Estimating the impacts of introducing Euro 6/VI vehicle emission standards for New Zealand: final report

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Executive summary

The health impacts of transport-related air pollution in New Zealand are considerable. Air pollution from motor vehicle emissions alone is estimated to result in 2,247 premature deaths, nearly 9,400 hospitalisations, over 13,200 cases of childhood asthma and more than 330,000 restricted activity days[1] each year in New Zealand at a cost of more than $10.5 billion (Kuschel *et al* 2022).

Regulating exhaust emissions is a key tool for reducing transport-related air pollution and New Zealand has required vehicles entering the fleet to meet emissions standards since 2003.[2] Over time, these standards in the *Vehicle Exhaust Emissions Rule* were tightened and all vehicles entering the New Zealand fleet are currently required to meet:

- Euro 5/V or equivalent for all **new** petrol and diesel light/heavy vehicles and
- Euro 4/IV equivalent for all **used** petrol and diesel light/heavy vehicles.

However, the current Emissions Rule does not cover the next generational steps - Euro 6/VI requirements – which were introduced in Europe seven years ago on light vehicles, and nine years ago for heavy vehicles; and which were subsequently revised frequently to be stricter still.

The latest Euro 6 and Euro VI standards deliver a step change reduction in harmful NOx emissions from diesel vehicles. This is largely due to real world emission test requirements, which have been implemented to address the growing gap between laboratory and real-world emissions, not only for NOx, but also fuel consumption and CO_2. This is important because we estimate that diesel vehicles account for around 34% of vehicle kilometres travelled, but account for more than 80% of the social costs of air pollution from motor vehicles in New Zealand.

New Zealand is a generation behind current global emission standards and is still importing new vehicles which only meet Euro 5 and Euro V -- these will remain in the fleet for many years. The considerable delay in the introduction of current emission standards will have significant implications for the health of New Zealanders for decades to come.

Te Manatū Waka Ministry of Transport (the Ministry) is considering changes to the Emissions Rule and commissioned us to investigate the air quality implications associated with different introduction dates of Euro 6/VI for **new** vehicles. [3]

The key steps in our assessment involved:

1. Estimating the emissions reduction per annum from 2021 to 2050 that would be achieved by introducing Euro 6d and Euro VI step E emissions standards
2. Calculating the social benefits (in June$2019 prices), due to avoided health effects, associated with the estimated emissions reductions

[1] A restricted activity day is one in which a person due to exposure to air pollution does not feel well enough to go to work, school or undertake their normal activities.

[2] *Land Transport Rule: Vehicle Exhaust Emissions 2007*, consolidated rule 33001/2, available from https://www.nzta.govt.nz/resources/rules/vehicle-exhaust-emissions-2007-index.html

[3] Assessing the impacts of regulations for motorcycles was outside the scope of this project.

3. Comparing the changes in emissions and social benefits resulting from a range of potential introduction dates.
4. Estimating the potential cost of the different introduction dates, based on an estimated maximum cost premium for manufacturing Euro 6/VI vehicles compared with Euro 5/V.

Our assessment found that the implementation of Euro 6 and Euro VI standards achieves substantial benefits due to harmful emissions reduction relative to a base case (no policy) scenario. We found that social benefits due to reduced health effects of air pollution ranged from $8,342 million to $1,076 million (in 2019 NZ$ as net present value).

We assume that the proportion of new vehicles that are Euro 6 and Euro VI gradually increases even in the absence of policy. However, the earlier the introduction of the standards the greater the benefits will be.

We found that estimated benefits are between 35 and 48 times higher than the estimated potential cost of the policy. For each of the introduction dates assessed, we estimated costs and benefits (in $2019 as net present value) as follows:

- Implementation of Euro 6/VI in 2024: benefits of $8,342 million, costs of $236 million
- Implementation of Euro 6/VI in 2025: benefits of $6,662 million, costs of $182 million
- Implementation of Euro 6/VI in 2027: benefits of $3,749 million, costs of $92 million
- Implementation of Euro 6/VI in 2030: benefits of $1,076 million, costs of $22 million

Nearly all (at least 98%) of the estimated benefit of the Euro 6 and Euro VI standards is due to reduction of emissions from diesel trucks and light commercial vehicles (utes and vans).

Modelling the impacts of emission standards for **used** vehicle imports was outside of the scope of this project. However, we reviewed the implications of tightening used vehicle requirements and found that:

- A regulation requiring used vehicles to meet Euro 5 and Euro V standards would have minor impacts on our findings because the majority of used vehicles entering the fleet already meet emissions levels that are equivalent to Euro 5 and Euro V.
- Used vehicle imports accounted for 30% of diesel heavy commercial vehicles, 8% of diesel light commercial vehicles and 27% of diesel passenger cars entering the fleet in 2020. This is a significant proportion of diesel imports and there is potential for this proportion to increase (e.g. if buyers choose to buy used vehicles to avoid tougher Euro 6/VI standards). This could undermine the benefits of Euro 6/VI requirements for new vehicles.
- The current Japanese standards for new diesel vehicles are not as strict as Euro 6 and Euro VI requirements.

To protect the health of New Zealanders, it is important that emission regulations for used vehicle imports do not lag too far behind new vehicle requirements. It is also important that regulations for used vehicles reflect the differences between emission standards. For example, regulations might need to specify that diesel vehicles perform better than Japanese standards to be considered equivalent to Euro 6 and Euro VI.

Finally, even vehicles achieving Euro 6/VI will continue to cause considerable health impacts in New Zealand. It is therefore important that stricter Euro 7/VI limits, which are currently being considered in Europe, should be pursued in New Zealand without long delays.

Contents

Executive summary i
1. Introduction 5
1.1 Purpose and scope of our assessment 5
1.2 Report layout 6
2. Vehicle emissions 7
2.1 Which transport-related air pollutants matter? 7
2.2 Types of vehicle emissions 8
2.3 Vehicle emission standards 9
2.4 How are vehicle emissions measured? 9
2.4.1 Type-approval test methods 9
2.4.2 Real world test methods 10
2.5 The gap between real world and test cycle emissions 11
2.5.1 Real world emissions for heavy duty vehicles 13
2.6 Current NZ emissions standards regulations 14
2.7 Euro 6/VI standards 15
2.7.1 Light duty vehicles (Euro 6) 15
2.7.2 Heavy duty vehicles (Euro VI) 16
3. Social costs of transport emissions 18
3.1 How are transport impacts assessed? 18
3.1.1 Detailed assessments 18
3.1.2 Screening assessments using damage costs 19
3.2 Social costs of transport emissions in New Zealand 19
3.2.1 Health and Air Pollution in New Zealand (HAPINZ) study 19
3.2.2 New Zealand damage costs 21
3.3 Emissions and social costs of vehicles in New Zealand 21
3.3.1 Estimated social costs per kilometre 23
4. Estimating impacts of Euro 6/VI 25
4.1 Overall methodology 25
4.2 Scenarios evaluated 25
4.3 Pollutants assessed 26
4.4 Calculating fleet weighted emission factors 26

4.4.1 Modified fleet assumptions in VEPM 28
4.4.2 Average speed assumption in VEPM 32
4.4.3 Generating emission factors 32
4.5 Estimating annual emissions 33
4.6 Calculating social costs and benefits 33
5. Estimating costs of Euro 6/VI 35
5.1 Scenarios evaluated 35
5.2 Estimating the number of Euro 6/VI vehicles 35
5.3 Estimating the cost 36
6. Results: estimated impact of Euro 6/VI for new vehicles 37
6.1 Overall social costs 37
6.2 Overall trend in emissions 37
6.3 Benefits and costs comparison 38
7. Results: likely impacts of Euro 5-6/V-VI for used vehicles 41
7.1 Japanese emissions standards 41
7.1.1 Light duty vehicles 41
7.1.2 Heavy duty vehicles 43
7.2 Impacts of tightening used vehicle emission regulation 44
8. Conclusions 46
Glossary of terms and abbreviations 47
References 49

1. Introduction

The health impacts of transport-related air pollution in New Zealand are considerable. Air pollution from motor vehicle emissions alone is estimated to result in 2,247 premature deaths, nearly 9,400 hospitalisations, over 13,200 cases of childhood asthma and more than 330,000 restricted activity days[4] each year in New Zealand at a cost of more than $10.5 billion (Kuschel *et al* 2022).

Regulating exhaust emissions is a key tool for reducing transport-related air pollution and New Zealand has required vehicles entering the fleet to meet emissions standards since 2003.[5] Over time, these standards in the *Vehicle Exhaust Emissions Rule* were tightened and all vehicles entering the New Zealand fleet are currently required to meet:

- Euro 5/V or equivalent for all **new** petrol and diesel light/heavy vehicles and
- Euro 4/IV equivalent for all **used** petrol and diesel light/heavy vehicles.

However, the current Emissions Rule does not cover the Euro 6/VI requirements – which were introduced in Europe seven years ago on light vehicles, and nine years ago for heavy vehicles. The Euro 6 and VI standards have subsequently been revised with increasingly stringent emissions test requirements and have delivered a step change reduction in NOx emissions from diesel vehicles. The European Commission is currently developing Euro 7 and Euro VII standards, which are expected to be introduced around 2025. Other major automotive markets, including Japan and North America (from whom we accept vehicles meeting their domestic standards) but also the world's largest car market, China have introduced tougher emissions standards similar to Euro 6/VI in recent years. Australia is currently still on Euro 5/V but has indicated it should shift to Euro 6/VI later this decade.

New Zealand is a generation behind current global emission standards and is still importing new vehicles that only meet Euro 5 and Euro V - these will remain in the fleet for many years. The considerable delay in the introduction of current emission standards will have significant implications for the health of New Zealanders for decades to come.

1.1 Purpose and scope of our assessment

The Ministry of Transport is considering changes to the Emissions Rule and commissioned us to investigate the air quality implications associated with different introduction dates of Euro 6/VI standards for **new** vehicles.

We have undertaken an assessment by:

- Estimating the emissions reduction per annum from 2021 to 2050 that would be achieved by introducing Euro 6d and Euro VI step e emissions standards

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[4] A restricted activity day is one in which a person due to exposure to air pollution does not feel well enough to go to work, school or undertake their normal activities.

[5] *Land Transport Rule: Vehicle Exhaust Emissions 2007*, consolidated rule 33001/2, available from https://www.nzta.govt.nz/resources/rules/vehicle-exhaust-emissions-2007-index.html

- Calculating the social benefits (in 2019 NZ$), due to avoided health effects, associated with the estimated emissions reductions
- Comparing the changes in emissions and social benefits resulting from a range of potential introduction dates.

We have also quantified the potential cost of the different introduction dates of Euro 6/VI standards, based on estimated maximum cost premium for manufacturing for Euro 6 and Euro VI vehicles compared with Euro 5/VI.

The impacts of requiring **used vehicles** entering the fleet to meet Euro 5/V or later standards **are not included in the quantitative modelliing**, however possible impacts of changes to used vehicle emission regulation are discussed qualitatively.

Motorcycles and mopeds are not included in the quantitative modelling either, primarily due to lack of data on their emissions profile however for completeness some commentary is provided.

1.2 Report layout

This report is structured as follows:

- Chapter 2 provides background information on motor vehicle emissions
- Chapter 3 discusses the social costs of motor vehicle emissions in New Zealand
- Chapter 4 describes the methodology we followed to assess the emissions and social benefits Euro 6 and Euro VI requirements for new vehicles for each scenario tested
- Chapter 5 describes the methodology we used to estimate the potential cost of Euro 6 and Euro VI requirements for new vehicles for each scenario
- Chapter 6 presents the results of the assessment for Euro 6 and Euro VI requirements
- Chapter 7 provides a qualitative assessment of emission standard requirements for used vehicles.
- Chapter 8 summarises our findings and their implications.

A glossary of terms and abbreviations is included at the end followed by a list of all references.

All data, assumptions and calculations are contained in an Excel workbook model, which is available separately.

2. Vehicle emissions

This chapter provides background information on vehicle emissions, describing which pollutants are important, how they are tested and how real world emissions compare to test results.

2.1 Which transport-related air pollutants matter?

Air pollution comprises a complex mixture of particles (usually referred to as particulate matter) and gases. Air pollutants are typically split into harmful air pollutants (which impact locally) and greenhouse gases (which impact globally). **Harmful air pollutants** are so-called because they can cause adverse human health effects ranging from increased **morbidity** (illness) to increased **mortality** (loss of life). The effects depend on the pollutant, the concentration and the length of time exposed – **acute** (short-term) or **chronic** (long-term). Figure 1 illustrates health effects associated with harmful air pollution.

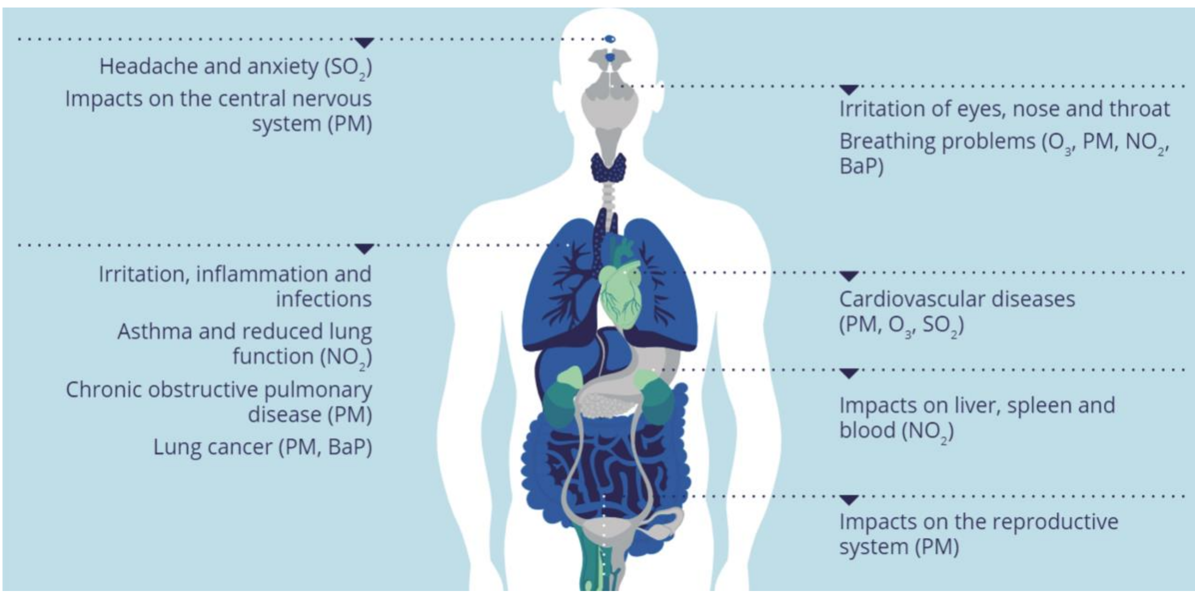

Figure 1: The impact of harmful air pollution on the human body

BaP = benzo(a)pyrene; NO_2 = nitrogen dioxide; O_3 = ozone; PM = particulate matter; SO_2 = sulphur dioxide
Source: EEA (2020).

