Vehicle Fuel Efficiency Standard

Preliminary Cost- Benefit Analysis

June 2018

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Preface

This report documents the preliminary cost-benefit analysis of introducing a vehicle fuel efficiency standard to improve the average emissions performance of vehicles entering New Zealand's light vehicle fleet. The policy would require vehicle importers to achieve a minimum level of emissions performance/fuel efficiency, on average, across the fleet of vehicles they import and sell in a given year. This is one of the proposed policy options that aims to reduce greenhouse gas emissions from road transport and to contribute towards New Zealand's efforts to transition to a net zero carbon economy.

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Acknowledgement

This preliminary Cost-Benefit Analysis has been prepared by the Domain Strategy, Economics and Evaluation team at the Ministry of Transport.

The Domain Strategy, Economics and Evaluation team operates within the Regulatory and Data Group of the Ministry of Transport. The team supports the Ministry's policy teams by providing the evidence base at each stage of the policy development.

The team is responsible for:

- Developing the Transport Evidence Base and the Transport Knowledge Hub which connects people from across the wider transport sector and promotes the sharing of transport data, evidence, knowledge, research, information, capabilities, and ideas.
- Providing economic input on business cases, funding requests, competition issues and specific projects such as value capture, natural disasters, and the social impacts on environment and health.
- Providing the evaluation function for the Ministry, including designing evaluation frameworks, developing performance metrics and indicators, and designing, conducting and procuring evaluations.

Important qualifications

Due to lack of information, time and resources, this cost-benefit analysis does not include the following items:

- The mechanism with which vehicle importers might work together to meet their combined minimum level of emissions performance across the fleet of vehicles imported each year.
- Road safety impacts associated with changes in vehicle mixes, new technologies and scrappage rates.
- Health impacts from a reduction air pollution and noise from lower fuel consumption or abatement technologies and the accelerated take-up of electric vehicles.
- Changes in vehicle maintenance costs due to changes in vehicle technology, engine size and vehicle type.
- Any wider economic or distributional impacts by region or by income cohort.

Where possible and appropriate, a sensitivity analysis has been carried out to understand the materiality of varying some of the key inputs on the model results.

An earlier draft of this Cost-Benefit Analysis has been peer reviewed by the Schiff Consulting.

Disclaimer

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GLOSSARY OF TERMS AND ABBREVIATIONS

BEV	Battery Electric Vehicle
BCR	Benefit-cost ratio
CBA	Cost benefit analysis
CAPEX	Capital Expenditure
CO_2	Carbon Dioxide
CO_2 emission level	Level of CO_2 emitted
CO_2 emission target	Targeted value of CO_2 emission level
CRF	Common Reporting Framework
EEM	Economic Evaluation Manual
EPA	Environment Protection Agency
ETS	Emissions Trading Scheme
EV	Electric Vehicle
FIRR	Financial Internal Rate of Return
GHG	Greenhouse Gas
GVM	Gross Vehicle Mass
GST	Goods and services tax
ICCT	International Council for Clean Transportation
ICE	Internal Combustion Engine
LCV	Light Commercial Vehicles
MAC	Marginal Abatement Cost
MVR	Motor Vehicle Register
NEDC	New European Driving Cycle
NPV	Net Present Value
NZTA	New Zealand Transport Agency
OPEX	Operational Expenditure
PV	Present value
SUV	Sports Utility Vehicle
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VFEM	Vehicle Fleet Emissions Model
VFES	Vehicle Fuel Efficiency standard
VKT	Vehicle Kilometres Travelled
WLTP	World Harmonised Light Vehicles Test Procedure

1. Executive Summary

The proposed introduction of a vehicle fuel efficiency standard (VFES) in 2020 is aimed at reducing average emissions of imported vehicles in New Zealand to 105 gCO_2/km by 2025. It is expected to result in a net benefit ranging from $1.21 billion - $4.75 billion (midpoint $2.41 billion) in present value to private vehicle users and to the wider society. Most of the benefits (98%) are gained by private vehicle users from fuel savings while the remaining benefits are obtained by the wider society through reductions in greenhouse gas (GHG) emissions.

This policy intervention is expected to induce behavioural changes in consumers' purchasing decisions in favour of low emission vehicles including electric and hybrid vehicles. Examples of low emissions vehicles by makes and models can be found in Annex 9. Without any direct intervention, the current (2018) average emissions of 180 gCO_2/km will only decline to 158 gCO_2/km by 2025 and will reach 105 gCO_2/km by around 2039.

The majority of the costs (96%) are incurred by vehicle buyers to pay for the higher incremental 'technology' cost of vehicles that have the necessary equipment to meet lower emissions levels. The welfare impact borne by consumers who opt to buy a vehicle which is different from their preferred one as a result of changes in vehicle prices, or possibly in availability, consist of a minor share of total costs (1.5%). The remaining (2.2%) of total costs are incurred by the Government and its agencies to cover the upfront capital costs and annual costs to implement, regulate and enforce this policy intervention. The total costs from implementing a VFES are estimated to range between $0.7 billion - $1.3 billion (midpoint $1.1 billion) over its lifetime.

Accelerating the reduction in the average emissions level of the vehicle imports through improvements in fuel efficiency will result in substantial benefits that offset the aforementioned costs. Fuel cost savings account for a major share (96.5%) of total benefits and are gained by private vehicle users when they purchase a vehicle that is more fuel efficient. Fuel savings are expected to offset the initial 'technology cost' of buying a more fuel efficient vehicle after approximately 7 years, which is well below the average lifetime of a new vehicle (17 years) or close to that of a used vehicle (10 years). The monetary benefits of reducing greenhouse gases account for a small share of total benefits (3.5%). The total benefits from implementing a VFES are estimated to range between $2.2 billion - $5.8 billion (midpoint $3.5 billion) in present value over its lifetime.

The net present value (NPV) from the implementation of a VFES is estimated to range between $1.2 billion - $4.7 billion (midpoint $2.41 billion) over its lifetime (2020-2041) and is expected to reduce GHG emissions ranging between 3.9 million – 6.7 million tonnes of CO_2 (midpoint 5.1 million tonnes). Excluding the fixed costs, the net social benefit from abating an additional tonne of CO_2 is estimated to range between $260 – $851 per tonne (midpoint $469 per tonne).

A Monte Carlo simulation was carried out to test the viability of the VFES by changing a number of parameters independently or jointly. The estimated NPV ranges from $1.2 billion to $4.7 billion and the corresponding estimated BCR ranges from 2.1 and 6.5 at the 90% confidence interval. Table 1 below summarizes the main economic indicators and their range of uncertainty obtained from the sensitivity analysis.

Table 1: Summary of the estimated costs and benefits of the VFES regime from 2020 to 2025

All dollar estimates are expressed in present value at a 6% discount rate and cover years 2020 to 2041	Mid-Range	Minimum	Maximum	90% Confidence Interval	
Benefits:					
Fuel Savings ($ million)	3,405	1,436	9,809	2,162	5,618
Reduction in GHG emission ($ million)	5.15	3.31	7.93	3.91	6.72
Costs:					
Technology Cost ($ million)	1,074	480	1,394	683	1,252
Welfare Loss to vehicle buyers ($ million)	17	2	50	6	34
Implementation Costs to the Government ($ million)	25	17	35	20	30
Economic Viability Indicators:					
Net Present Value ($ million)	2,413	367	9,012	1,208	4,746
Benefit-Cost Ratio	3.16	1.29	15.53	2.09	6.48
Marginal Abatement Cost ($/tCO2)[1]	-469	-1,297	-93	-851	-260

The VFES is expected to contribute to closing the emissions gap between the baseline scenario and the target trajectory by up to 13% (in 2026 when the policy is fully implemented). However, this will narrow over time if the VFES does not continue post-2025. Further details are found in Annex 7 of this report. To appreciate the scale of the CO_2 reduction from the policy change, Annex 8 provides estimates of the equivalent CO_2 emission in other sectors (such as electricity generation and forestry).

