C, in this case TCO) for utility, reinterpreting σ.

$$Ln(S_j) = \alpha_j - \sigma Ln(C_j)$$

This equation is applied in each year(t), with α_j calculated from base year data:

$$(S_{jt}) = \alpha_{j0} - \sigma(C_{jt})$$

Three scenarios are modelled: base case, fast EV uptake, and slow EV uptake. Base case projections of petrol, diesel and electricity prices as input data to this model are provided by MBIE. New Zealand may face supply constraint of used EV from Japan and this is analysed based on historic EV registrations in Japan.

[5] TCO includes all the costs for owning a vehicle, e.g. upfront purchase price, maintenance costs and depreciation. For BEVs and PHEVs, penalty is applied when estimating their TCO regarding driving range limitation and variety limitation (limited vehicle models available).

Appendix: Vehicle Fleet Emissions Model – Structure of Key Data Files

Vehicle types	Max. Size bands(*)	Fuel types	New/ used	Vehicle age	Projected and historic years	Data value
8	5	9	2	31	55	4
1. cars and SUVs	5 CC bands	1 conventional petrol		Current year	2001-2055	Vehicles
2. vans and Utes	5 CC bands	2 conventional diesel		plus the 30 before		Total travel
3. shared ownership - cars	5 CC bands	3 hybrid petrol				Scaled travel (**)
4. shared ownership - vans	5 CC bands	4 hybrid diesel				Fuel used
5. motorcycles	2 CC bands	5 LPG/CNG				
6. light trucks (*)	3 GVM bands	6 plugin hybrid - petrol				
7. heavy trucks (*)	4 GVM bands	7 plugin diesel hybrid - diesel				
8. buses	3 GVM bands	8 battery electric				
		9 hydrogen fuel Cell/ wild card				

(*) light truck GVM bands are :
1. < 5000
2. < 7500
3. < 10000

heavy truck GVM bands are :
1. < 20000 (incorporates the old < 15000)
2. < 25000
3. < 30000
4. >= 30000

(**) travel is scaled to match the results of the VKT/Vehicle Numbers model

Vehicle types	Max. Size bands	Fuel types	New/ used	History years
8	5	11	2	86
Cars and SUVs	5 CC bands	1. Conventional Gasoline		1970-2055
Vans and Utes	5 CC bands	2. Conventional Diesel		
Shared ownership - cars	5 CC bands	3. Hybrid Gasoline		
Shared ownership - vans	5 CC bands	4. Hybrid Diesel		
Motorcycles	2 CC bands	5. LPG/CNG		
Light trucks	3 GVM bands	6. Plug-In Hybrid - Petrol		
Heavy trucks	4 GVM bands	7. Plug-In Hybrid - Diesel		
Buses	3 GVM bands	8. Battery Electric		
		9. Hydrogen Fuel Cell/Wild card		
		10. Plugin petrol hybrid - electricity		
		11. Plugin diesel hybrid - electricity		

Scrappage history (for example, for 2001-2017) in number of vehicles					
Vehicle types	Max. Size bands	Fuel types	New/ used	Vehicle age	2001-17
8	5	2	2	31	17
Cars and SUVs	5 CC bands	Conventional Gasoline		Current year	
Vans and Utes	5 CC bands	Conventional Diesel		plus the 30	
Shared ownership - cars	5 CC bands			before	
Shared ownership - vans	5 CC bands				
Motorcycles	2 CC bands				
Light trucks	3 GVM bands				
Heavy trucks	4 GVM bands				
Bus	3 GVM bands				

Ongoing scrappage factors in percent – these are based on, e.g. an average of actual 2015 to 2017 values for the first projection year (2018) and rolling averages of the prior three years thereafter				
Vehicle types	Size bands	Fuel types	New/ used	Vehicle age
8	5	2	2	31
Cars and SUVs	5 CC bands	Conventional Gasoline		Current year
Vans and Utes	5 CC bands	Conventional Diesel		plus the 30
Shared ownership - cars	5 CC bands			before
Shared ownership - vans	5 CC bands			
Motorcycles	2 CC bands			
Light trucks	3 GVM bands			
Heavy trucks	4 GVM bands			
Bus	3 GVM bands			

Registration history (for example, for 2001-2017) in number of vehicles					
Vehicle types	Max. Size bands	Fuel types	New/ used	Vehicle age when first registered	2001-17
8	5	9	2	31	17
Cars and SUVs	5 CC bands	Conventional Gasoline		Current year	
Vans and Utes	5 CC bands	Conventional Diesel		plus the 30	
Shared ownership - cars	5 CC bands	Hybrid Gasoline		before	
Shared ownership - vans	5 CC bands	Hybrid Diesel			
Motorcycles	2 CC bands	LPG/CNG			
Light trucks	3 GVM bands	Plug-In Hybrid - Petrol			
Heavy trucks	4 GVM bands	Plug-In Hybrid - Diesel			
Bus	3 GVM bands	Battery Electric			
		Hydrogen Fuel Cell/Wild card			