The harmful air pollutants that are typically regulated through vehicle emission standards include:

- Particulate matter smaller than 10 µm (**PM_{10}**) or smaller than 2.5 µm (**$PM_{2.5}$**) – which arises primarily from diesel fuel combustion, brake/tyre wear and road dust. Combustion-related PM is usually in the $PM_{2.5}$ size range (known as *fine particulate*) whereas abrasion-related PM is usually in the $PM_{10-2.5}$ size range (known as *coarse particulate*). Short – and long-term exposure to PM, even at low levels, can lead to a range of health impacts especially in vulnerable people (the young, the elderly, and people with existing respiratory conditions). At the less-severe end, it can cause temporary and reversible effects such as shortness of breath, coughing, or chest pain. However, there is strong evidence of more severe effects, namely, illness and premature death from heart attacks, strokes, or emphysema (where the air sacs in the lungs are damaged). Exposure to PM can also cause lung cancer and exacerbate asthma. Studies point to possible links with diabetes and atherosclerosis (the accumulation of fat, cholesterol, and other substances on artery walls, reducing blood flow) due to increased inflammation caused by particulate matter (MfE & StatsNZ 2021)

- Nitrogen oxides (**NO_X**), in particular, nitrogen dioxide (**NO_2**) – which is emitted primarily from diesel and petrol fuel combustion. There are health impacts from short-term and long-term exposure to nitrogen dioxide. Short-term exposure to high concentrations of nitrogen dioxide causes inflammation of the airways and respiratory problems and can cause asthma attacks. Short-term exposure may also trigger heart attacks and increase the risk of premature death. Long-term exposure may cause asthma to develop and lead to decreased lung development in children. It may also increase the risk of certain forms of cancer and premature death (MfE and Stats NZ 2021). Nitrogen dioxide contributes to brown haze, which occurs in Auckland, and which is associated with an increase in hospital admissions. It also contributes to the formation of ground-level ozone and secondary particulate matter (when gases in the atmosphere react in the presence of sunlight), both of which can have negative health impacts (MfE & StatsNZ 2021).
- Hydrocarbons (**HC**)– which come from evaporation of fuel in engines and refuelling systems as well as fuel combustion. Hydrocarbons, particularly the volatile organic compounds (**VOC**) from motor vehicles, include a wide variety of chemicals which may have short- and long-term health effects ranging from irritation of the eyes through to cancer (Smith *et al*, 2009).
- Carbon monoxide (**CO**) – which is associated particularly with the incomplete combustion of petrol. Carbon monoxide can have a range of health effects even after short-term exposure to relatively low concentrations. When inhaled, carbon monoxide enters the blood stream and attaches to haemoglobin in red blood cells, which transport oxygen around the body. This reduces the amount of oxygen that body tissues receive and can have adverse effects on the brain, heart, and general health. Exposure to low levels can causes dizziness, weakness, nausea, confusion, and disorientation. However, higher levels can cause collapse, loss of consciousness, coma, and death (MfE & StatsNZ 2021).

2.2 Types of vehicle emissions

Vehicle emissions can be categorised into three groups (EEA, 2016):

- **Exhaust** emissions – vehicle engines emit many different pollutants in addition to CO_2. The amount of each pollutant depends on the fuel used (e.g. petrol or diesel) and the engine technology (including emission control equipment).
- **Abrasion** emissions – the emissions produced from the mechanical abrasion and corrosion of vehicle parts and road surface wear. Abrasion is important for PM emissions and emissions of some heavy metals.
- **Evaporative** emissions- due to vapours escaping from the vehicles fuel system. Evaporative emissions are important for VOC’s.

Figure 2 illustrates the different types of emissions from vehicles.

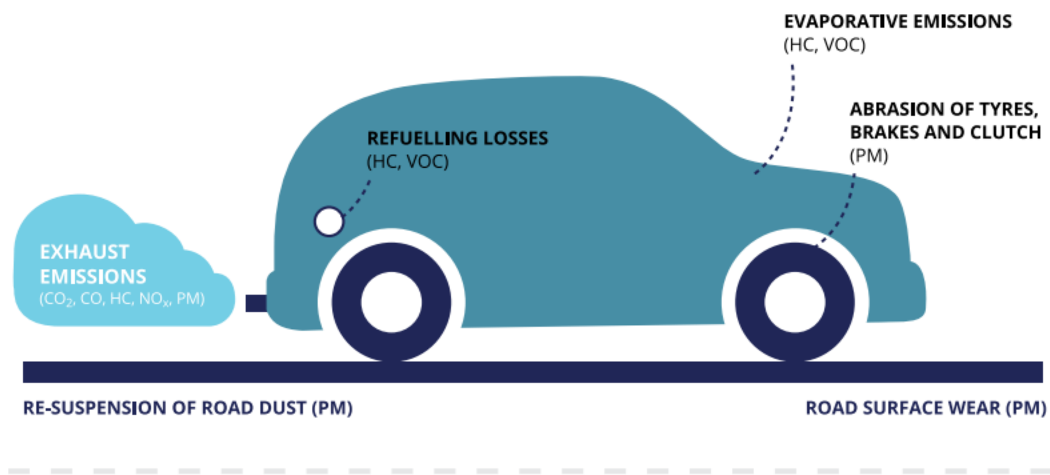

Figure 2: The different types of emissions from vehicles

Source: EEA (2016).

2.3 Vehicle emission standards

Exhaust emission limits have successfully reduced levels of air pollution exposure around the world over the past decades. Pollutant emission standards were first introduced in Europe in 1970, becoming the Euro standards in 1992. Increasingly tighter emission limits have led to the introduction of new emission control technologies and substantial reductions in vehicle emissions over the last 40 to 45 years. As an example, the latest technology Euro 6 diesel car must emit almost 97% less PM when tested compared with a 20-year-old Euro 1 vehicle (EEA 2016).

Standardised measurements in laboratories are used to check that vehicles meet requirements for exhaust emissions. As it is not practical to test all vehicles, one production vehicle is tested – with this vehicle being considered representative of the 'type'. If all standards are met 'type approval' is issued. The most recent Euro 6 and VI emission standards also introduced requirements for real world emissions testing (measured on the road). These requirements are described in the following sections.

2.4 How are vehicle emissions measured?

2.4.1 Type-approval test methods

Historically, 'type-approval testing' (i.e. confirming a vehicle model complies with its regulated emissions standard) has been performed under controlled conditions using a chassis dynamometer (see Figure 3).

Figure 3: Chassis dynamometer testing at the Energy and Fuels Research Unit, University of Auckland

During chassis dynamometer testing, the test vehicle is driven on a set of rollers that simulate driving resistances according to a standard time/velocity profile known as a 'drive cycle' (Franco *et al* 2014). The emissions of the test vehicle are collected and then compared with the exhaust (harmful) emission standard (e.g. Euro 5) or the applicable fuel consumption limit. The standard drive cycles used for type-approval testing include a prescribed set of typical driving events (e.g. cold start, warm start, accelerations, decelerations and steady state driving) but typically under-represent real-world emissions.

2.4.2 Real world test methods

Real world vehicle emissions can be estimated from chassis dynamometer emissions tests undertaken with real world drive cycles. These drive cycles are designed to represent real world driving conditions and cover a much wider range of operating conditions compared to type-approval drive cycles. Real world emissions have more recently been measured, while vehicles are being driven on the road, with remote sensing devices or portable emissions measurement systems (PEMS).

Remote sensing refers to measuring vehicle exhaust emissions as the vehicle passes using equipment located on the roadside (known as a remote sensing device or RSD). Unlike chassis dynamometer or PEMS equipment, RSDs do not need to be physically connected and therefore do not interfere with the operation of the vehicle.

Remote sensing provides snapshots of emission rates from thousands of individual vehicles, as they are driven on actual roadways by their owners, relatively easily and cost effectively versus other methods. It provides information on trends in fleet and subfleet emissions (if sufficient numbers of vehicles are sampled) and can be used to identify potential 'gross emitters' (ie vehicles that emit considerably more than their type on average due to poor maintenance or tampering). However, while remote sensing is valuable as a screening method, it cannot be used for type approval or compliance because it records only a small fraction of a drive cycle.

The use of PEMS involves carrying a full set of instruments on board the test vehicle to record instantaneous measurements of emissions, engine operating conditions and road conditions while the vehicle drives a real-world route (see Figure 4).

Figure 4: PEMS equipment being installed in a test vehicle in Auckland

Source: Kuschel *et al* (2019)

2.5 The gap between real world and test cycle emissions

Studies carried out overseas and in New Zealand have found that vehicles on the road generally emit more in the 'real world' (i.e. when being driven on real roads experiencing real traffic conditions) than the emissions standards to which they are 'type approved' (i.e. being driven in a laboratory according to test conditions designed to simulate real-world driving). A study undertaken by the International Council for Clean Transportation summarised the results of PEMS studies from Europe and the United States and found that on average, real world NOx emissions were around seven times higher than the limits set by the Euro 6 standard (Franco *et al* 2014).

Figure 5 illustrates the difference between real world emission and emission standards for light duty petrol and diesel vehicles from Euro 3 through to Euro 6 (EEA, 2016). Similar results were found in a New Zealand PEMS study which gathered measurements for 32 vehicles in total, comprising six light duty petrol vehicles, 20 light duty diesel vehicles and six heavy duty diesel vehicles (Kuschel *et al* 2019).

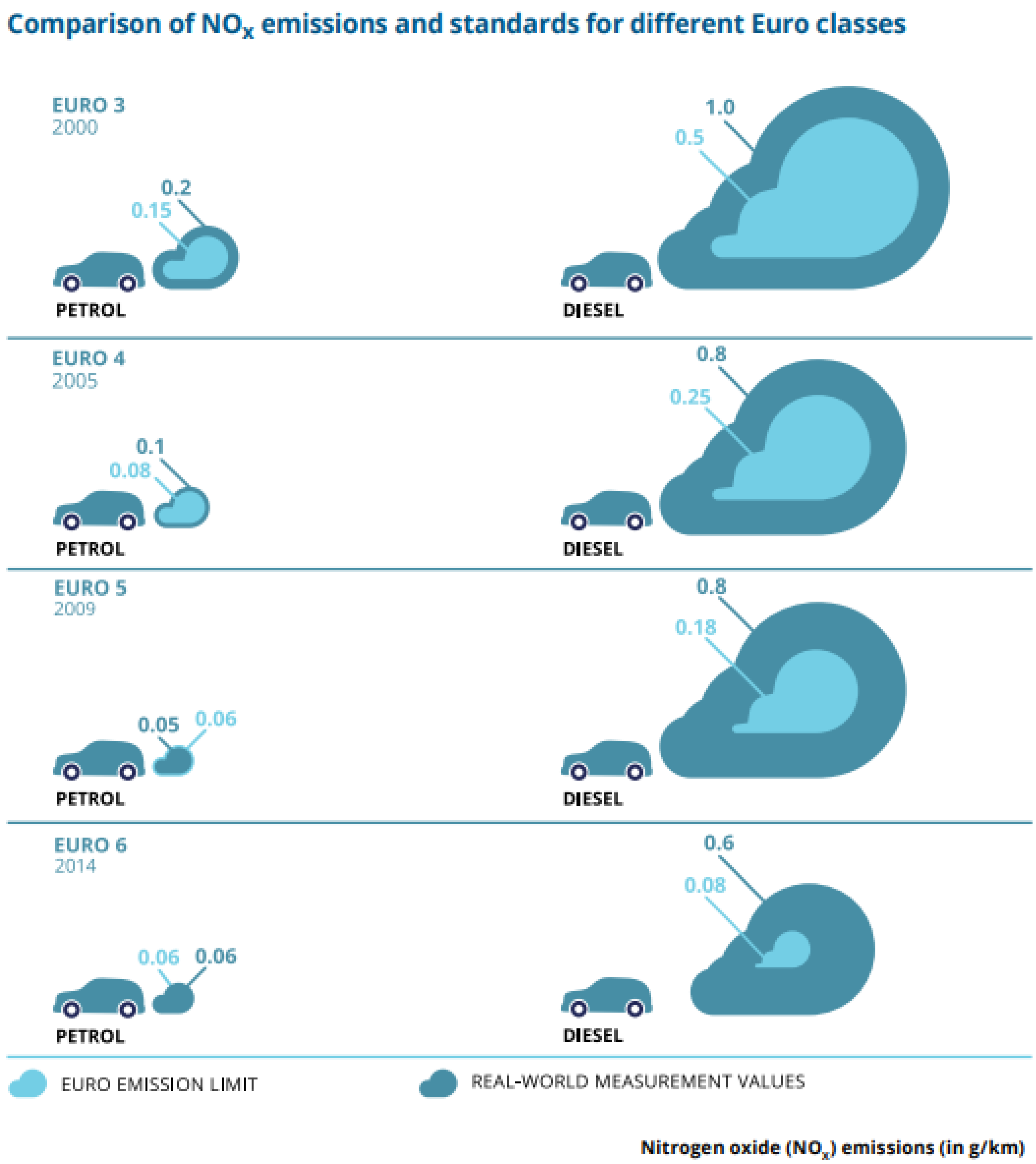

Figure 5: Comparison of real world NOx emissions and standards for different Euro vehicles

Source: EEA (2016).

In response to the significant (and growing) gap between emissions standards and real-world emissions, vehicle emission test procedures have become more stringent since Euro 6 standards were first introduced in 2014. These increasingly stringent requirements have been introduced in stages (Euro 6b, Euro 6c, Euro 6d-TEMP and Euro 6d). Stages 6d-TEMP and 6d include requirements for real world emissions testing with PEMS as part of type approval, as well as in-service conformity testing to demonstrate that emissions standards continue to be achieved as vehicles age.

The stages of Euro 6 have shown a progressive reduction in real world driving emissions of NOx from light duty diesel vehicles.

Figure 6 illustrates the overall reduction in real world NOx and PM emissions from light duty diesel (shown in blue) and light duty petrol (shown in red) vehicles (Lee *et al* 2021). These emission factors are estimated from the results of remote sensing campaigns across Europe. The emission factors shown for Euro 6d and Euro 7 are estimated by the authors based on expected improvements. The authors expect Euro 7 to come into force in 2025 with a fuel neutral NOx emission factor (i.e. diesel and petrol vehicles are expected to have similar emission standards).

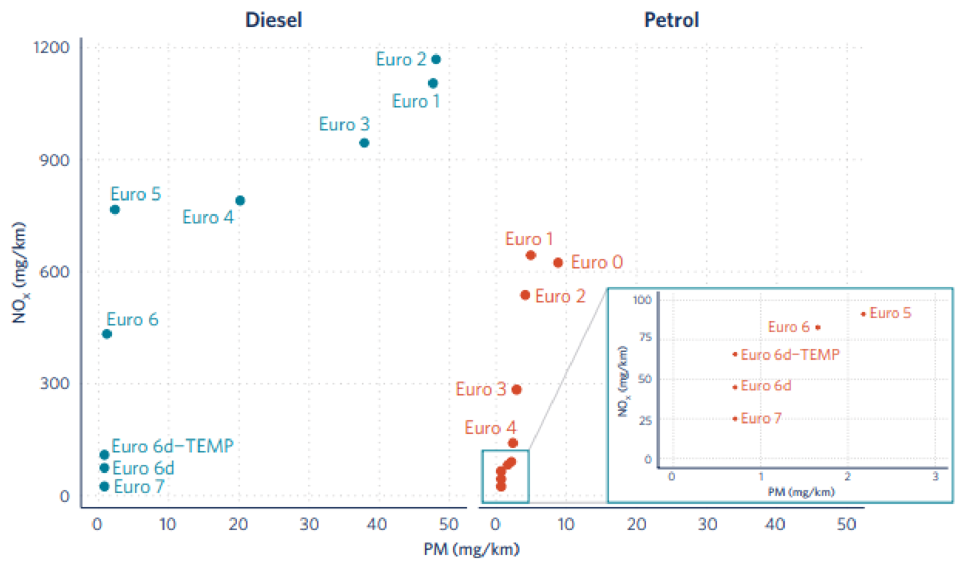

Figure 2. Comparison of NO_x and PM emissions performance by Euro standard and fuel type grouping.