[1] A MAC is the cost of eliminating an additional unit of emissions. A MAC curve represents the relationship between the quantity of abated emissions and the [incremental] price of CO_2 through the implementation of abatement measures

2. Background

2.1. Overview

This report provides a preliminary assessment of the benefits and costs accruing to the society associated with the introduction of a VFES on light vehicles entering the New Zealand fleet. This intervention is expected to accelerate the move to a low emissions light vehicle fleet. The assessment is based on implementation of the VFES on its own, without combining other additional policy interventions currently being considered. Such an exercise will be conducted separately and documented in a separate report.

The monetary benefits considered in this report are gains by private users in the form of fuel savings and by the wider society through lower greenhouse gas emissions. On the other hand, the bulk of the monetary costs are associated with the potentially higher purchase price of vehicles equipped with better fuel efficiency or emissions abatement technology and the associated welfare loss to vehicle buyers.

This analysis also includes the costs incurred by the Government, mainly the New Zealand Transport Agency (NZTA), which is the entity responsible for the implementation and enforcement of the VFES. The initial capital cost includes the drafting of the appropriate guidance and standards, and the development of a new automated reporting system. Annual operational costs cover the additional compliance, monitoring activities and ongoing awareness raising campaigns. These costs have been estimated by NZTA.

2.2. The Policy Problem and Objective

Under the Paris Agreement on Climate Change, New Zealand committed to reduce greenhouse gas (GHG) emissions to 30 percent below 2005 levels by 2030 [1]. To ensure that New Zealand joins with international leading countries to combat climate change, the Government has set a goal for New Zealand to be a net zero emissions economy by 2050 [2]. Transport accounts for 18 percent of New Zealand's GHG emissions, with light vehicles contributing to around two-third [3].

The Ministry of Transport is currently investigating a range of policy interventions to supplement existing policy settings, such as emissions trading scheme and the Electric Vehicles (EVs) programme implemented in 2016, to help reduce New Zealand's GHG emissions from light vehicles. The policy options range from awareness-raising programmes to incentive-based or performance-based measures to increase the uptake of more fuel efficient light vehicles entering the New Zealand fleet. This report focuses only on mandating a Vehicle Fuel Efficiency Standard.

2.3. Policy Description

The VFES aims to achieve a maximum of 105 grams of CO_2 emitted per kilometre travelled (gCO_2/km) by 2025, averaged over the imported fleet of light passenger and commercial vehicles. The policy intervention intends to incrementally lower the average CO_2 emissions from its baseline in 2020. In 2017, the sales weighted average CO_2 emissions of the vehicle imports stood at 178 gCO_2/km and this is expected to decrease to 175 gCO_2/km by 2020.

The VFES will be applied to all light vehicles with a gross vehicle mass (GVM)[2] of 3.5 tonnes or less and which are first registered in New Zealand from 2020. It will therefore encompass passenger cars, sports utility vehicles (SUVs), people movers, utes and light commercial vehicles (LCVs), including pickups and mini buses. It will also apply equally to both new and used vehicle imports.

The standard will be based on the New European Driving Cycle (NEDC)[3] test or an equivalent type approval driving cycle if the model is non-European. It is expected that the World Harmonised Light Vehicles Test Procedure (WLTP) will be adopted in European and UN Regulations by 2020. If New Zealand also adopts the WLTP, then it may be the case that the CO_2 emission target will need to be redefined, accordingly.

At the importer level, the CO_2 emission target will vary according to the sales-weighted average GVM of the vehicle fleet for each importer. This weight-adjusted standard accommodates the diversity of the vehicle imports amongst vehicle importers, which in turn is a reflection of consumer preferences for specific vehicle types.

There are three ways vehicle importers can comply with the VFES. Firstly, vehicle importers can meet their own weight-adjusted CO_2 emission target based on the vehicles they import during that year. Second, if an importer's vehicle imports exceed its target by importing more fuel efficient vehicles, it will receive emission credits that can be used for future years (up to 3 years). Third, a vehicle supplier could group together with any other supplier(s) and comply as a group. This is a form of trading, where a commercial arrangement would determine the advantage that a supplier with a relatively low emission fleet would receive from the other supplier(s) in the arrangement. If a vehicle importer subsequently does not meet its respective target for a given year a penalty would apply.

Overall, the standard provides some flexibility to importers to adapt their fleets in favour of vehicles having a better CO_2 value without reducing supply or restricting the range of vehicle choice to consumers.

2.4. Description of Costs & Benefits

The report identifies two main benefits from the implementation of a mandatory VFES regime, namely CO_2 emissions savings and fuel savings[4]. Due to data limitations, this report excludes health benefits from potentially lower concentrations of air pollution and from lower noise pollution levels due to the expected increase in EVs. Also excluded are benefits obtained from lower fuel imports that would favourably impact the security of energy supply and New Zealand's trade balance. Therefore, the actual total benefits from the implementation of a VFES regime would be higher than the figures estimated in this report.

The monetary costs incurred from the implementation of a VFES regime mainly relate to the incremental 'technology' costs of purchasing vehicles that have the necessary equipment and technology to meet a lower emissions standard. Given the high level of competition in the light vehicle market, particularly for used vehicles, some importers might need to absorb part of the increase in the vehicle price. In which case, the technology costs will be borne by the vehicle importers and the private vehicle owners.

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[2] In the absence of comprehensive data on the tare weight (or unladen weight) by vehicle type, the GVM was used for this analysis. The tare weight would be a more useful metric because it represents the vehicle mass at the point of importation and hence, the true 'sales-weighted' mass of the importer's fleet.

[3] The NEDC is a test driving cycle specified in the United Nations Economic Commission for Europe (UNECE) regulations which sets out procedures for determining fuel consumption and CO_2 emissions from light vehicles. It attempts to represent typical on-road driving conditions better than previous regulatory test cycles.

[4] More precisely, the private user will save on the fuel cost that is avoided due to the purchase (and use) of a vehicle that has a better fuel consumption target.

Alternatively, some vehicle importers might use price discrimination strategies to extract the maximum price a buyer is willing to pay for their preferred vehicle and to minimise the impact on their profitability. Thus, an element of cross subsidisation in-between buyers is to be expected. The way by which the higher technology costs are paid for will affect how the impact of this intervention will be distributed amongst different consumers. Notwithstanding, we do not expect the overall costs and benefits of the policy to be drastically different in either situations.

Another cost identified in this report relates to the welfare impact (measured by the deadweight loss) borne by consumers due to a change in their vehicle purchasing decision as a result of changes in the price or possibly in the availability, of the vehicle of their preferred choice. In other words, if some consumers opt to buy a vehicle that is different from their preferred one, then this would have an adverse impact on their utility and thus need to be accounted for as part of the cost of this intervention.

Government and its agencies are expected to incur both upfront capital costs and annual costs to implement, regulate and enforce this policy intervention. These include the cost to set up the required IT system, information campaigns and the *ex ante* monitoring that will be required to ensure that each importer is adhering to its CO_2 emission target.

3. The Baseline Scenario

3.1. Baseline Description

To assess the impact of a VFES of 105 gCO_2/km by 2025, it is necessary to first define the counterfactual or the baseline scenario for comparative purposes. In this scenario, it is assumed that there will be no additional policy intervention apart from those already implemented (such as emission trading scheme) to alter the predicted trend in the average CO_2 emission level of the light vehicle imports. The average CO_2 emission level would reflect the changes in the number of vehicle imports by vehicle type and the level of travel by vehicle age and other characteristics[5].

3.2. Baseline Methodological Approach

Data on the total vehicle imports in 2017 was obtained from the motor vehicle register (MVR) [4] and subsequently grouped by vehicle type, mass and CO_2 emission level. From this information, the sales-weighted CO_2 emission level and the sales-weighted GVM of the imported vehicles was estimated for that year.

This data was subsequently projected over the period 2018-2040 using the annual growth rates obtained from the Vehicle Fleet Emissions Model (VFEM) [5]. Since this CBA encompasses a longer time period, the post-2040 growth rates were estimated using a 3-year moving linear trend starting from 2041. The 2020 figures obtained using this approach were taken as the starting point of the CBA.