Figure 6: Comparison of real world NOx and PM emissions estimated from remote sensing. Results are grouped by Euro standard with diesel vehicles shown in blue and petrol vehicles in red.

Source: Lee *et al* (2021)

2.5.1 Real world emissions for heavy duty vehicles

Emission tests have shown similar trends for heavy duty vehicles. Emissions testing has shown that heavy duty vehicles built to Euro IV and Euro V standards frequently do not meet emissions limits in real world conditions. However, test results show that Euro VI vehicles deliver a step change reduction in real world NOx emissions compared with previous standards. A key reason for this step change was the introduction of real driving emission requirements through on road testing with PEMS. These requirements help to ensure that type approval emissions more closely match real world emissions for Euro VI vehicles. In service testing requirements were also introduced with Euro VI, requiring that manufacturers regularly test in-use vehicles to ensure that vehicles continue to achieve emissions standards even as they age.

Figure 7 illustrates the results of emissions testing undertaken on Euro IV, V and VI heavy duty diesel vehicles. These tests were undertaken on a chassis dynamometer for a range of test cycles that were designed to simulate real world conditions (ICCT 2015).

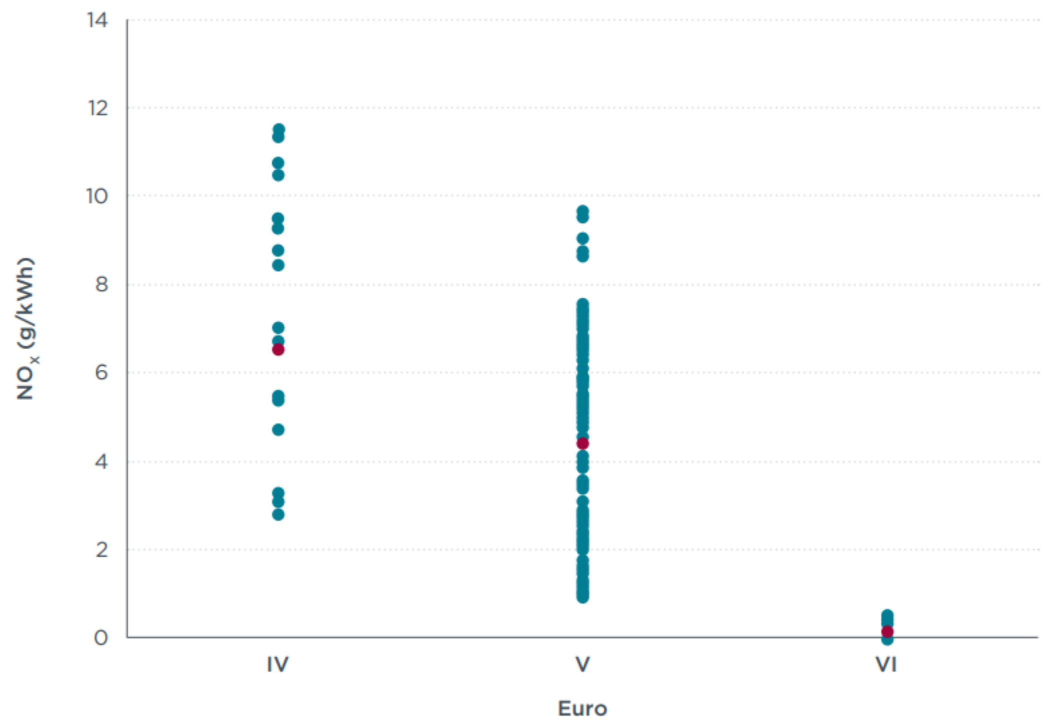

Figure 7: NOx emissions from heavy duty vehicles tested on a chassis dynamometer with real-world test cycles. Red dot points to average.

Source: ICCT (2015)

2.6 Current NZ emissions standards regulations

New Zealand does not manufacture vehicles. This means that all vehicles imported into New Zealand are built to international emission standards. Nearly all vehicles imported into New Zealand are either:

- new vehicles manufactured to European emission standards, or
- used Japanese vehicles manufactured to Japanese emission standards.

New Zealand has required vehicles entering the fleet to meet emissions standards since 2003.[6] Over time, these standards in the *Vehicle Exhaust Emissions Rule* have tightened and all vehicles entering the New Zealand fleet are currently required to meet:

- Euro 5/V or equivalent for all **new** petrol and diesel light/heavy vehicles. These requirements applied to newly introduced light vehicle models manufactured from 2013 and existing models from 2016. For heavy duty vehicles the requirements applied to newly introduced models manufactured from 2011 and existing models from 2012[7] and

[6] *Land Transport Rule: Vehicle Exhaust Emissions 2007*, consolidated rule 33001/2, available from https://www.nzta.govt.nz/resources/rules/vehicle-exhaust-emissions-2007-index.html

[7] Entry dates for equivalent Japanese and American standards differ slightly.

- Euro 4/IV equivalent for all **used** petrol and diesel light/heavy vehicles. These requirements applied to used light duty diesel vehicles entering service from 2008, heavy duty diesel vehicles from 2009 and light duty petrol vehicles from 2012. These requirements have not been updated since.

However, a significant amount of time has elapsed since these requirements were last updated, and the current Emissions Rule does not cover the next steps - Euro 6/VI requirements.

2.7 Euro 6/VI standards

2.7.1 Light duty vehicles (Euro 6)

Euro 6 requirements were applied in Europe to all sales of new cars from 2015 and light commercial vehicles from 2016, which is about the same timeframe that New Zealand mandated the earlier generation Euro 5 standards for new vehicles. Table 1 compares the Euro 5 and Euro 6 standards for **light duty**[8] vehicles, showing the most significant changes are reduced NO_X emission limits for diesel vehicles.

Euro 6 standards are specified as steps (Euro 6a, Euro 6b, Euro 6c, Euro 6d-TEMP, and Euro 6d). The emission limit is unchanged, however these steps have increasingly stringent test requirements. These requirements have been designed to close the gap between real world and regulated emissions as discussed previously.

Up to 2018, light duty vehicles were tested in Europe accordance with a pre-defined drive cycle known as the New European Drive Cycle (**NEDC**). The more recently developed Worldwide Harmonised Light Vehicles Test Cycle (**WLTC**[9]) was designed to better represent real world driving conditions[10]. The WLTC has been required for new light duty vehicles since September 2018. More recently, Real Driving Emissions (**RDE**) requirements have been introduced which requires road testing with PEMS equipment. The type approval test requirements have become more stringent in stages as follows:

- Euro 6b – tests based on the NEDC – phased in from September 2014
- Euro 6c – tests based on the WLTC – phased in from April 2016
- Euro 6d-TEMP – tests based on the WLTC. RDE test requirements introduced with temporary conformity factor for NOx – phased in from September 2017
- Euro 6d – is the full Euro 6 emission requirement including RDE testing against final conformity factors – phased in from January 2020

[8] Vehicles with a gross vehicle mass less than 3.5 tonnes.

[9] The WLTC refers to the chassis dynamometer test cycle for the determination of emissions and fuel consumption from light-duty vehicles. The WLTP procedures define a number of other procedures – in addition to the WLTC test cycle – that are needed to type approve a vehicle.

[10] The WLTC has been designed to address the growing gap between type approval and real world emissions for fuel consumption and CO_2 emissions (used in climate change policy) as well as harmful emissions.

To ensure emissions compliance over the life of vehicles, the Euro 6d-TEMP and Euro 6d requirements include in service conformity testing which periodically requires manufacturers to test and report real world emissions using PEMS on vehicles that have been in use for up to five years.

The current standard for light duty vehicles in Europe is Euro 6d.

Table 1: Comparison of Euro 5 and Euro 6 emission standards

Vehicle type	Emission standard	CO	HC	NO_X	PM
		(g/km)			
Petrol passenger car	Euro 5	1.0	0.1	0.06	0.005
	Euro 6	1.0	0.1	0.06	0.005
Diesel passenger car	Euro 5	0.5	-	0.18	0.005
	Euro 6	0.5		0.08	0.005
Petrol LCV > 1760kg	Euro 5	2.27	0.16	0.082	0.005
	Euro 6	0.74	0.16	0.082	0.005
Diesel LCV > 1760kg	Euro 5	0.74	-	0.28	0.005
	Euro 6	0.74		0.125	0.005

Source: dieselnet.com

2.7.2 Heavy duty vehicles (Euro VI)

Euro VI[11] requirements were applied in Europe to all sales of new **heavy duty**[12] vehicles from 2013, which is also about the timeframe that New Zealand mandated the earlier generation Euro V standard for new vehicle imports. Table 2 compares the Euro V and Euro VI standards for heavy duty vehicles, showing the most significant changes are reduced NO_X emission limits for diesel vehicles.

Emissions from Euro VI diesel vehicles are tested in accordance with the World Harmonised Transient Cycle (**WHTC**) and the World Harmonised Stationery Cycle (**WHSC**) which were developed to represent real world driving conditions. Test requirements also include in-use vehicle PEMS testing for type approval. The Euro VI regulation also introduced in service conformity testing, which requires in-use PEMS testing on vehicles that have been in use for a certain number of kilometres or years to ensure that they still have pollution performance that is within limits. Euro VI emission standards are specified as step A, B, C, D or E. Steps D and E have more stringent PEMS test requirements, compared with steps A/B/C, however the limit values remain unchanged at each step.

[11] Note the convention is to use Roman numerals for the Euro standards applying to heavy vehicles (e.g. Euro V) and Arabic for those applying to light vehicles (e.g. Euro 5).

[12] Vehicles with a gross vehicle mass greater than 3.5 tonnes.

The current standard for heavy duty vehicles in Europe is Euro VI step E.

Table 2: Comparison of Euro V and Euro VI emission standards, for steady state testing

Emission standard	CO	HC	NO_X	PM
	(g/kwh)			
Euro V	1.5	0.46	2.0	0.02
Euro VI	1.5	0.13	0.4	0.01

Source: dieselnet.com

3. Social costs of transport emissions

This chapter briefly describes how the social costs of harmful emissions from transport are assessed. Background information about the social costs of harmful emissions from motor vehicles in New Zealand is also provided.

3.1 How are transport impacts assessed?

The social costs of health impacts associated with transport emissions can be assessed using either detailed or screening methods.

3.1.1 Detailed assessments

Detailed assessments go through a rigorous set of steps as shown in Figure 8.

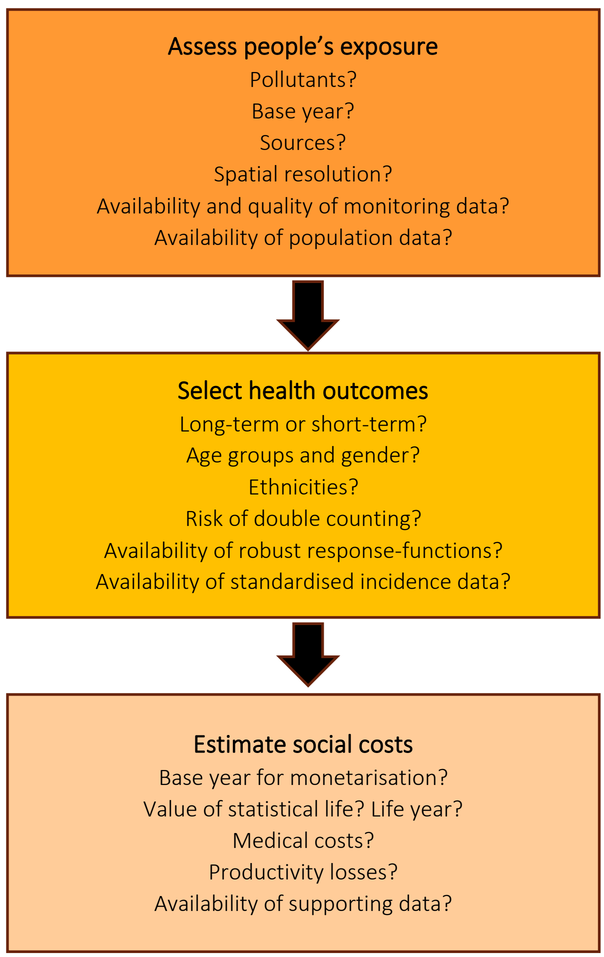

Figure 8: Typical steps involved in a detailed assessment of air pollution health effects

Source: Kuschel *et al* (2012)

Effects are usually estimated at a fine scale then aggregated up to airshed, regional or national totals (a *bottom up* process). While they provide information that is vital for tailoring local emissions management strategies, detailed assessments are time and resource intensive and and are therefore usually undertaken infrequently.

3.1.2 Screening assessments using damage costs

A simpler way to estimate health impacts is to use a screening method, e.g. damage costs for air pollution health impacts. Emissions to air, either air quality or greenhouse gas, cause an impact on society through increased medications use, lost productivity through illness, increased hospitalisations, death and extremes in climate.

Damage costs are a way to value changes in air emissions so that the benefits to society of a change in policy/operation can be compared against the cost of implementing the change. They can also be used to compare a range of options to see which will yield the best overall outcome. The social costs associated with changes in harmful and GHG pollution can be calculated by combining the emissions (usually expressed in grams or tonnes of each pollutant) with unit damage costs (expressed in $ per tonne). Damage costs **are typically derived from the results of detailed assessments**.

Damage cost assessments based on emissions are relatively easy to undertake. However, they are only a **proxy for air pollution health effects**. The concentration of a pollutant in ambient air does depend on emissions but is influenced by other factors – such as meteorology, atmospheric chemistry and topography. Nonetheless, this approach is a reasonable approximation and is widely used for policy evaluation.

3.2 Social costs of transport emissions in New Zealand

3.2.1 Health and Air Pollution in New Zealand (HAPINZ) study

The Health and Air Pollution in New Zealand (HAPINZ) study is a detailed assessment of air pollution health effects for New Zealand. The most recent update (**HAPINZ 3.0**), which is based on 2016 data, is due to be published in April 2022 (Kuschel *et al* 2022).