The VFEM projects the composition of the future vehicle fleet including the total vehicle kilometres travelled, the energy used (fuel and electricity) and the greenhouse gas emissions based on assumed economic, demographic and technological trends, including the likely EV uptake and fuel efficiency improvements in conventional vehicles. For the purposes of this CBA, the growth rates were based on VFEM's **'Slow EV Uptake'** scenario. In the sensitivity analysis shown in section 7, the growth rate was varied by +/-5% from the Slow EV Uptake scenario.

In the 'Slow EV Uptake' scenario, the annual growth rates in vehicle registrations differ depending on the vehicle's fuel type. For EVs, the growth rate is projected to be much faster than that of fossil fuel powered (or internal combustion engine or ICE) vehicles over the policy period. Table 2 below shows the projected annual growth rates of vehicle registrations by fuel type.

Table 2: Annual growth rates in vehicle registrations – baseline scenario

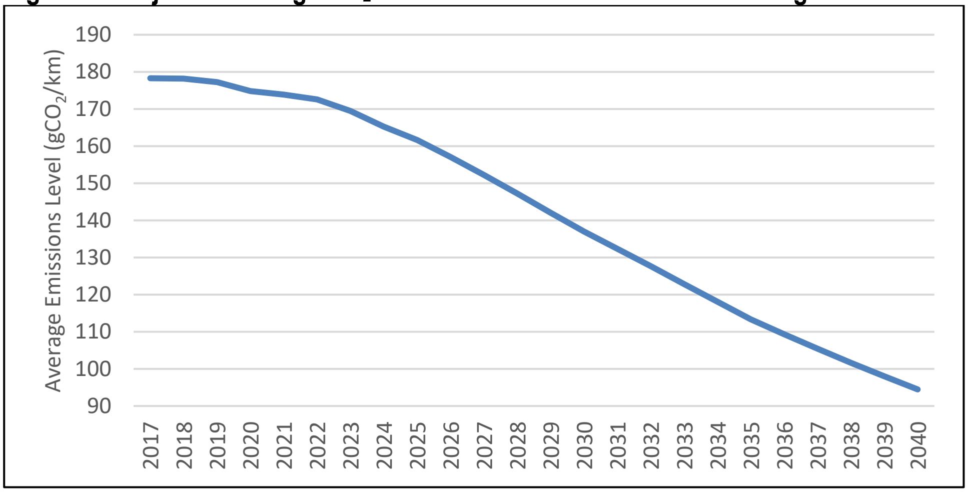
	Diesel	Petrol	Electric	Plug-in Diesel	Plug-in Petrol	Hybrid Diesel	Hybrid Petrol
2017	9%	-1%	77%	0%	21%	-100%	52%
2018	-4%	-4%	58%	500%	137%	0%	27%
2019	-5%	-5%	63%	78%	52%	0%	20%
2020	0%	-2%	43%	153%	123%	0%	20%
2021	1%	0%	10%	65%	7%	0%	11%
2022	0%	0%	10%	41%	7%	106%	10%
2023	-4%	-8%	12%	21%	9%	42%	10%
2024	-5%	-9%	14%	15%	15%	26%	5%
2025	0%	1%	10%	20%	12%	28%	4%
2026	1%	-2%	13%	22%	14%	22%	17%
2027	1%	-2%	13%	19%	13%	19%	16%

[5] These travel needs are reflected in the annual average vehicle kilometres travelled. These are, in turn, influenced by the driving preferences of vehicle users, the average age of the vehicle fleet and the fuel pump price.

	Diesel	Petrol	Electric	Plug-in Diesel	Plug-in Petrol	Hybrid Diesel	Hybrid Petrol
2028	0%	-4%	11%	15%	11%	15%	12%
2029	0%	-5%	10%	13%	10%	13%	10%
2030	1%	-3%	10%	13%	10%	13%	11%
2031	-1%	-2%	8%	7%	0%	12%	10%
2032	-1%	-2%	8%	6%	0%	10%	9%
2033	-3%	-4%	7%	5%	-1%	8%	6%
2034	-3%	-4%	7%	4%	-2%	8%	5%
2035	-2%	-3%	7%	5%	-1%	8%	7%
2036	-2%	-1%	5%	13%	2%	8%	3%
2037	-2%	-1%	5%	12%	2%	7%	2%
2038	-1%	-1%	5%	12%	2%	8%	2%
2039	-2%	-2%	5%	11%	2%	8%	2%
2040	-3%	-2%	4%	9%	1%	6%	2%

The projected increase in EVs in the baseline scenario will improve the average CO_2 emission level of new and used vehicle imports from the current (2018) average of 180 gCO_2/km to 158 gCO_2/km by 2025, as shown in Figure 1. An emissions level of 105 gCO_2/km for the vehicle fleet entering New Zealand will only be attained by around 2039 [6]. The policy intervention intends to accelerate this improvement.

Figure 1: Projected average CO_2 emission level of baseline vehicle registrations[6] - baseline scenario



Compared to other developed countries, the light vehicles entering the New Zealand fleet are more emissions-intensive. In Japan, the average passenger vehicle entering its fleet had an emissions intensity of 105 gCO_2/km in 2014. In Europe the average car and SUV was 118 gCO_2/km and light commercial vehicle was 164 gCO_2/km, in 2016. As stated above, the average vehicle entering New Zealand emitted around 180 gCO2/km.

This higher average CO2 emission level of New Zealand vehicle imports results in a relatively higher fuel cost compared to the European Union, United States and Japan. On average, New Zealanders pay 65 percent more on petrol than the average person in the European Union, even though petrol prices are higher in Europe, as shown in Table 3 below.

Table 3: Comparison of Average Annual Petrol Cost with Selected Developed Countries

[6] based on the VFEM 'slow EV uptake' scenario

		New Zealand	United Kingdom	European Union(a)	Japan	United States
Fuel efficiency - petrol equivalent [7] [8] [9]	ltrs/100km	9.5	5.8	5.05	6.2	8.6
Petrol Price inclusive of duties & taxes [5] [10] [11] (b)	$/ltr	$1.92	$2.26	$2.25	$1.81	$1.05
Vehicle use [11]	kms	11,000	11,000	11,000	11,000	11,000
Average Annual Petrol Cost	**$**	**$2,007**	**$1,443**	**$1,251**	**$1,235**	**$995**

Notes:
(a) Fuel efficiency figures for the European Union are based on the New European Driving Cycle and refer to 2016
(b) Fuel prices were converted to NZ$ using a 90 day average foreign exchange rate

The baseline scenario rests upon a range of other factors, including those used in the VFEM 'Slow EV Uptake' scenario [3], that are required to obtain robust projections, namely:

- Consumer preferences between used and new vehicles will be at the ratio used in the VFEM projections. In 2017, the share of new vehicles was 52% of total imports [3].
- The average economic life of a brand new vehicle is 17 years and that of a used vehicles is 7 years (i.e. the average age for a used import is 10 years when it enters the fleet) [11].
- Historic data on the average annual VKT are based on the Vehicle Fleet Statistics published by the Ministry of Transport [11] while the projections of these figures are based on the VFEM 'Slow EV Uptake' scenario [3]. An annual reduction of 4% in the average annual VKT is then applied to account for reducing travel as the vehicle ages [12].
- The proportion of total trips between different travel modes is unchanged throughout the time series, which means that commuters are assumed to maintain their travel habits from those observed today.

4. Modelling the Impact of a Mandatory VFES

4.1. Key assumptions

To support the analysis of the VFES policy as described in Section 2.3, it is necessary to make additional assumptions. First, it was assumed that the monetary penalties for not meeting the CO_2 emission target provide a sufficient incentive for importers to change the mix of the imported fleet in order to meet the emission target by 2025. For importers that already have an average CO_2 emission level lower than the target, it was assumed that the importer will maintain this average CO_2 emission level and will not change its imports in a way that would worsen it.

4.2. VFES Modelling Approach

The impact from the implementation of a VFES is modelled in the following stages:

(1) The vehicles imported in 2017 were categorised between new imports and used imports.

(2) The required standard that needs to be met in 2025 for both new and used vehicle imports is calculated using a weight-adjusted approach, described in section 4.3.

(3) The CO_2 emissions target of 105 gCO_2/km is compared with the required standard identified in (2) for both new and used vehicles and subsequently, the number of vehicles are summed up into two categories: (i) vehicles that are worse than the required standard and (ii) vehicle that are better than the standard. These two categories are then sub-divided according to the vehicle fuel type. The average CO_2 emission levels were calculated for each of the two categories using emission information obtained for the 2017 import fleet and the difference between the two categories show the aggregated 'effort' required. The assessment has been completed for the new and used vehicle fleets separately.

(4) The number of imported vehicles that will need to be substituted by those with a better CO_2 level over the period 2020-2025 in order to attain the required target in 2025 are then estimated. A linear interpolation[7] was used to gradually improve the average CO_2 emissions over the interim period of 2020-2024. In reality, the substitution in favour of vehicle imports with lower average emissions will depend on a number of factors including the price differential between existing and new vehicles, the level of competition in the light vehicle import market and the range of models sold by the importer, amongst others. In this analysis, a 'least effort' approach[8] was taken, whereby the vehicle importers, on aggregate, are assumed to sell more of those vehicles that have a CO_2 level that is exactly at the required target.

(5) Notwithstanding the 'least effort' approach described in (4) above, it was further assumed that each importer will import 30% more EVs over-and-above those assumed in the VFEM 'Slow EV Uptake' scenario.

4.3. Weight-adjusted emission target

To overcome the inflexibility associated with a uniform average target, a weight-adjusted CO_2 emissions target is used to cater for the diversity and characteristics of the vehicle fleet. For example, the EU used a vehicle mass-based standard whereas the US used a vehicle footprint-based standard [13]. The VFES is considering a mass-based standard, with a weight-adjusted emission target. This approach allows for maximum flexibility to importers and avoids any undue disruption to consumers' choice of the number and ranges of vehicles supplied to the New Zealand market. A potential difficulty is to design the standard such that to enable the attainment of the desired national standard by the

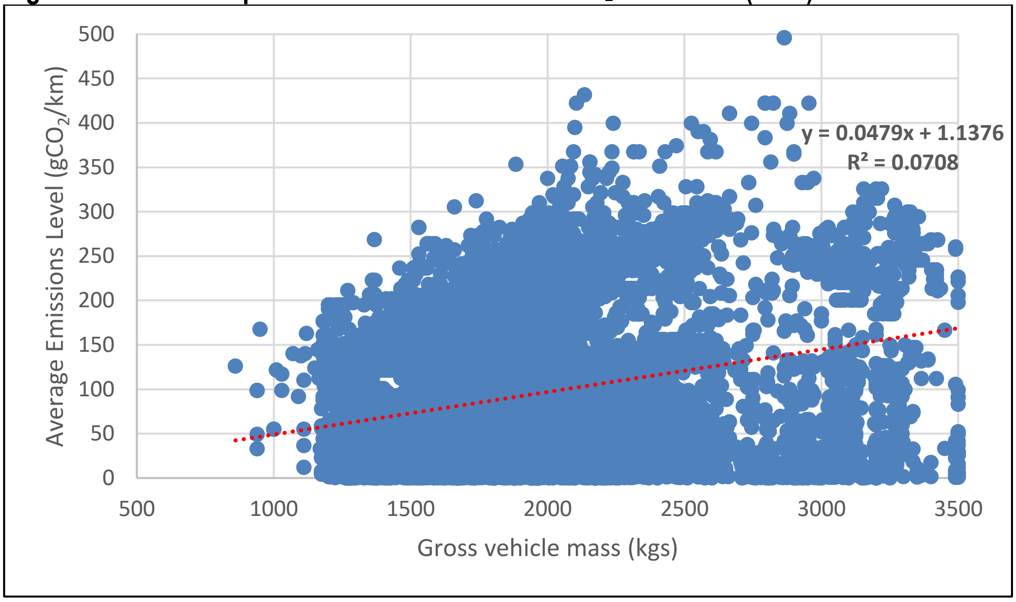
[7] Importers may be able to change their fleet composition faster than is being assumed and thus will be in a position to attain the required standard at an earlier date.

[8] In reality, the importers will optimise their fleet composition in a way that maximises their total profits while attaining the required standard.

target date. This is achieved by setting a weight-based formula for calculating the emission target for each importer or group of importers. The formula is referred to as a "limit curve".

In this analysis, the attribute that was chosen is GVM, which was taken as a proxy to the vehicle mass [14]. The relationship between the vehicle's GVM and CO_2 emissions of vehicles imported in 2017 appears to be slightly positive, albeit the wide range of emission levels within each weight class, as shown in Figure 2.

Figure 2: Relationship between Vehicle GVM and CO_2 emissions (2017)



The 'effort' required by the importer in terms of improvement in its respective fleet would vary depending on the fleet composition and the importer's required target as determined by the limit curve.

The relationship between a vehicle's GVM and CO_2 emissions is defined by a mathematical function or "limit curve" as follows:

$$CO_2\,lim = CO_2\,ref + aX(GVM - M0) \qquad [1]$$

Where:

CO_2 lim = the importer's sales weighted average target
CO_2 ref = the total fleet average target (national standard) of 105 g/tCO_2
a = the slope of the limit curve based on the correlation between mass and CO_2 emissions
Gvm = the sales weighted average mass of the vehicles sold by the importer
M0 = the sales weighted average GVM of all vehicles imported

The required average CO_2 target level that each importer will need to attain would depend on the sales weighted average CO_2 target and the sales weighted average mass, as denoted by the GVM, of it's vehicle fleet. It is expected that the limit curve is estimated on the GVM and CO_2 emissions of the vehicles imported in 2019 and annually updated thereafter.

5. Cost-benefit Analysis - Methodology

5.1. Quantified Benefits

The CO_2 emissions savings and fuel cost savings from the implementation of a mandatory VFES have been quantified and valued in monetary terms[9]. Other potential benefits such as those obtained from lower air and noise pollution and from the amelioration of security of supply and trade balance have not been quantified due to data limitations.

5.1.1. CO_2 Emissions Savings

The implementation of a VFES would greatly accelerate the improvement in average CO_2 emissions of vehicle imports – from a projected average of 177 gCO_2 /km in 2019 to 105 gCO_2 /km in the span of 6 years (2020-2025, both years included).

The CO_2 savings are estimated by multiplying the improvement in the average CO_2 level of the imported vehicles by the number of vehicles imported in each year and multiplied again by the average lifetime of the vehicle (which varies according to whether it is a new or used vehicle). The fuel savings obtained in the first year have been deducted since it is being assumed that consumers have already taken these savings into consideration when weighing different purchase options and in their choice of preferred vehicle. This assumption has the largest impact on the net benefits of this measure out of all other assumptions and thus, it was simulated separately in the sensitivity analysis, as described in section 7.

The total annual savings thus obtained are summed up and converted into tonnes of CO_2 emissions to obtain the total gross emissions savings over the evaluation period (2020-2041). This period covers the policy implementation timeframes (2020-2025) and the benefits that continue to be gained post-2025.

As stated above, this analysis assumes that this policy intervention will incentivise the purchase of EVs and thus, the emissions generated from the electricity needed to power these additional[10] EVs must be accounted for and deducted from the gross emissions savings accordingly. These additional emissions are estimated in a similar fashion to the CO_2 savings, namely by multiplying the number of additional EVs by their average lifetime and average annual vehicle kilometres driven by EV users.

It is assumed that this substitution in favour of EVs will be subject to the rebound effect. The rebound effect is the reduction in the gains from adopting new technologies that increase the efficiency of the resource use due to behavioural changes of the user. In the context of this study, this means that users of EVs will drive them for a longer distance since it is perceived that the fuel cost relative to an ICE vehicle is very low. In this analysis, the rebound effect has been accounted for by deducting the fuel savings by 10% throughout the time series. Given the lack of data on this effect, the assumption was tested in the sensitivity analysis to gauge the impact on the net benefits of this intervention, as further detailed in section 7.