Air pollution health effects in New Zealand were first assessed in detail in the Health and Air Pollution in New Zealand (**HAPINZ 1.0**)[13] study undertaken by Fisher *et al* (2007). In this study, health effects were evaluated for 67 urban areas based on 2001 population and ambient monitoring data. This work was later updated by Kuschel *et al* (2012) to incorporate population data from the 2006 census and more comprehensive monitoring being undertaken across New Zealand in response to the introduction of a national environmental standard for ambient particulate matter (**PM_{10}**) concentrations in September 2005 (MfE 2011). This updated study (**HAPINZ 2.0**) estimated that air pollution from *anthropogenic* (human-generated) sources in New Zealand in 2006 was responsible for approximately 1,175 premature deaths, more than 600 hospitalisations and almost 1.5 million restricted activity days at a total cost of

[13] This report refers to the previous studies of Fisher *et al* (2007) and Kuschel *et al* (2012) as HAPINZ 1.0 and HAPINZ 2.0 respectively to make it easier to differentiate between those studies and this one (HAPINZ 3.0).

NZ$4.3 billion as at June 2010. Motor vehicles were estimated to account for 22% of anthropogenic air pollution with an estimated social cost of NZ$0.9 billion as at June 2010.

Since 2012, the database of ambient monitoring across New Zealand has further expanded, including many more locations, pollutants and sources, and exposure-response functions are now available for a greater range of health endpoints. In recognition, the Ministry for the Environment commissioned a new update – **HAPINZ 3.0** – in 2019 to better reflect the air pollution health impacts experienced by New Zealanders and update the effects for 2016.

This latest update - **HAPINZ 3.0** –differs to the previous studies in that it:

- uses more recent population, health and air quality monitoring data - based on 2016 - with relevant data averaged over 2015-2017 to account for inter-annual variability in meteorological conditions
- extends the assessment of impacts to a broader range of contaminants - pollutants covered include not only particulate matter less than 10 µm[14] in size (**PM_{10}**) but also particulate matter less than 2.5 µm (**$PM_{2.5}$**) and nitrogen dioxide (**NO_2**). Particulate matter and NO_2 contribute to most air pollution health effects in New Zealand.
- incorporates New Zealand-specific exposure-response functions for primary health impacts of air pollution exposure, such as mortality and hospital admissions
- assesses the impacts on childhood asthma using indicators for increased prevalence and exacerbation in the community
- presents updated social costs (in NZ$ as at June 2019[15]) for the value of a statistical life (**VoSL**), as well as the value of a life year lost (**VoLY**) and loss of life quality.

HAPINZ 3.0 estimates the **total social costs** associated with anthropogenic air pollution in New Zealand in 2016 to be **$15.6 billion or $3,312 per person.** Air pollution from motor vehicle emissions is estimated to result in 2,160 premature deaths, nearly 9,400 hospitalisations and more than 330,000 restricted activity days[16] each year in New Zealand at a cost of more than $10.5 billion.

HAPINZ 3.0 estimates that motor vehicles account for 67% of the health effects associated with air pollution from anthropogenic sources. This is a significant change from HAPINZ 2.0 which estimated that motor vehicles accounted for 22% of the health impacts associated with anthropogenic sources. In HAPINZ 2.0, the total anthropogenic costs were assigned to PM_{10} only (as a proxy for all air pollution) because of limitations in data availability. Because the impacts were assigned to sources based on their contributions to PM_{10} (rather than all) air pollution, the findings prioritised addressing domestic fire emissions over motor vehicle emissions for most locations across New Zealand.

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[14] A µm, also known as a micrometre, is a millionth of a metre, i.e. 0.0000001 m.

[15] HAPINZ 3.0 uses a base year of 2016 because it is the most recent year for which we have a complete set of relevant air quality, population and health data. However, the social costs are calculated for 2019 to align with the latest road safety VoSL value.

[16] A restricted activity day is one in which a person due to exposure to air pollution does not feel well enough to go to work, school or undertake their normal activities.

In HAPINZ 3.0, sufficient information meant that both $PM_{2.5}$ and NO_2 were able to be used as the indicators for air pollution. While domestic fires were identified as the primary contributor to anthropogenic $PM_{2.5}$ impacts ($6.1 billion), motor vehicles were assigned as the sole source of NO_2 impacts ($9.5 billion).

3.2.2 New Zealand damage costs

In New Zealand, damage costs for air emissions are published in the *Monetised Benefits and Costs Manual* (**MBCM**) (NZTA 2021a) and were updated as part of the Domestic Transport Costs and Charges (**DTCC**) project commissioned by the Ministry (Kuschel *et al* 2021). The MBCM and DTCC costs for PM_{10} were based on **HAPINZ 2.0** (Kuschel *et al* 2012) which assessed the effects from PM_{10} only. Damage costs for other pollutants were estimated based on international data.

More recently, HAPINZ has been updated to include a New Zealand assessment of NO_2 health effects in addition to particulate matter (**HAPINZ 3.0**). Updated damage costs for New Zealand have been derived from the results of HAPINZ 3.0 as national average values, but also differentiated between *urban* (reflecting the higher exposure to emissions in more densely populated areas) versus *rural* (much lower exposures) (Kuschel *et al* 2022).

New Zealand average damage costs from HAPINZ 3.0 are shown in Table 3.

Table 3: New Zealand average air emissions damage costs in $/tonne (June 2019 prices)

Pollutant	Costs in NZ$/tonne New Zealand	Value base date (at end June)
PM_{10}	$382,524	2019
NO_X	$186,037	2019
VOC	$880	2019
CO	$3	2019

Source: Kuschel *et al* (2022)

3.3 Emissions and social costs of vehicles in New Zealand

A detailed assessment of transport emissions in New Zealand was recently undertaken as part of the Domestic Transport Costs and Charges (**DTCC**) project (Kuschel *et al* 2021). Figure 9 shows estimated vehicle kilometres travelled (**VKT**) and emissions of NOx and $PM_{2.5}$ (including exhaust, brake and tyre wear) from the New Zealand vehicle fleet in 2018/19[17]. This assessment shows that, although petrol vehicles account for 66% of VKT, they only account for 21% of NOx and 14% of $PM_{2.5}$ emissions from all on-road motor vehicles in New Zealand. As shown in Figure 9 diesel heavy commercial vehicles (**HCV**s)

[17] This estimate is based on all vehicles on the road in 2018/19 including new and used imports.

and light commercial vehicles (**LCV**s) account for most of the NOx and $PM_{2.5}$ emissions from motor vehicles in New Zealand[18].

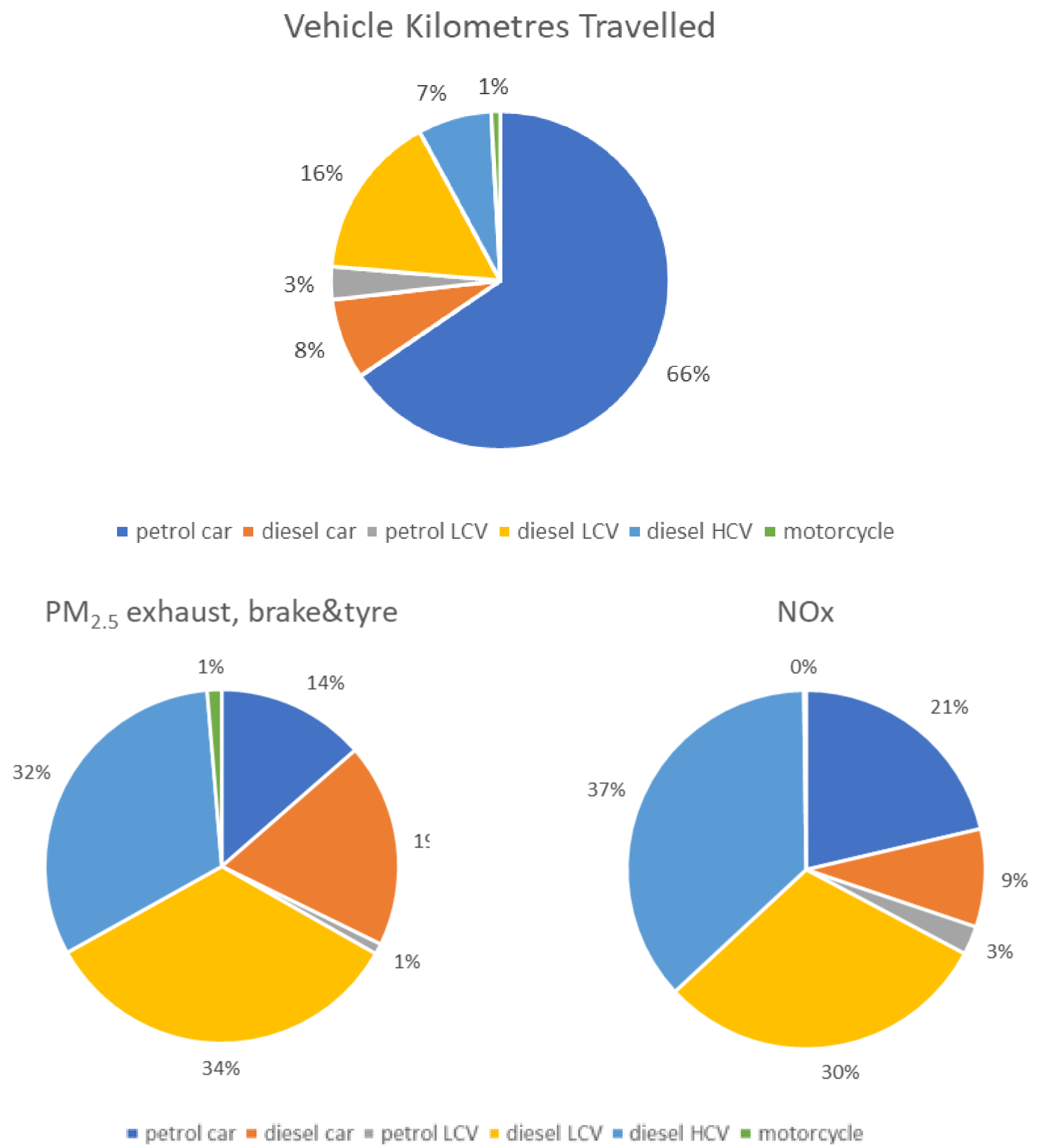

Figure 9: **Proportion of vehicle kilometres travelled, $PM_{2.5}$ emissions (exhaust, brake & tyre) and NOx emissions by vehicle type for the entire fleet in New Zealand in 2018/19.**

Note: Petrol car includes petrol, hybrid and plug-in hybrids. Road surface wear is not included in the $PM_{2.5}$ total. Source: DTCC project (Kuschel *et al* 2021).

[18] Motorcycle emissions were assessed as part of the DTCC project but only using a Tier 1 EMEP/EEA methodology based on VKT because a detailed motorcycle fleet profile was not available (EMEP/EEA 2019). This assessment suggests that motorcycles contribute less than 1.2% of PM (from exhaust and brake/tyre wear) and less than 0.2% of NOx emitted by all road transport in 2018/19.

3.3.1 Estimated social costs per kilometre

We have estimated the social costs per kilometre associated with emissions from different vehicle classes to illustrate the difference between vehicles. Table 4 compares estimated emissions and damage costs on a per kilometre basis for:

- Fleet average vehicles in New Zealand (at 2022)
- Euro 6/VI vehicles
- Electric vehicles.

Emission factors are estimated based on emission factors from the Waka Kotahi *Vehicle Emission Prediction Model* (**VEPM 6.3**)[19] for 2022 with an average speed of 48km/hr and all other settings at default, except:

- Road wear which is from EMEP/EEA (2019)[20]
- Motorcycles[21] which are from the Domestic Transport Costs and Charges project (Kuschel *et al* 2021). A Tier 1 EMEP/EEA methodology (EMEP/EEA 2019[22]) was used to estimate emissions for motorcycles in DTCC, based on VKT, because a detailed motorcycle fleet profile was not available.

Social costs are based on HAPINZ 3.0 damage costs as shown in Table 3 for harmful emissions.

The estimated social costs in Table 4 show, for light duty vehicles:

- An average petrol car costs society (in terms of harmful emissions) around 6 times more than an EV for every km driven. By comparison, an average diesel LCV (van or ute) costs society around 39 times more than an EV.
- However, modern vehicles are substantially better. A petrol car complying with the latest European emission standards (Euro 6d) costs society (in terms of harmful emissions) around 1.5 times more than an EV. By comparison a diesel LCV (van or ute) complying with the latest European emission standards (Euro 6d) would cost society around 4.4 times more than an EV.

For HCVs, the estimates show:

- An average 20 tonne diesel truck costs society (in terms of harmful emissions) around 40 times more than an equivalent electric truck for every km driven.
- However, modern vehicles are substantially better. A truck complying with the latest European emission standards (Euro VI) costs society (in terms of harmful emissions) around 3.3 times more than an electric truck.

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

[20] See Chapter 1.A.3.b vi - *Road Transport: Automobile Tyre and Brake Wear* and Chapter 1.A.3.b vii - *Road Transport: Automobile Road Abrasion*

[21] In this report, the term “motorcycles” includes mopeds.

[22] See Chapters 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv *Passenger cars, light commercial trucks, heavy-duty vehicles including buses and motor cycles*

Table 4: Estimated emissions and damage cost per km for fleet average, Euro 6/VI, and electric vehicles. The ratio of cost/km for internal combustion engine (ICE) vehicles to the equivalent electric vehicle (EV) is shown.

Emissions factor	Vehicle type	CO	VOC	NOx	$PM_{2.5}$ exhaust	$PM_{2.5}$ brake and tyre	$PM_{2.5}$ road wear	Social cost ($2019)	Ratio ICE/EV cost
		g/km						$/km	
Light vehicles									
Fleet average	petrol car	1.403	0.076	0.148	0.002	0.010	0.004	$0.034	6.1
	diesel car	0.109	0.024	0.605	0.064	0.010	0.004	$0.143	25.7
	diesel LCV	0.147	0.031	1.064	0.034	0.016	0.004	$0.219	39.4
Euro 6d	petrol car	0.221	0.008	0.015	0.001	0.010	0.004	$0.009	1.5
	diesel car	0.017	0.001	0.045	0.002	0.010	0.004	$0.015	2.6
	diesel LCV	0.000	0.000	0.087	0.001	0.016	0.004	$0.024	4.4
Electric*	car					0.010	0.004	$0.006	6.1
Motorcycles									
Fleet average	motorcycle	17.400	4.600	0.200	0.077	0.003	0.002	$0.073	
Electric*	motorcycle					0.003	0.004	$0.003	
Heavy commercial vehicles									
Fleet average	7.5-10 tonne	1.035	0.135	2.879	0.111	0.016	0.021	$0.592	42.4
	20-25 tonne	1.421	0.168	4.922	0.167	0.043	0.021	$1.004	41.1
Euro VI	7.5-10 tonne	0.093	0.018	0.174	0.002	0.016	0.021	$0.047	3.4
	20-25 tonne	0.143	0.032	0.295	0.004	0.043	0.021	$0.081	3.3
Electric*	7.5-10 tonne					0.016	0.021	$0.014	
	20-25 tonne					0.043	0.021	$0.024	25.5

Note: * Electric vehicle emissions above include brake and tyre wear and road dust only. These are assumed to be the same as the emission factors for the equivalent internal combustion engine vehicle in VEPM 6.3. Research suggests that brake and tyre wear factors for battery electric and hybrid vehicles may be lower than equivalent vehicles due to regenerative braking. However, this is an area of ongoing research and different emission factors for battery electric and hybrid vehicles are not yet available.