The additional emissions from accelerating the substitution in favour of EVs are summed up and deducted from the gross emissions savings in order to obtain the net emissions savings from this policy intervention. The net CO_2 savings are subsequently converted in monetary terms by multiplying the tonnes of emissions savings by the projected price of carbon as published in New Zealand's Seventh

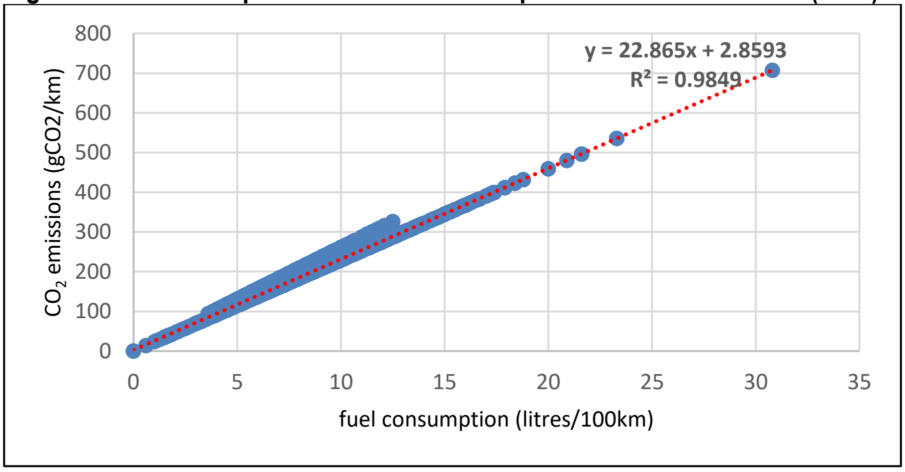
[9] All cost/price values are in 2017 New Zealand dollars, unless otherwise specified.
[10] Additional EVs relative to the VFEM slow case scenario.

National Communication to the UNFCCC [11] [15] and the results are then converted to present values using a real discount rate of 6% p.a. [4].

5.1.2. Fuel Cost Savings

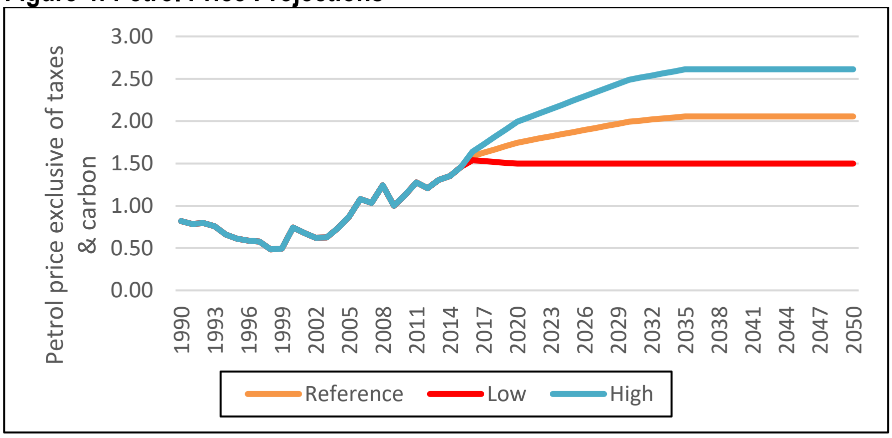
Fuel cost savings are gained by consumers when they purchase a vehicle that is more fuel efficient than they would otherwise without the policy intervention. The extent of these savings will depend on a range of factors, including retail fuel prices, the user's travel needs and the type of vehicle purchased, which in turn depends on the consumer's preferences and choice availability. For modelling purposes, the fuel cost savings are a function of the CO_2 improvements in the vehicle fleet multiplied by the projected, sales-weighted GHG conversion factor [3]. This simply reflects the strong positive linear relationship between the CO_2 emission and fuel consumption, as shown in Figure 3.

Figure 3: Relationship between Fuel Consumption and CO_2 emissions (2017)



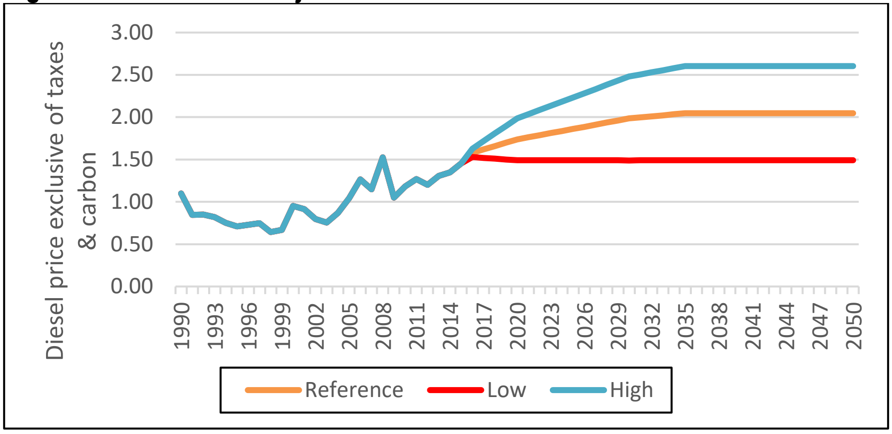
The estimated fuel cost savings are then multiplied by the projected fuel prices (exclusive of GST and ETS) **[5]**. Given the uncertain nature of future fuel prices, two additional scenarios have been modelled in the sensitivity analysis to reflect 'high price' and 'low price' projections, as further detailed in section 7. The projected price of petrol and diesel are shown in Figure 4 and Figure 5 below.

Figure 4: Petrol Price Projections



[11] A review of the current carbon price or recommended carbon cost reveals a number of different figures, including €13/tonne ($22/tonne @0.58 exchange rate) (EU ETS) [21], $21.50/tonne (NZ ETS) [19], $40/tonne (EEM) [4], and US$105 ($150/tonne @ 0.71 exchange rate) (EPA) [22]

Figure 5: Diesel Price Projections



5.1.3. Other Benefits

As stated above, the benefits from accelerating the average CO_2 target of the vehicle import fleet may extend to other areas such as lower air pollution due to the more widespread use of fuel efficient vehicles and possibly lower noise pollution from the increased uptake of EVs. However, the estimations of these benefits would also depend on the concentrations of air or noise pollution within populated areas rather than solely from the vehicle numbers themselves.

Another potential benefit from this policy intervention is obtained from improvements in the security of supply from the importation of lower volumes of fuel imports. A smaller import fuel bill would also favourably impact the trade balance given that New Zealand relies heavily on fossil fuel imports. Notwithstanding, this benefit is expected to be relatively small given that petrol imports only accounted for around 5% of total import values in 2017.

Due to the lack of data available on the above benefits, their quantified and monetary impact has been excluded from this report. Therefore, the benefits to society are likely to be higher than the ones being quantified and reported.

5.2. Quantified Costs

5.2.1. Technology Costs

The main cost associated with this policy intervention is the incremental vehicle cost (hereinafter referred as technology costs) incurred by consumers when purchasing a vehicle that has a better CO_2 emission level. This reflects the long run additional costs incurred by vehicle manufacturers to develop the range of technologies that are needed to improve fuel efficiency and/or to lower emissions for conventional light vehicles.

This report uses cost estimates reported in a study undertaken by Australia's Department of Infrastructure and Regional Development [13], which were primarily informed by European[12] studies and US[13] estimates for packages of various fuel-saving technologies. These additional costs for ICE vehicles typically increase as the CO_2 emission target becomes more stringent and subsequently stabilise or decline slowly, thereafter.

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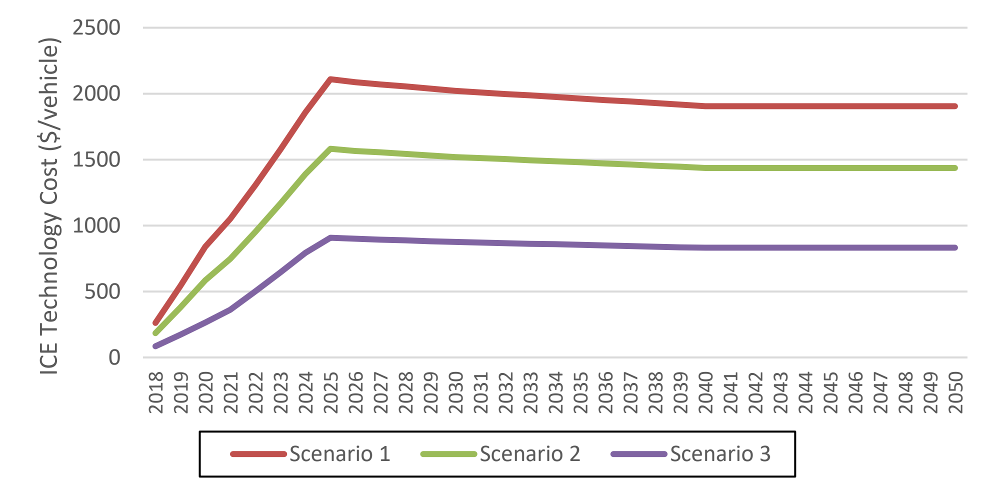
[12] International Council for Clean Transportation (ICCT) summary values adjusted for the different composition of the European fleet and the indirect cost multipliers to scale up extra manufacturing costs to final market-delivered levels

[13] Derived as part of the US Government's own assessment of efficiency standards

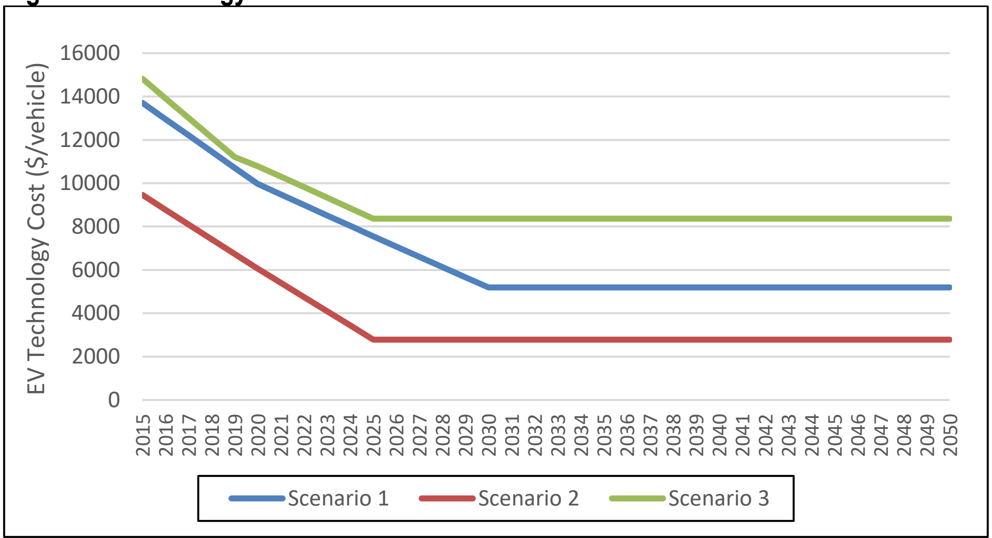
Three technology cost scenarios have been estimated, as shown in Figure 6 below, and which were based on the rate of 'learning' by the manufacturers. Cost scenario 1 has been conservatively taken for this CBA.

Figure 6: Technology Cost – Conventional Vehicles



The cost estimates for new EVs were obtained from a study undertaken to support the VFEM projections [16]. These costs refer to a battery electric vehicle (BEV) with a range of 160km. Three price scenarios have been estimated with Scenario 1 being taken for this CBA. All three cost scenarios are expected to decrease, albeit at different rates, and with all scenarios assumed to remain constant after 2030[14], as shown in Figure 7.

Figure 7: Technology Cost – Electric Vehicles



It is important to recognise that data on the costs of these technologies is highly sensitive and reliable cost estimates for these technologies and the extent that these will be passed on to consumers currently does not exist. Furthermore, there are many unknown factors that could affect future technology costs, such as economies of scale, technical advances, 'learning' effects and the rate of uptake of vehicles with latest fuel efficiency technologies (manufacturers would be able to achieve efficiency gains if the level of uptake is high).

[14] EVs are expected to attain cost parity with conventional vehicles as early as mid-2020 [3]. If this is the case, the technology costs for EVs used in this report are overstated.

Due to data limitations, an average cost figure was assumed for all light vehicles using conventional fuels irrespective of the vehicle type or brand, with a separate cost assumption for electric and hybrid vehicles, as shown above in Figures 6 and 7. However, it is likely that the equipment required to be installed in a vehicle to improve its average CO_2 emissions will vary. The sensitivity analysis presented in section 7 simulates the impact of the other two cost scenarios presented above on the viability of the intervention.

5.2.2. Welfare Impact

The incremental cost incurred to improve the average CO_2 emission level of the light fleet will impact social welfare as measured by the 'deadweight loss'. This reflects the net loss in consumer and producer surplus resulting from the change in vehicle purchase preferences. The implementation of a mandatory VFES regime is expected to induce behavioural changes in the consumers' purchasing decisions i.e. some consumers may have to opt to purchase a vehicle that was different from their preferred one (in terms of vehicle brand, vehicle type or engine size) or that is more expensive (due to the technology cost). Either way, this will lead to a loss in consumer welfare. The extent of these losses will depend on a number of factors, including the consumer response to vehicle price changes and how importers will adapt their fleet to meet the requirements of this policy.

In this analysis, the consumer welfare impacts have been estimated by modelling the projected changes in vehicle demand from the increase in price equal to the technology cost. This assumes that consumers are price-takers and that vehicle importers will wholly pass-on this incremental cost to consumers. The extent to which demand changes will depend on the own price and cross price elasticity of demand for vehicles having a different average CO_2 level. The elasticity values were based on a study carried out by MoT in 2017 [17] and which heavily relies on a UK study on the demand for cars and their attributes [18]. The elasticities used in this report are as shown in Annex 1.

The estimated impact on consumers' welfare is difficult to establish given the number of uncertainties in key variables, particularly related to consumers' preferences, importers' selling strategies and price elasticities of vehicles with different CO_2 rating, amongst others. It is thus recognised that further research is required to reduce these uncertainties.

In the sensitivity analysis presented in section 7, the main parameters impacting consumer welfare such as the price and cross elasticity, projected vehicle prices, rate of substitution between new and used vehicles and technology costs have been simulated in order to determine their respective impact on the viability of the intervention.

5.2.3. Implementation Costs

The implementation of the policy intervention is expected to require initial capital costs, including the setup of the IT system to regulate the implementation of the intervention, and to enable the timely enforcement of the standard. Annual costs are also expected to be incurred to maintain, update and analyse the vehicle fleet's average CO_2 emissions. Miscellaneous costs are also expected to be incurred during the consultation process, the pre-launch event and from regular information campaigns.

The initial capital cost is estimated to be $6.75 million and will be incurred in the year prior to the start of this intervention (2019). Annual operating costs are estimated at $1.5 million, starting from 2020 and running till 2041, which reflects the lifetime benefits obtained from the purchase of a new vehicle in the last year of this intervention (2025). The total discounted implementation costs are estimated to range between $20 million - $30 million (midpoint $25 million) for the duration of this intervention.

5.2.4. Other Costs

The implementation of a CO_2 emission target on vehicle importers may reduce the range of vehicles available to consumers, particularly for the larger petrol vehicles. However, adopting a target based on the sales-weighted average mass of the imported vehicles as opposed to an individual vehicle emission target, should minimise the impacts on vehicle supply and consumer choice[15].

The intervention may also have an indirect negative impact of increasing noxious emissions if consumers would show a greater preference for diesel vehicles as a result of the VFES. Hence, it is important that Euro 6 NOx standards are also implemented prior to, or in conjunction with, the launch of this intervention.

[15] Evidence corroborating this has been reported in the US and the EU.