4. Estimating impacts of Euro 6/VI

This chapter describes our methodology for estimating the emissions and social impacts of updating the NZ emissions standards regulations that vehicles entering the fleet are required to meet:

- Euro 6/VI or equivalent for all **new** petrol and diesel light/heavy vehicles.

Note: We acknowledge that **used** vehicles will be required to meet Euro 5/V or equivalent and Euro 6/VI at some future date. However, the impacts of this requirement are not explicitly modelled in this assessment. The potential impacts are discussed qualitatively in Section 7.

4.1 Overall methodology

Our overall methodology for the assessment followed three steps:

1. For the base case and each scenario, and for all years from 2021 to 2050, we:
    a. Calculated fleet weighted emission factors for a base case and policy scenarios
    b. Multiplied fleet weighted emissions factors (in g/km) by the annual vehicle kilometres travelled in New Zealand to arrive at tonnes per annum of pollutant
    c. Calculated social costs (for the base case and each scenario) by combining the emissions (tonnes per annum) with the unit damage costs (expressed in $ per tonne)
    d. Converted costs into present values.
2. We then added present value costs for all years from 2021 to 2050 to arrive at a total social cost for each scenario.
3. Finally, we calculated the difference between the base case and each scenario to arrive at the estimated total social benefit for each scenario.

These steps are described in more detail in the following sections. All calculations are provided in the accompanying spreadsheet *Euro 6 benefits.xlsx*.

4.2 Scenarios evaluated

Emissions and social costs were calculated for a base case and four policy scenarios as follows:

- **Base case**: expected uptake of Euro 6 and Euro VI vehicles without policy intervention
- **Scenario 1**: Euro 6d and Euro VI D/E from 2024
- **Scenario 2**: Euro 6d and Euro VI D/E from 2025
- **Scenario 3**: Euro 6d and Euro VI D/E from 2027
- **Scenario 4**: Euro 6d and Euro VI D/E from 2030

Under each scenario, we assumed that:

- all vehicles comply with Euro 6d and Euro VI D/E from the implementation date (i.e. including the year of implementation) onwards.
- prior to the date of implementation, the proportion of Euro 6 and Euro VI vehicles was unchanged from the base case (described in Section 4.4, Tables 5 and 6).

Note: We assessed the air quality implications associated with different introduction dates of Euro 6/VI for **new** vehicles only. Changes in emissions standards for used vehicles are discussed in Section 7.

4.3 Pollutants assessed

Our assessment included harmful air pollutants only and was restricted to those regulated by Euro vehicle emission standards, i.e. PM, NO_X, VOCs and CO.

Note: Greenhouse gas emissions were not included in our assessment of Euro 6/VI impacts as these are typically regulated separately to harmful emissions.

Light vehicle CO_2 is regulated by fleet average requirements enacted by *the Land Transport (Clean Vehicles) Amendment Act 2022*[23] and heavy vehicle CO_2 is currently unregulated in New Zealand except for an upcoming requirement that new public transport buses be zero emission vehicles from 2025[24].

4.4 Calculating fleet weighted emission factors

To estimate the impact of Euro 6 and Euro VI standards, we derived emission factors for all scenarios using VEPM 6.3[25] with modified assumptions for implementation of Euro 6 and Euro VI vehicles (described in the next section).

VEPM predicts real world emission factors for the New Zealand fleet under typical road, traffic, and operating conditions.

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

VEPM derives New Zealand-relevant factors based on emissions factors from the European COPERT model, which is published by the European Environment Agency in a spreadsheet (EMEP/EEA 2019). The emission factors are constantly being updated with improved factors for new technologies, emerging

[23] https://www.legislation.govt.nz/act/public/2022/0002/latest/whole.html#LMS536273

[24] https://www.nzta.govt.nz/resources/requirements-for-urban-buses/

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

issues and real-world effects. Emission factors are intended to represent real world emissions (as opposed to vehicle emission limits specified in standards).

VEPM 6.3 estimates fleet-weighted emissions, for all years from 2001 to 2050, based on detailed vehicle fleet projections from the Ministry's *Vehicle Fleet Emission Model* (**VFEM3**) which includes:

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

VKT for each vehicle category are assigned to a corresponding emission standard in VEPM 6.3 (Metcalfe & Peeters 2022) based on vehicle type, fuel, year of manufacture and origin.

Figure 10 illustrates the trend to 2050 in the percentage of VKT for different vehicle categories in VEPM 6.3. This shows the expected increase in battery electric vehicles (**BEVs**) over time. BEVs in VEPM 6.3 have zero tailpipe emissions, however they emit brake and tyre wear PM and we assume the same emission factor as for conventional vehicles.

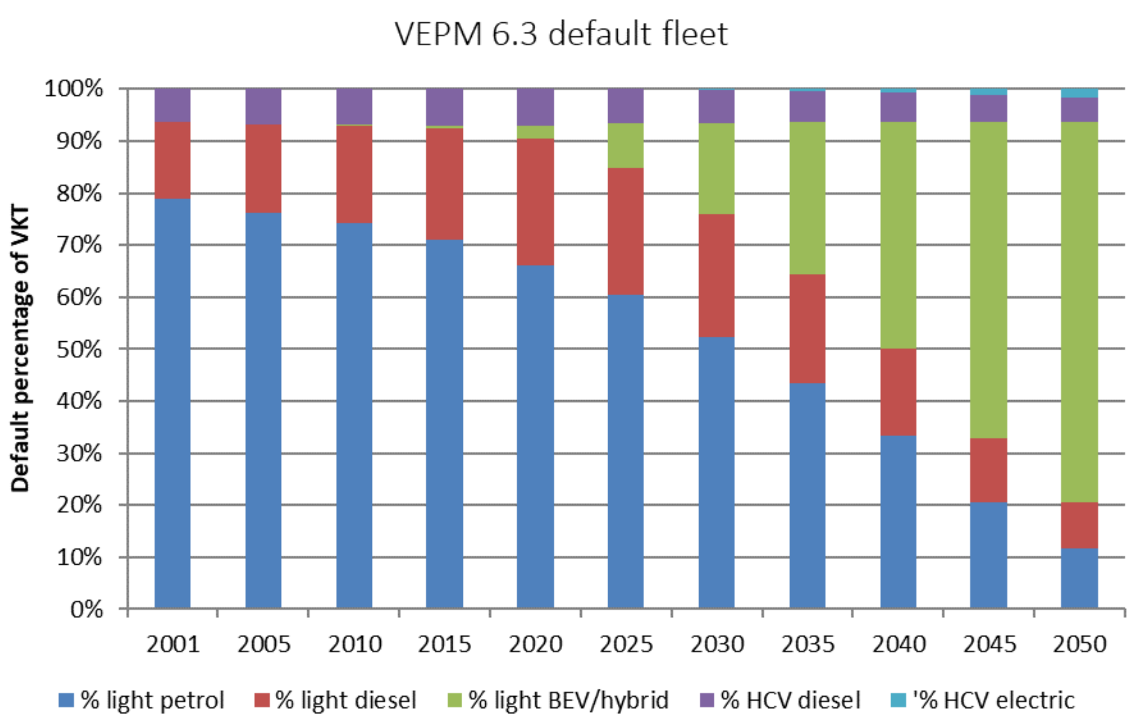

Figure 10: Default fleet profile in VEPM 6.3

The VKT data in VEPM 6.3 is from a VFEM3 *high carbon price* scenario, which was provided by the Ministry in December 2021. The fleet includes historical fleet and actual travel data up to the end of 2019.

We understand that the fleet projections in VEPM 6.3 do not account for the *Clean Car Package* or other recently announced policy initiatives, including the biofuels mandate and the March 2024 extension to the RUC exemption for light electric vehicles. However, these are unlikely to significantly affect the costs and benefits estimated by our modelling because these policies will primarily affect the light duty petrol fleet, and to some extent the light diesel fleet but will not affect the heavy diesel fleet[26]. We also understand that the fleet projections do not account for an upcoming requirement that new public transport buses be zero emission from 2025[27]. Again, this will not significantly affect our findings because public transport buses are estimated to account for less than 3% of NOx emissions and less than 2% of $PM_{2.5}$ emissions from all on-road transport (Kuschel *et al* 2021) and they are already subject to a Euro VI step C entry requirement.

4.4.1 Modified fleet assumptions in VEPM

VEPM 6.3 assumes that Euro 6 and Euro VI standards will be implemented in 2030 and that there are no Euro 6/VI vehicles in the fleet prior to this date. However, Ministry data shows that some new vehicle imports are built to Euro 6 and Euro VI standards already. The Ministry expects that, even without policy intervention, the proportion of vehicles built to Euro 6 and Euro VI standards will voluntarily increase, but only gradually.

A baseline projection of the proportion of new vehicles built to Euro 6 and Euro VI standards, by year of manufacture, was developed by Ministry staff for this analysis. A special version of the model - *VEPM 6.3 Euro6* - was created based on Euro 6 and Euro VI baselines provided by the Ministry, which are shown in Table 5, Table 6, and Figures 11 to 13. *VEPM 6.3 Euro6* allows this data to be overwritten to provide for scenario analysis.

VEPM includes different emission factors for Euro 6a/b/c and Euro 6d vehicles, so the baseline includes separate categories for these vehicles. However, emission factors for all Euro VI vehicles are the same in VEPM, regardless of stage (e.g. A/B/C/D/E), so the baseline included only one category of Euro VI vehicle[28].

[26] The 2021 proposal for the biofuels obligation only targets a gradual increase to 9% CO_2 reduction by 2035. Biofuels are expected to reduce harmful emissions to some extent. This reduction in emissions has not been modelled at this stage, however we expect any reduction in emissions from the introduction of biofuels would occur equally with or without Euro VI/6 regulation and would not affect the outcomes of this assessment.

[27] https://www.nzta.govt.nz/resources/requirements-for-urban-buses/

[28] For light duty vehicles, there is a substantial difference between emissions at stages a/b/c compared with stage d which introduced real driving emissions requirements through on road testing. Heavy duty Euro VI standards include real driving emission requirements at all stages A through E. It is likely that there will be some improvement (in the order of 12%) in NOx emissions going from Euro VI A/B/C to D/E (ICCT 2021), however this is not yet reflected in the published emission factors.

Table 5: Baseline percentage of new vehicle imports built to Euro 5, Euro 6a/b/c and Euro 6d standards

Model Year	Petrol			Diesel		
	Euro 5	**6a/b/c**	**6d**	**Euro 5**	**6a/b/c**	**6d**
2010	100%	0%	0%	100%	0%	0%
2011	100%	0%	0%	100%	0%	0%
2012	100%	0%	0%	100%	0%	0%
2013	100%	0%	0%	100%	0%	0%
2014	100%	0%	0%	100%	0%	0%
2015	100%	0%	0%	100%	0%	0%
2016	96%	4%	0%	96%	4%	0%
2017	95%	5%	0%	95%	5%	0%
2018	94%	6%	0%	94%	6%	0%
2019	93%	7%	0%	93%	7%	0%
2020	92%	8%	0%	92%	8%	0%
2021	89%	10%	1%	89%	10%	1%
2022	85%	13%	2%	88%	10%	2%
2023	80%	15%	5%	85%	12%	3%
2024	70%	20%	10%	80%	15%	5%
2025	65%	20%	15%	75%	15%	10%
2026	55%	10%	35%	65%	15%	20%
2027	45%	5%	50%	60%	10%	30%
2028	30%	5%	65%	50%	5%	45%
2029	15%	0%	85%	35%	5%	60%
2030	10%	0%	90%	30%	0%	70%
2031	5%	0%	95%	15%	0%	85%
2032	5%	0%	95%	10%	0%	90%
2033	5%	0%	95%	5%	0%	95%
2034	5%	0%	95%	5%	0%	95%
2035	0%	0%	100%	0%	0%	100%
2036-2050	0%	0%	100%	0%	0%	100%

Source: Ministry of Transport

Table 6: Baseline percentage of new heavy duty vehicle imports built to Euro V and Euro VI standards

Model Year	Euro V	Euro VI
2010	100.0%	0.0%
2011	100.0%	0.0%
2012	100.0%	0.0%
2013	100.0%	0.0%
2014	100.0%	0.0%
1015	100.0%	0.0%
2016	99.7%	0.3%
2017	95.6%	4.4%
2018	91.7%	8.3%
2019	90.0%	10.0%
2020	85.0%	15.0%
2021	80.0%	20.0%
2022	74.0%	26.0%
2023	69.0%	31.0%
2024	62.7%	37.3%
2025	56.4%	43.6%
2026	55.1%	44.9%
2027	50.0%	50.0%
2028	40.0%	60.0%
2029	30.0%	70.0%
2030	25.0%	75.0%
2031	20.0%	80.0%
2032	15.0%	85.0%
2033	10.0%	90.0%
2034	9.7%	90.3%
2035	5.4%	94.6%
2036-2050	0.0%	100.0%

Source: Ministry of Transport

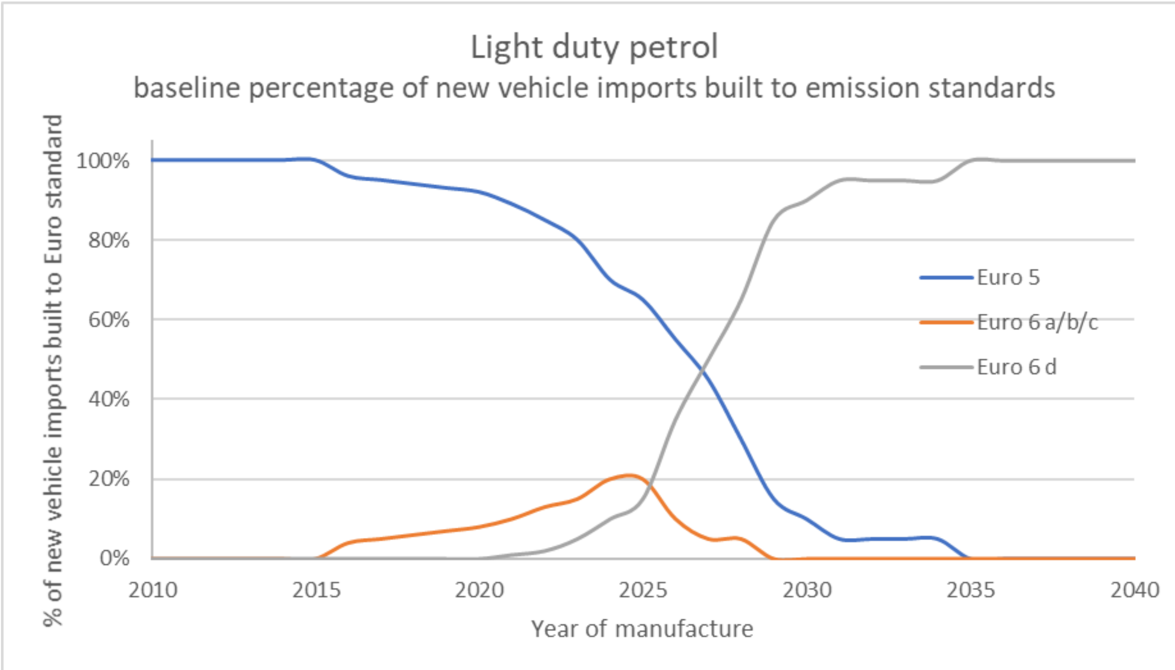

Figure 11: Baseline percentage of new vehicle imports built to Euro 6 standards: light duty petrol