6. *Cost-benefit Analysis – Results*

6.1. Introduction

The base year and price level have been set to 2019 and the evaluation period covers 2019 to 2041 to include the initial capital costs and the impact from the purchase of a new vehicle in the last year of this intervention (2025) over its expected lifetime (17 years for new vehicles). A real discount rate of 6% pa is used to convert cost and benefit estimates to present values [4].

6.2. Net Benefits

The total net benefit from the full implementation of a VFES regime using a weight-adjusted approach is estimated to range between \$1.21 billion - \$4.75 billion (midpoint \$2.41 billion) and would save between 3.9 million - 6.7 million tonnes of CO_2 (midpoint 5.1 million tonnes) over the evaluation period (2020-2041).

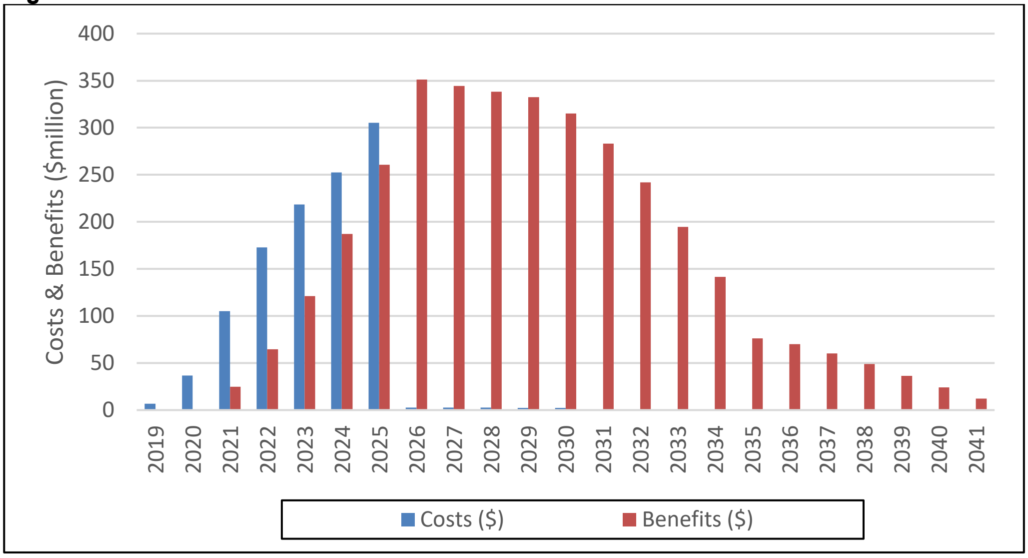
Almost all the benefits (96.5%) are from fuel cost savings to vehicle users, with only 3.5% obtained from the (monetized) benefits of lower GHG emissions. Additional sensitivity analysis of different carbon values is found in Annex 5. The increased supply of fuel efficient and electric vehicles (over-and-above the baseline) is estimated to save New Zealanders between \$2.16 billion - \$5.61 billion (midpoint \$3.4 billion) on fuel over the life of the vehicles affected by the standard. This would translate to \$6,800 lifetime savings per vehicle.

The total additional 'technology' costs on fuel-efficient vehicles were estimated to range between \$683 million – \$1.25 billion (midpoint \$1.07 billion) over 2020-2041. While estimated impact the on consumers' welfare (i.e. the deadweight loss) was estimated to range between \$5.55 million - \$34.4 million (midpoint \$17 million). The average financial[16] payback period to recover the additional costs incurred to equip vehicles with the technology required to improve their CO_2 target is approximately 7 years, which is well below the average lifetime of a new vehicle (17 years) or close to that of a used vehicle (10 years).

The net year-on-year benefit variations reflect the increasing costs and benefits as the required emission target becomes more stringent. The net annual costs and benefits are shown in Figure 8 and more detail is provided Annex 2.

[16] This figure is an indicative average payback period, since in reality, it will depend upon a number of factors that differ from one person/vehicle to another, such as the vehicle price and the user's travel needs.

Figure 8: Annual Costs and Benefits



6.3. Economic viability

The main indicators of economic viability are the Benefit/Cost Ratio (BCR), the Net Present Value (NPV) and the Marginal Abatement Cost (MAC). When there is a net cost (benefit) to reduce an additional tonne of CO_2 emission, the MAC has a positive (negative) value. Thus, the MAC is one way to rank different options based on the relative marginal costs and benefits. The results are shown in Table 4.

Table 4: Results of the Main Indicators for Economic Viability

	Mid-Range	90% Confidence Interval	
		Min	Max
Net Present Value ($ billion)	2.4	1.2	4.7
Benefit-Cost Ratio	3.16	2.1	6.5
Marginal Abatement Cost ($/t$CO_2$)	-469	-851	-260

The above table indicates that for every dollar that is spent on this intervention, society in-general would obtain three times the benefits in return (midpoint), as indicated by the BCR. In monetary terms, the net benefit would range between $1.2 billion - $4.7 billion (midpoint $2.4 billion) over the whole period, as shown by the NPV. The MAC is negative and substantial, meaning that the marginal cost of abating an additional tonne of CO_2 would result in a net social benefit of $469 per tonne (midpoint).

Apart from these significant net benefits to society, it is also important to ascertain the distributional impacts of this intervention. This would require a separate Social Impact Assessment to provide a better picture on those cohorts that would be unduly affected by this intervention, if any.

7. Sensitivity Analysis

An extensive sensitivity analysis was carried out to account for the inherent uncertainties in key parameters and to identify those ones that have a significant impact on the economic viability of this intervention. A sensitivity analysis also establishes the robustness of the results subject to alternative parameter values and scenarios. Table 5 lists the key parameters that have been simulated.

Table 5: Key parameters simulated in the sensitivity analysis

Discount Rate (Policy)
Carbon Price
Electricity Cost
Growth Rate in Vehicle Imports
Average Lifetime of a New Vehicle
Average Lifetime of a Used Vehicle
Average VKT driven by a Conventional Vehicle
Average VKT driven by an Electric/Hybrid Vehicle
Annual Decrease in VKT driven
Technology Cost of a Conventional Vehicle
Technology Cost of an Electric Vehicle
Technology Cost of a Hybrid Vehicle
Rebound Effect
Implementation Cost (CAPEX)
Implementation Cost (OPEX)

The parameter that represents the extent to which vehicle buyers internalise the operating costs of their preferred vehicle in their purchase decision ("Internalisation of Fuel Cost") was analysed separately given that the uncertainty is quite high. Furthermore, the impact on the feasibility of this intervention from varying this parameter is also relatively high. Economic theory states that a 'rational' individual would consider the full operating cost of all vehicle types available on the market and will subsequently purchase the one that maximises his/her utility over the whole lifetime of the vehicle.

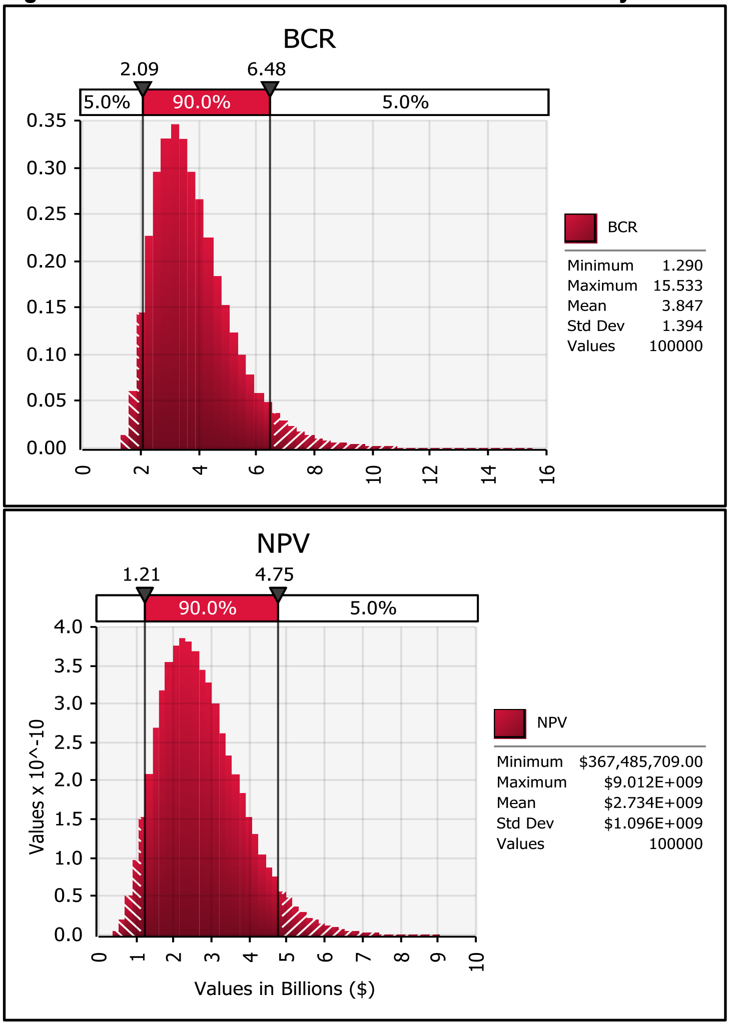
This implies that the individual would purchase the most fuel efficient vehicle available on the market since the fuel savings obtained therefrom would outweigh the additional 'technology' cost of these vehicle types. Hence, it follows that direct government intervention to change consumer behaviour would not be required since a 'rational' individual would automatically choose the best option.