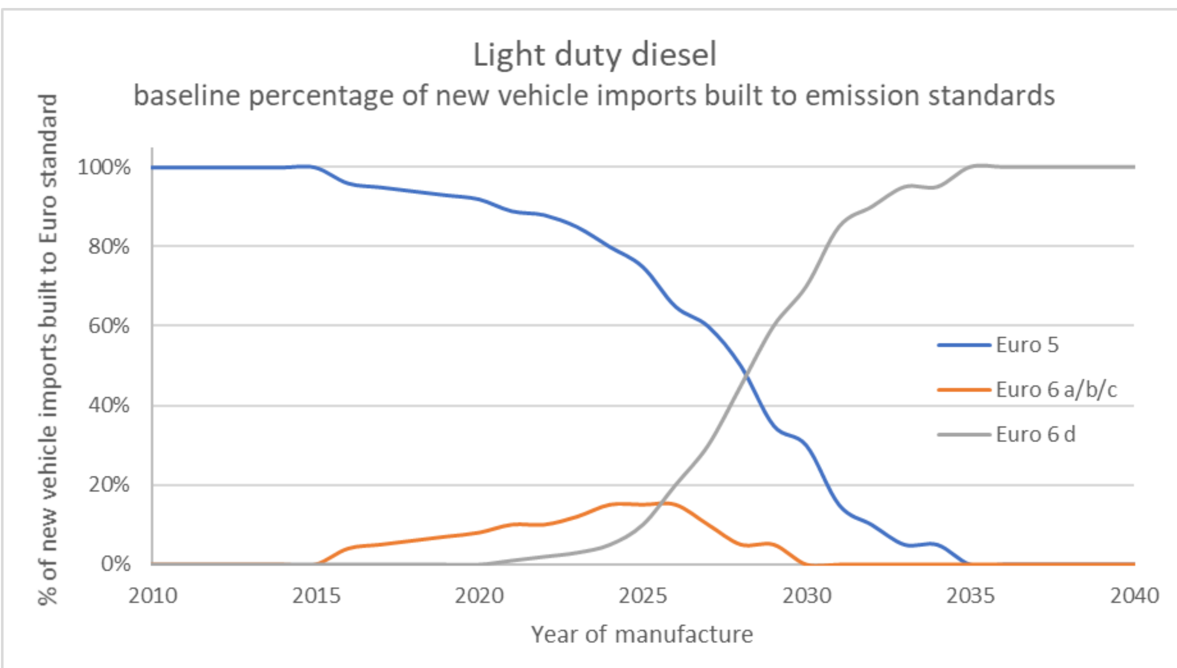

Figure 12: Baseline percentage of new vehicle imports built to Euro 6 standards: light duty diesel

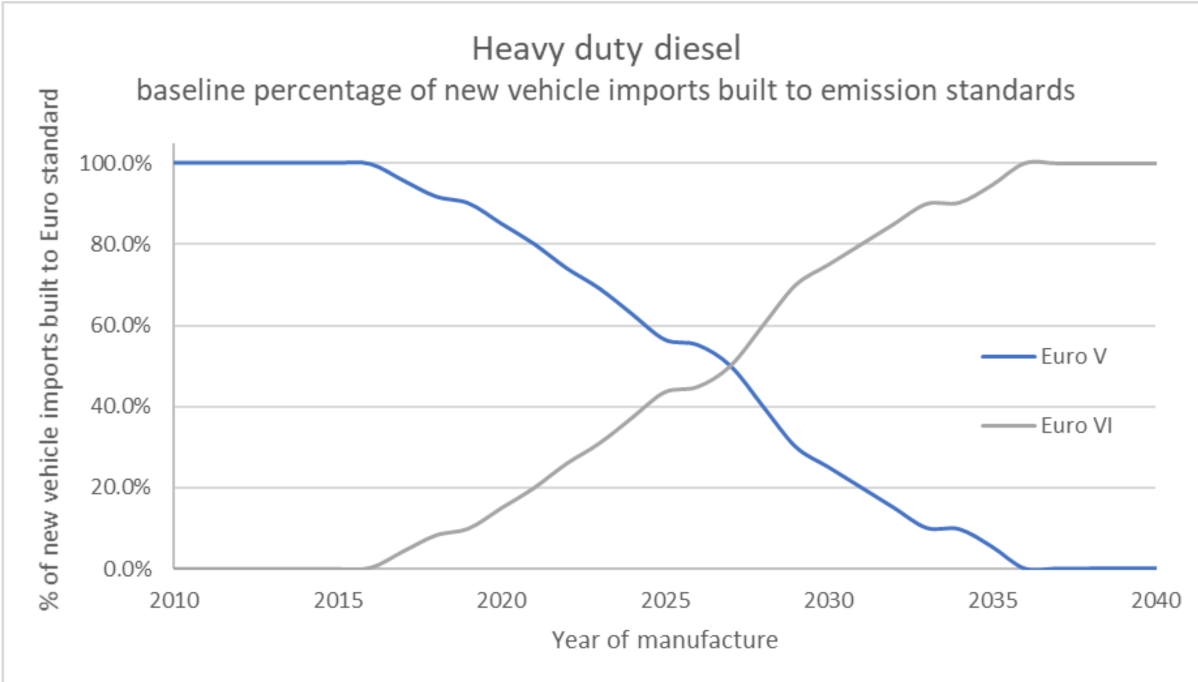

Figure 13: Baseline percentage of new vehicle imports built to Euro VI standards: heavy duty diesel

4.4.2 Average speed assumption in VEPM

VEPM is an average speed model. This means that VEPM predicts different emission factors for different speeds (between 10 and 110 km/hour).

To simplify this analysis, **emission factors were estimated for a single speed of 48 km/hour** for all years and all scenarios. This speed was selected based on previous research, which found that VEPM predicts realistic real world fuel consumption factors for New Zealand at 48 km/hour (Metcalfe *et al* 2021).

Emission factors were generated from "*VEPM6.3 Euro6*" using an average speed of 48 km/hour for all years from 2021 to 2050. Default values were used for all other settings in VEPM.

4.4.3 Generating emission factors

Emission factors were generated for the base case and for each of the scenarios. The base case emission factors were generated based on Euro 6 and Euro VI baseline data shown in Tables 5 and 6. The Euro 6 and Euro VI data was revised for each scenario to reflect the assumptions outlined in Section 4.4.

4.5 Estimating annual emissions

Annual VKT were extracted from the VFEM3 *high carbon price* scenario dataset provided by the Ministry. Total VKT per annum for all years from 2021 to 2050 were then disaggregated under the following vehicle categories:

- **Petrol car** (sum of petrol car/SUV and petrol multi ownership Car/SUV categories in VFEM)
- **Petrol LCV** (sum of petrol van/ute and petrol multi ownership van/ute categories in VFEM)
- **Diesel car** (sum of diesel car/SUV and diesel multi ownership car/SUV categories in VFEM)
- **Diesel LCV** (sum of diesel van/ute and diesel multi ownership van/ute categories in VFEM)
- **Diesel heavy duty** (sum of diesel bus, diesel light truck and diesel heavy truck categories in VFEM).

Fleet weighted emission factors from VEPM for the base case and each scenario, were then multiplied by total VKT to estimate total emissions for:

- Petrol cars, diesel cars, petrol LCVs, diesel LCVs and heavy vehicles
- All years from 2021 to 2050
- CO, VOC, NO_X and PM.

4.6 Calculating social costs and benefits

The social costs associated with emissions of harmful pollutants were estimated using the New Zealand average damage costs, as described in Chapter 3 and shown in Table 7, based on the findings of HAPINZ 3.0 (Kuschel et *al* 2022). **All costs were assumed to be additive** – i.e. there is no appreciable double-counting of effects across the different pollutants.

Table 7: New Zealand average air emissions damage costs in $/tonne (June 2019 prices)

Pollutant	**Costs in NZ$/tonne New Zealand**	Value base date (at end June)
PM_{10}	$382,524	2019
NO_X	$186,037	2019
VOC	$880	2019
CO	$3	2019

Source: Kuschel *et al* (2022)

Note: The revised New Zealand damage cost for NO_X emissions based on HAPINZ 3.0 is substantially higher than previously published damage costs.[29]

[29] Currently $16,347/tonne as at 2016 in the MBCM, based on international values.

Social costs were assessed for each year then converted into present values using the Treasury recommended rate of 5% for road and other transport projects (Treasury 2021). This meant social costs for each scenario could be aggregated to a total covering all years 2021 to 2050 for comparison with the base case.

The total social benefit of implementation of Euro 6 and Euro VI requirements was then calculated for each scenario as the difference between the total social costs of the base case compared with the total social cost of each scenario between 2021 and 2050.

Note: Discounting renders benefits and costs that occur in different time periods comparable by expressing their values in present terms.

The net present value (**NPV**) of a projected stream of current and future benefits and costs relative to the base case is estimated by multiplying the benefits and costs in each year by a discount factor, ***d*** (e.g. 5%), and adding all of the weighted values as shown in the following equation:

$$\mathrm{NPV} = \mathrm{NB}_0 + \mathrm{d}^1\mathrm{NB}_1 + \mathrm{d}^2\mathrm{NB}_2 + \dots + \mathrm{d}^{n-1}\mathrm{NB}_{n-1} + \mathrm{d}^n\mathrm{NB}_n \qquad (1)$$

where NB_t is the net difference between benefits and costs (B_t - C_t) that accrue at the end of period ***t***. The discounting weights, d_t, are given by:

$$\mathrm{d}_t = 1/(1 + \mathrm{r})^t \qquad (2)$$

where ***r*** is the discount rate. The final period of the policy's future effects is designated as time ***n***.

5. Estimating costs of Euro 6/VI

This section describes our methodology for estimating the potential vehicle manufacturing cost premium of mandating Euro 6/VI requirements for new vehicles in New Zealand. The overall methodology followed four steps:

1. For the base case and for each scenario, and for all years from 2021 to 2050, we estimated the number of new Euro 6/VI vehicles entering the fleet
2. For each scenario and for all years from 2021 to 2050 we then calculated the number of vehicles potentially impacted by the policy as the difference between the number of Euro 6/VI vehicles in the scenario compared with the base case
3. For each scenario and for all years from 2021 to 2050 we then:
    - calculated the potential costs based on the potential cost per vehicle and the number of vehicles affected by the policy
    - converted the costs into present values
4. We then added present value costs for all years to arrive at a total cost for each scenario.

These steps are described in more detail in the following sections. All calculations are provided in the accompanying spreadsheet "*Euro 6 benefits.xlsx*".

5.1 Scenarios evaluated

The scenarios evaluated for the potential vehicle manufacturing costs were the same as those listed in section 4.2 for the benefits.

5.2 Estimating the number of Euro 6/VI vehicles

Projected vehicle registration data were extracted from the VFEM3 *high carbon price scenario* dataset provided by the Ministry.

Costs were assessed for vehicles based on the following categories:

- Light duty petrol vehicles, which includes petrol, petrol plug in and petrol hybrid cars and light commercial vehicles (vans/utes) [30].
- Light duty diesel vehicles, which includes cars and light commercial vehicles (vans/utes)
- Heavy duty diesel vehicles, which includes trucks and buses.

The number of new light duty petrol and diesel Euro 6 d vehicles entering the fleet under the base case was estimated for each year from 2022 to 2050 based on:

- the projected number of new light duty petrol and diesel vehicle registrations from VFEM 3

[30] In the calculation of costs, the *number* of light duty petrol registrations was assumed to include petrol, hybrid and plug-in hybrid vehicles for conservatism. However, the assessment of benefits does not include any air quality *benefit* from hybrid or plug-in hybrid vehicles.

- the baseline projection of the proportion of new vehicles built to Euro 6d standards shown in Table 5, Chapter 4.

Similarly, the number of new Euro VI vehicles entering the fleet under the base case was estimated for each year from 2022 to 2050 based on:

- the projected number of new heavy duty diesel vehicle registrations from VFEM 3
- the baseline projection of the proportion of new vehicles built to Euro VI standards shown in Table 6, Chapter 4.

The number of Euro 6d and Euro VI vehicles entering the fleet under each scenario was then estimated based on the assumption that all new vehicle entering the fleet are built to Euro 6d or Euro VI emission standards from the implementation date assumed in each scenario.

5.3 Estimating the cost

For each scenario, and for all years from 2021 to 2050, the number of vehicles potentially impacted by the policy was calculated as the difference between the number of Euro 6/VI vehicles in the scenario compared with the base case.

The cost premium was based on an estimated worst case cost premium for manufacturing a Euro 6/VI vehicle compared with a Euro 5/V vehicle. The per vehicle costs provided by the Ministry are as follows:

- Petrol light duty: $300 per vehicle
- Diesel light duty: $900 per vehicle
- Diesel heavy duty: $4000 per vehicle[31]

We assume that these approximate *costs* can be directly compared against the social *benefits* estimated in Chapter 4, which are reported as $NZ 2019.

Costs were converted into present values using the Treasury recommended discount rate of 5% for road and other transport projects (Treasury 2021) using the methodology described in Chapter 4.

[31] On average. Very heavy trucks cost more to achieve Euro VI however there are far fewer of them.

6. Results: estimated impact of Euro 6/VI for new vehicles

The detailed results, including emissions and estimated social benefits are tabulated in the accompanying spreadsheet *Euro 6 benefits.xlsx*.

6.1 Overall social costs

The social costs (estimated from the methodology outlined in Chapter 4) associated with motor vehicle emissions in 2022 are dominated by diesel vehicles, as shown in Figure 14.

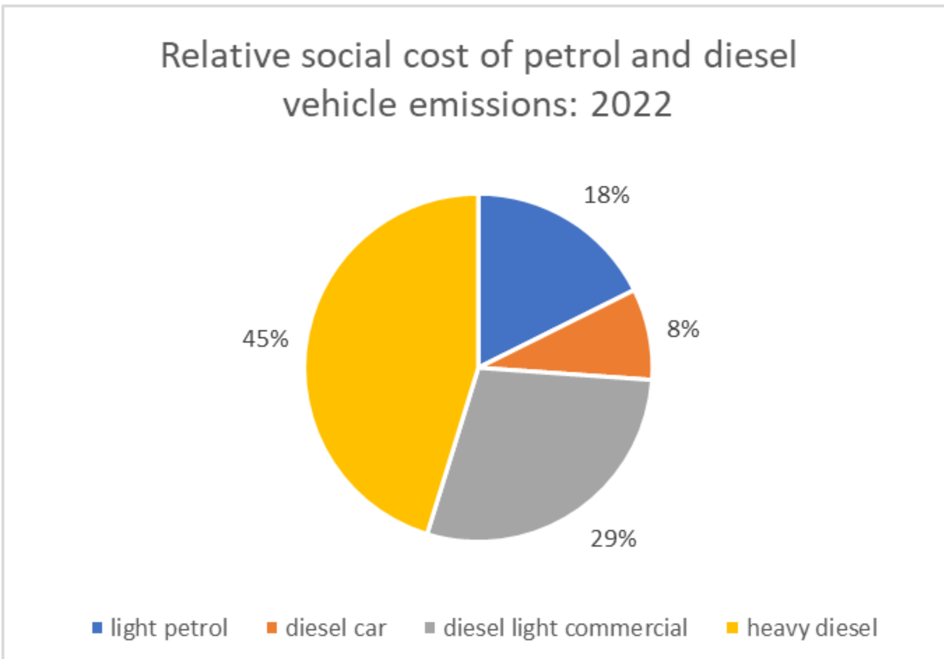

Figure 14: Relative contribution of petrol and diesel vehicles to estimated social costs of emissions.

6.2 Overall trend in emissions

In the base case, emissions and the associated social costs of air pollution from motor vehicles are expected to substantially reduce over time due to the uptake of electric vehicles as well as voluntary uptake of Euro 6/VI vehicles. Mandating Euro 6 and Euro VI vehicles is one option to accelerate the reduction of social costs from motor vehicle air pollution.

Figure 15 illustrates the overall expected trend for NOx and $PM_{2.5}$ from motor vehicles in New Zealand under the base case compared with scenario 1, which assumes that Euro 6 and Euro VI vehicles are mandated from 2024.

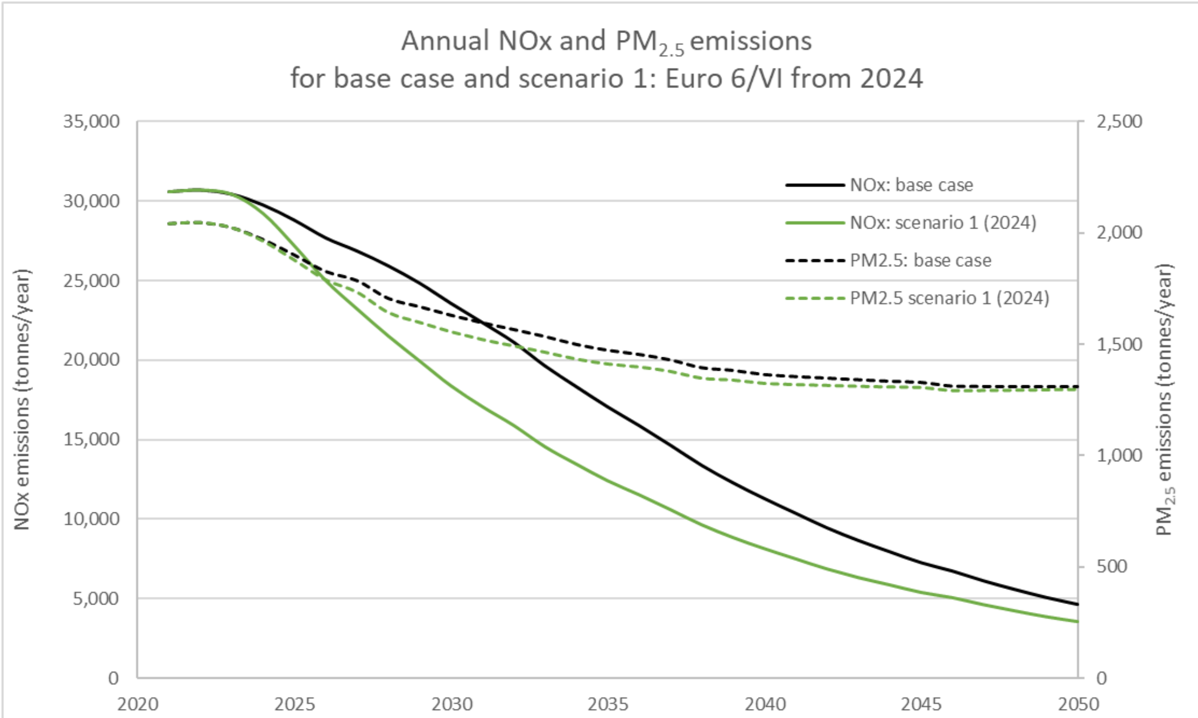

Figure 15: Projected NOx and $PM_{2.5}$ emissions per annum from motor vehicles for the base case and scenario 1: implementation of Euro 6 and Euro VI standards in 2024

Note: Figure 15 shows total emissions from motor vehicles between 2022 and 2050 to illustrate the overall trend. This shows estimated emissions for the entire fleet, including battery electric vehicles, and includes exhaust emissions, brake and tyre wear and road wear.

6.3 Benefits and costs comparison

Table 8 compares the total benefits and costs (shown as net present value) from 2021 to 2050 for the four scenarios.

The results show that **the implementation of Euro 6 and Euro VI standards achieves substantial benefits due to harmful air pollutant emissions reduction relative to the base case.** Scenario 1 (introduction in 2024) delivers nearly eight times the benefits for Scenario 1 (introduction delayed to 2030).

These benefits are primarily due to reduction of emissions from diesel vehicles, as shown in Figure 16, which illustrates the results of Scenario 1 (Euro 6 d and Euro VI from 2024) disaggregated by vehicle type.

The results also show that the benefits due to harmful air pollution emissions reduction are substantially higher than the potential costs of the policy scenarios. The estimated benefits shown in Table 8 are between 35 and 48 times higher than the potential costs depending on the scenario.

The base case projection assumes that the proportion of new vehicles that are Euro 6 and Euro VI gradually increases in the absence of policy. This means that earlier introduction of Euro 6d and Euro VI emission standards achieves greater benefits compared with the base case. This is illustrated in Figure 17 and Figure 18, which show the tonnes of emissions avoided per annum under each policy scenario.

Table 8: Estimated benefits and costs of policy scenarios from 2021 to 2050

Scenario	Benefit* NPV $2019 (in $million)	Cost** NPV $2019 (in $million)
Scenario 1: 2024	$ 8,342	$236
Scenario 2: 2025	$6,662	$182
Scenario 3: 2027	$3,749	$92
Scenario 4: 2030	$1,076	$22

Notes:
*The benefit is the difference between the base case and the scenario total NPV of air pollution costs from diesel and petrol vehicle emissions from 2021 to 2050
**The cost is the estimated total NPV of the additional cost of manufacturing Euro 6/VI vehicles (compared with a Euro 5/V vehicles) for the vehicles affected under each policy scenario between 2021 and 2050. The cost is based on an estimated worst case manufacturing cost premium.

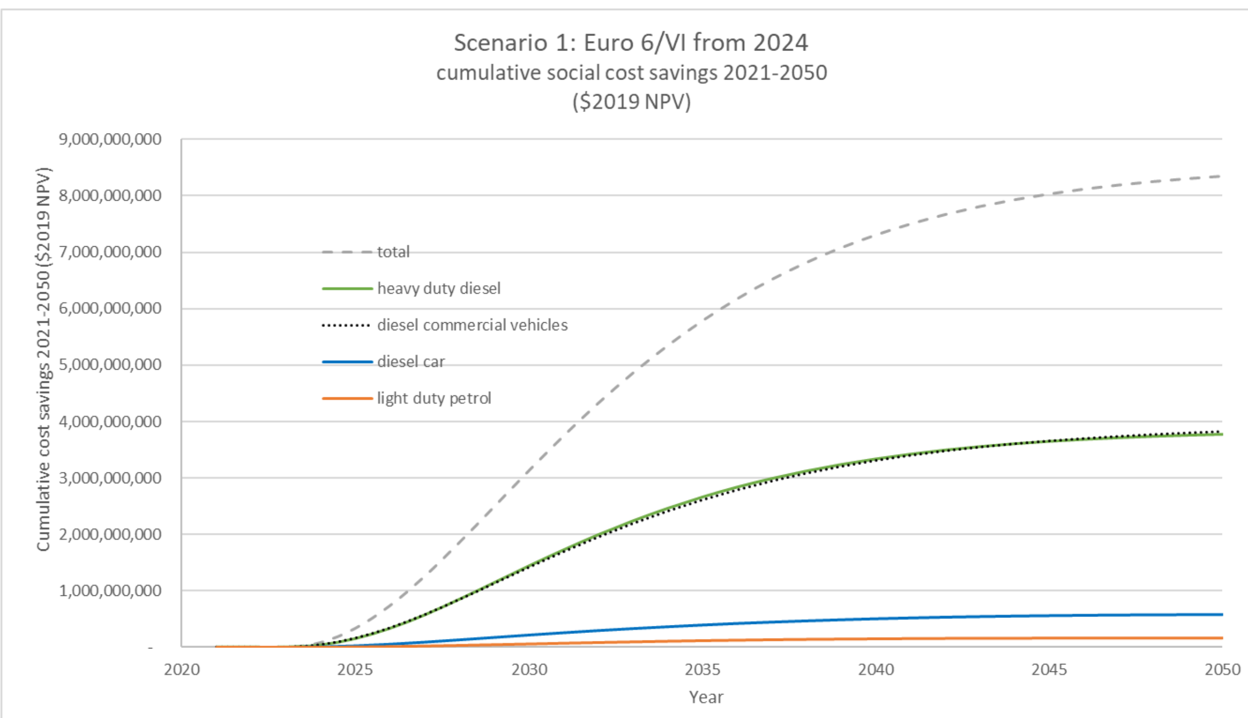

Figure 16: Cumulative social costs savings between 2021 and 2050 for scenario 1: Euro 6 from 2024 ($2019 NPV)

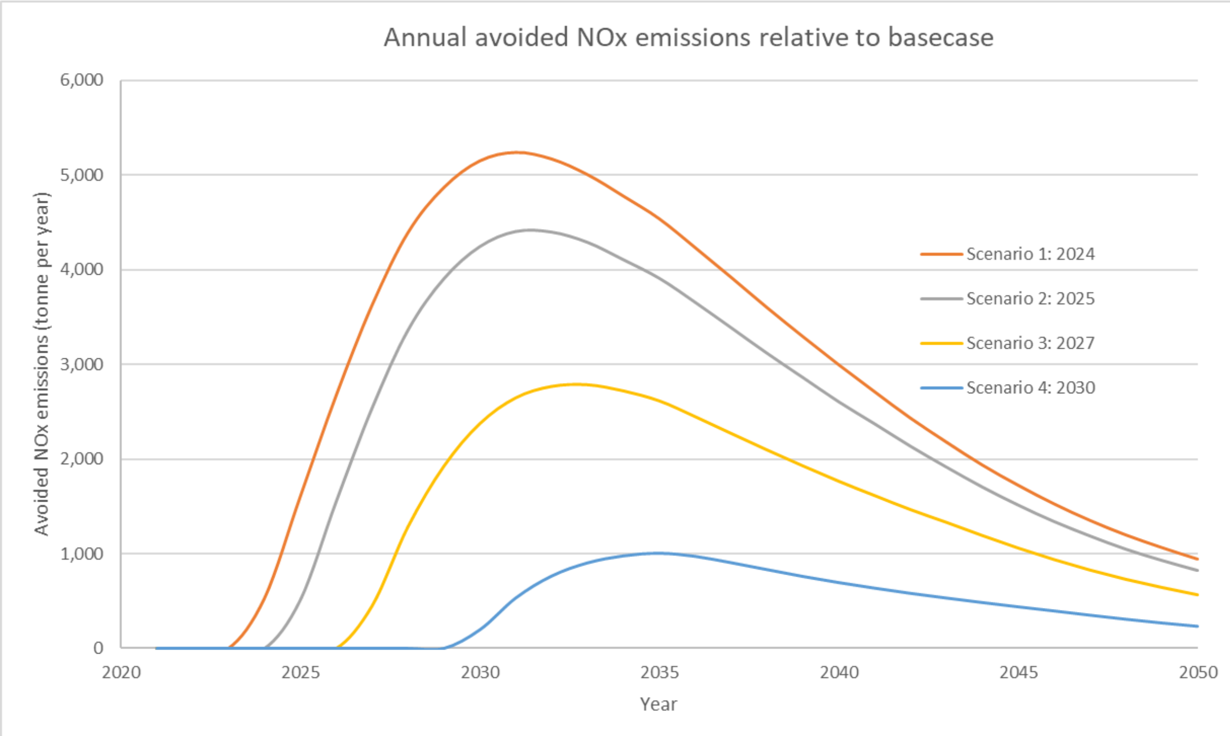

Figure 17: Avoided NO_X emissions compared with base case (tonnes per annum)

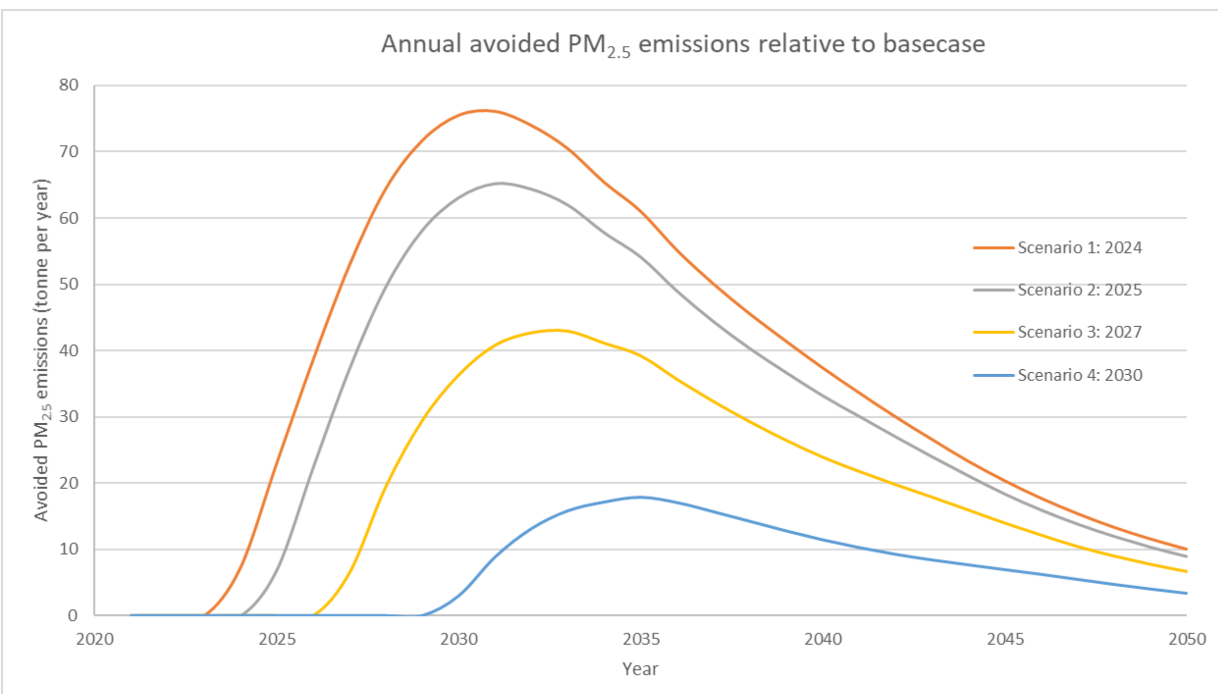

Figure 18: Avoided $PM_{2.5}$ emissions compared with base case (tonnes per annum)

7. Results: likely impacts of Euro 5-6/V-VI for used vehicles

All vehicles entering the New Zealand fleet are currently required to meet:

- Euro 5/V or equivalent for all **new** petrol and diesel light/heavy vehicles and
- Euro 4/IV equivalent for all **used** petrol and diesel light/heavy vehicles.

The assessment estimates the impact of Euro 6/VI requirements for new vehicles. We acknowledge that **used** vehicles will be required to meet Euro 5/V or equivalent and Euro 6/VI at some future date. However, the impacts of this requirement are not explicitly modelled in this assessment.

This chapter compares the current Japanese and European emission standards and briefly discusses the potential impacts of a Euro 5/V and eventual Euro 6/VI requirement for used vehicle imports.

Impacts on updating US regulations are not modelled given very few vehicles enter New Zealand that are certified to them. However, an international study suggests current (2010) US heavy vehicle regulations may be less effective than Euro VI in real world performance, especially at speeds below 80km/hour[32].

7.1 Japanese emissions standards

Most of the used petrol and diesel vehicles entering the New Zealand fleet are manufactured to Japanese standards.

This section summarises differences between recent Japanese and European emission standards.

7.1.1 Light duty vehicles

Japan's *New Long Term Emissions Standards* were phased in from 2005 and *Post New Long-Term Emissions Standards* were phased in for new light duty vehicles from 2009.

As shown in Table 9 and Table 10, the emission limits specified in these standards are similar to Euro 5 and Euro 6 standards for petrol vehicles, and Euro 5 standards for diesel vehicles. However, there are significant differences in test methodologies which mean that the standards are not equivalent.

The WLTC has been used for all vehicles from 2018 in Europe, and from 2019 in Japan. However, Japan has adopted a definition of WLTC that is different to Europe.

As discussed in Section 2.7, European test requirements have also included real driving emission test requirements based on in-use vehicle PEMS testing from 2018 as part of type approval, as well as in service conformity testing. Japan plans to begin implementing real driving emissions testing in October 2022, and to fully implement requirements by October 2024[33] however there will be differences in the requirements compared with Europe. These differences in emission test requirements mean that, even

[32] https://theicct.org/publication/in-use-nox-emissions-and-compliance-evaluation-for-modern-heavy-duty-vehicles-in-europe-and-the-united-states/

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

the newest Japanese vehicles may have higher real world emissions compared with the latest Euro 6d vehicles.

Table 9: Japanese and European emission standards for year of manufacture >2005; passenger cars

Vehicle type	Emission standard	Date[1]	Test cycle	CO (g/km)	NMHC (g/km)	NOx (g/km)	PM (g/km)
Petrol passenger car	Euro 5	2011[a]	NEDC	1.0	0.068	0.06	0.005[b]
	Euro 6	2014[c]	NEDC	1.0	0.068	0.06	0.005[b]
	Euro 6	2018[d]	WLTC-4P				
Petrol passenger car	New Long Term	2005	JC08[f]	1.15	0.05	0.05	-
	Post New Long Term	2009	JC08[f]	1.15	0.05	0.05	0.005[e]
		2018	WLTC-3P	1.15	0.1	0.05	0.005[e]
Diesel passenger car	Euro 5	2011[a]	NEDC	0.5	-	0.18	0.005
	Euro 6	2014[c]	NEDC	0.5		0.08	0.005
	Euro 6	2018[d]	WLTC-4P				
Diesel passenger car >1250kg	New Long Term	2005	JC08[f]	0.63	0.024	0.15	0.014
	Post New Long Term	2010	JC08[f]	0.63	0.024	0.08	0.005
		2019	WLTC-3P	0.63	0.024	0.15	0.005

Source: dieselnet.com and transportpolicy.net

Note: J10-15 + Japan 10-15 mode test = Japanese transient emission test cycle introduced in 2005 for light duty vehicles; WLTC = World Harmonised Light Vehicle Test Cycle (either 3 phase or 4 phase); NEDC = New European Driving Cycle; CO = carbon monoxide; NMHC = non methane hydrocarbons; NOx = nitrogen oxides; PM = particulate matter.

[1.] all dates for Japanese standards apply to new models produced by domestic manufacturers. Applicability to continuing models and imports is delayed

a. 2011.01 for all models

b. applicable only to vehicles using DI engines

c. 2014.09

d. all vehicles from 2018.09

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

f. The JC08 test cycle was phased in from 2005

Table 10: Comparison of Japanese and European emission standards for year of manufacture >2005; light commercial vehicles

Vehicle type	Emission standard	Date[1]	Test cycle	CO	NMHC	Nox	PM
				(g/km)			
Petrol LCV > 1760kg	Euro 5	2012[a]	NEDC	2.27	0.108	0.082	0.005[b]
	Euro 6	2015[c]	NEDC	0.74	0.108	0.082	0.005[b]
	Euro 6	2018[d]	WLTC-4P				
Petrol LCV >1700kg	New Long Term	2005	JC08[f]	2.55	0.05	0.07	-
	Post New Long Term	2009	JC08[f]	2.55	0.05	0.07	0.007[e]
		2019	WLTC-3P	2.55	0.15	0.07	0.007[e]
Diesel LCV > 1760kg	Euro 5	2012[a]	NEDC	0.74	-	0.28	0.005
	Euro 6	2015[b]	NEDC	0.74		0.125	0.005
	Euro 6	2019[f]	WLTC-4P				
Diesel LCV >1700kg	New Long Term	2005	JC08[f]	0.63	0.024	0.25	0.015
	Post New Long Term	2009[e]	JC08[f]	0.63	0.024	0.15	0.007
		2019	WLTC-3P	0.63	0.024	0.24	0.007

Source: dieselnet.com and transportpolicy.net

Note: JC08 = Japanese transient emission test cycle introduced in 2005 for light duty vehicles; WLTC = World Harmonised Light Vehicle Test Cycle (either 3 phase or 4 phase); NEDC = New European Driving Cycle; CO = carbon monoxide; NMHC = non methane hydrocarbons; Nox = nitrogen oxides; PM = particulate matter.

[1.] all dates for Japanese standards apply to new models produced by domestic manufacturers. Applicability to continuing models and imports is delayed
a. 2012.01 for all models
b. applicable only to vehicles using DI engines
c. 2015.09
d all vehicles from 2019.09
e. From 2009, PM values apply only to vehicles with lean-burn DI gasoline engines equipped with Nox adsorber catalysts; from 2020, PM values apply to all vehicles with DI gasoline engines, including stoichiometric DI vehicles
f. The JC08 test cycle was phased in from 2005

7.1.2 Heavy duty vehicles

Japan's *Post New Long-Term Emissions Standards* have applied to all new heavy commercial vehicles since 2010. As shown in Table 11, Japanese emission limits from 2010 are broadly equivalent to Euro VI. From 2016, the NOx standard was tightened and the standards apply the World Harmonized Transient Cycle (WHTC) for certification testing.

However, as discussed in Section 2.7, Euro VI emission standards include requirements for real driving emissions testing as part of type approval, as well as in service conformity testing based on in-use vehicle PEMS testing. Real driving emissions test requirements have not yet been introduced in Japanese emission test requirements for heavy commercial vehicles. This means that, even the newest Japanese heavy duty vehicles, could have higher real world emissions compared with Euro VI heavy duty vehicles.

Table 11: Japanese and European emission standards for year of manufacture >2009; diesel heavy vehicles

Emission standard	Date	Test cycle	CO	NMHC	NOx	PM
			(g/kWh)			
Japan New Long Term	2005	JE05	2.22	0.17	2.0	0.027
Japan Post New Long Term	2009	JE05	2.22	0.17	0.7	0.01
	2016-18	WHTC	2.22	0.17	0.4	0.01
Euro V	2008	ETC	4.0	0.55	2.0	0.03
Euro VI	2013	WHTC	4.0	0.16	0.46	0.01

Source: dieselnet.com and transportpolicy.net

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

7.2 Impacts of tightening used vehicle emission regulation

The impacts of changes to emission requirements for used vehicles are not explicitly modelled in this assessment. Further work would be required to model changes to used vehicle emission regulations. However, Ministry of Transport has confirmed it is reasonable to assume that the impact of regulation requiring used vehicles to meet Euro 5/V or an equivalent would be minor because the majority of used vehicles being imported to New Zealand already achieve equivalence with Euro 5 and V standards.

In general terms, Japanese emission standards and test requirements are becoming progressively more stringent. However, there are significant differences between Euro and Japanese emission standards including:

- The current Japanese light duty diesel emission standard for NOx is equivalent to Euro 5.
- Emission limits and test requirements are phased in slowly in Japan.
- Japanese vehicle test procedures are less demanding, with light vehicles not being tested at extra-high speeds (the fourth test phase of the WLTC).
- Requirements for in-use vehicle PEMS testing as part of type approval and in service conformity testing have not yet been introduced in Japan.

The analysis presented in Chapter 6 demonstrates that benefits of Euro 6 and Euro VI requirements for new vehicles are primarily due to reduction of emissions from diesel vehicles. This means that these differences between Japanese and European emission standards are most important for diesel vehicles.

Ministry of Transport vehicle registration data shows used vehicle imports accounted for 30% of all diesel heavy commercial vehicles, 8% of all diesel light commercial vehicles and 27% of all diesel passenger cars entering the fleet in 2020[34].

Used vehicles make up significant proportions of the total (used and new) diesel vehicles entering the fleet, and without regulation there is potential for these proportions to increase (e.g. if buyers choose to buy used vehicles to avoid tougher Euro 6/VI standards applying to new vehicles). This could undermine the benefits of Euro 6/VI requirements for new vehicles.

To protect the health of New Zealanders, it is important that emission regulations for used vehicle imports do not lag too far behind new vehicle requirements. It is also important that regulations for used vehicles reflect the differences between emission standards. For example, regulations might need to specify that diesel vehicles perform better than Japanese standards to be considered equivalent to Euro 6 and Euro VI.

[34] MoT (2021). *Te tatauranga rāngai waka a tau 2020 | Annual fleet statistics 2020*. Te Manatū Waka Ministry of Transport, Wellington, NZ, December 2021. https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/sheet/2020-annual-fleet-statistics

8. Conclusions

Our assessment found that the implementation of Euro 6 and Euro VI standards achieves substantial benefits due to harmful emissions reduction relative to a base case (no policy) scenario. We found that social benefits due to reduced health effects of air pollution ranged from $8,342 million to $1,076 million ($2019 as net present value) with earlier introduction of the standards delivering the greatest benefits.

We found that estimated benefits are between 35 and 48 times higher than the estimated potential cost of the policy. For each of the introduction dates assessed we estimated costs and benefits (all in $2019 as net present value) as follows:

- Implementation of Euro 6/VI in 2024: benefits of $8,342 million, costs of $236 million
- Implementation of Euro 6/VI in 2025: benefits of $6,662 million, costs of $182 million
- Implementation of Euro 6/VI in 2027: benefits of $3,749 million, costs of $92 million
- Implementation of Euro 6/VI in 2030: benefits of $1,076 million, costs of $22 million

Nearly all (at least 98%) of the estimated benefit of the Euro 6 and Euro VI standards is due to reduction of emissions from diesel trucks and light commercial vehicles (utes and vans).

Modelling the impacts of emission standards for **used** vehicle imports was outside of the scope of this project. However, we reviewed the implications of tightening used vehicle requirements and found that:

- A regulation requiring used vehicles to meet Euro 5 and Euro V standards would have minor impacts on our assessment because the majority of used vehicles entering the fleet already meet emissions levels that are equivalent to Euro 5 and Euro V.
- Used vehicle imports accounted for 30% of diesel heavy commercial vehicles, 8% of diesel light commercial vehicles and 27% of diesel passenger cars entering the fleet in 2020. This is a significant proportion of total diesel imports and there is potential for this proportion to increase (e.g. if buyers choose to buy used vehicles to avoid tougher Euro 6/VI standards). This could undermine the benefits of Euro 6/VI requirements for new vehicles.
- The latest Japanese standards for diesel vehicles are not as strong as Euro 6 and Euro VI requirements.

To protect the health of New Zealanders, it is important that emission regulations for used vehicle imports do not lag too far behind new vehicle requirements. It is also important that regulations for used vehicles reflect the differences between emission standards. For example, regulations might need to specify that diesel vehicles perform better than Japanese standards to be considered equivalent to Euro 6 and Euro VI.

Finally, even vehicles achieving Euro 6/VI will continue to cause considerable health impacts in New Zealand. It is therefore important that stricter Euro 7/VI limits, which are currently being considered in Europe, should be pursued in New Zealand without long delays.

Glossary of terms and abbreviations

$M	millions of dollars
BEV	battery electric vehicle
CO	carbon monoxide, an air quality pollutant
CO_2	carbon dioxide, a greenhouse gas
CO_2e	carbon dioxide equivalent, a way to express the impact of each different greenhouse gas in terms of the amount of CO_2 that would create the same amount of warming
COPERT	the European Computer Model to Calculate Emissions from Road Transport
DTCC	Domestic Transport Costs and Charges project
FC	fuel consumption
g	gram, a unit of mass
GHG	greenhouse gas
GVM	gross vehicle mass
HAPINZ	Health and Air Pollution in New Zealand, a study of the air pollution impacts and associated social costs
HC	hydrocarbon
HCV	heavy commercial vehicle, a commercial vehicle with a GVM >10 tonnes
ICCT	International Council on Clean Transportation
km	kilometre
LCV	light commercial vehicle, a commercial vehicle with a GVM < 3.5 tonnes
light duty vehicle	a vehicle with a GVM < 3.5 tonnes
MBCM	Monetised Benefits and Costs Manual, published by Waka Kotahi NZ Transport Agency in 2020 replacing the Economic Evaluation Manual (EEM)
MfE	Ministry for the Environment
MoT	Te Manatū Waka Ministry of Transport

NEDC	New European Driving Cycle
NO_X	oxides of nitrogen
NO_2	nitrogen dioxide, an air quality pollutant
NZ$	New Zealand dollars
NZTA	Waka Kotahi NZ Transport Agency
PEMS	portable emissions measurement system
PM	particulate matter, an air quality pollutant
$PM_{2.5}$	particulate matter smaller than 2.5 µm in diameter
PM_{10}	particulate matter smaller than 10 µm in diameter
RDE	Real driving emissions.
RSD	remote sensing device
SO_2	sulphur dioxide, an air quality pollutant
t	tonne, a unit of mass
$\mu g/m^3$	microgram per cubic metre, a unit of air pollution concentration
µm	micrometre, one millionth of a metre
VEPM	Vehicle Emissions Prediction Model, developed by Waka Kotahi to predict air emissions and fuel consumption for the New Zealand fleet
VFEM	Vehicle Fleet Emissions Model, developed by MoT to predict the makeup, travel, energy (fuel and electricity) use and greenhouse gas emissions of the future New Zealand vehicle fleet
VKT	vehicle kilometres travelled
VOC	Volatile organic compounds
Waka Kotahi	Waka Kotahi NZ Transport Agency
WHO	World Health Organization
WHSC	World Harmonised Stationary Cycle
WHTC	World Harmonised Transient Cycle
WLTC	Worldwide harmonized Light vehicles Test Cycles
WLTP	Worldwide harmonized Light vehicles Test Procedures

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