However, various studies show that individuals do not internalise the full operating cost of their preferred type and will only consider the total cost of operating the vehicle over one or two years. Therefore, the need for government intervention to incentivise a change in behaviour in favour of fuel efficiency or low emissions vehicles. The results from varying this key parameter, denoted as "Internalisation of Fuel Cost" are presented in Annex 4.

A Monte Carlo simulation was carried out to test the impact on the economic viability indicators (shown in Table 4) when changing the key assumptions (listed in Table 5) and a separate simulation was carried out to test the "Internalisation Fuel Cost" parameter. The minimum and maximum variation simulated for each key parameter, including at the 5% and 95% confidence level, are listed in Annex 3.

The results of the simulation indicate that the VFES is economically viable, at a 90% confidence interval, as attested by a BCR that varies between 2.09 and 6.48, and an NPV that varies between \$1.2 billion and \$4.7 billion when applying the uncertainty margins of each key parameter simultaneously. The results are shown in Figure 9 below.

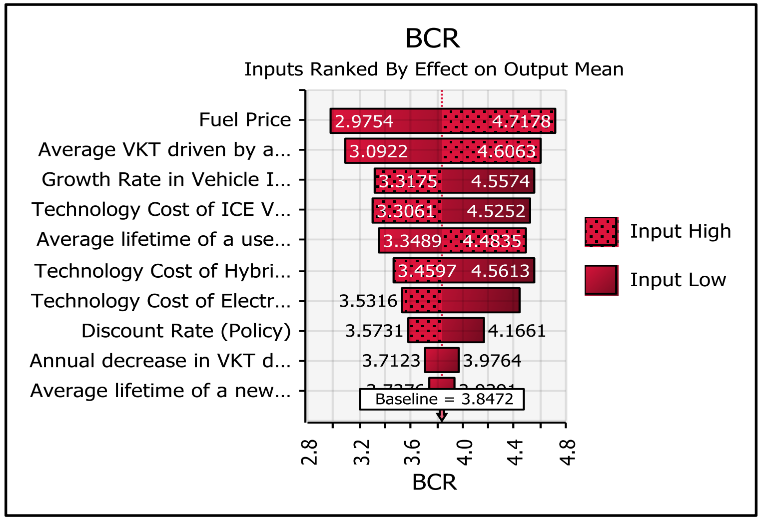
Figure 9: Results of the Monte Carlo Simulation on Key Parameters



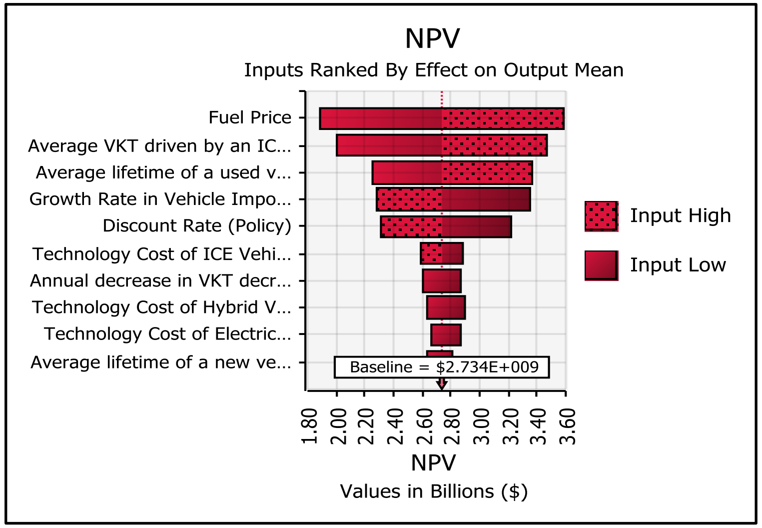
The key parameters that have the greatest impact on the BCR and NPV are shown in Figure 10 below.

Figure 10: Top 10 Key Parameters

Change in Output Statistic for BCR			
Rank	**Name**	**Lower**	**Upper**
1	Fuel Price	2.98	4.72
2	Average VKT driven by an ICE vehicle	3.09	4.61
3	Growth Rate in Vehicle Imports	3.32	4.56
4	Technology Cost of ICE Vehicles	3.31	4.53
5	Average lifetime of a used vehicle	3.35	4.48
6	Technology Cost of Hybrid Vehicles	3.46	4.56
7	Technology Cost of Electric Vehicles	3.53	4.44
8	Discount Rate (Policy)	3.57	4.17
9	Annual decrease in VKT decrease	3.71	3.98
10	Average lifetime of a new vehicle	3.74	3.94



Change in Output Statistic for NPV ($ millions)			
Rank	**Name**	**Lower**	**Upper**
1	Fuel Price	$1,886	$3,580
2	Average VKT driven by an ICE vehicle	$2,000	$3,465
3	Average lifetime of a used vehicle	$2,247	$3,359
4	Growth Rate in Vehicle Imports	$2,277	$3,350
5	Discount Rate (Policy)	$2,316	$3,220
6	Technology Cost of ICE Vehicles	$2,594	$2,889
7	Annual decrease in VKT decrease	$2,598	$2,867
8	Technology Cost of Hybrid Vehicles	$2,636	$2,900
9	Technology Cost of Electric Vehicles	$2,661	$2,870
10	Average lifetime of a new vehicle	$2,630	$2,817



Annex 1 - Elasticities

Table 6: Own price and cross price elasticities

	Emissions Band (gCO_2/km)																
	0 to 4	**5 to 49**	**50 to 69**	**70 to 89**	**90 to 105**	**106 to 120**	**121 to 130**	**131 to 140**	**141 to 150**	**151 to 160**	**161 to 170**	**171 to 180**	**181 to 190**	**191 to 200**	**201 to 225**	**226 to 250**	**<251**
0 to 4	**-4.30%**	0.19%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
5 to 49	0.02%	**-4.30%**	0.19%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
50 to 69	0.02%	0.02%	**-4.30%**	0.19%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
70 to 89	0.02%	0.02%	0.02%	**-4.30%**	0.19%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
90 to 105	0.02%	0.02%	0.02%	0.19%	**-3.58%**	0.56%	0.52%	0.35%	1.82%	0.14%	0.02%	0.10%	0.14%	0.00%	0.00%	0.00%	0.00%
106 to 120	0.13%	0.13%	0.13%	0.13%	0.13%	**-3.80%**	0.28%	0.48%	1.22%	0.62%	0.19%	0.35%	0.20%	0.05%	0.03%	0.01%	0.00%
121 to 130	0.09%	0.09%	0.09%	0.09%	0.09%	0.22%	**-3.95%**	0.45%	0.99%	0.65%	0.33%	0.46%	0.24%	0.11%	0.07%	0.03%	0.00%
131 to 140	0.02%	0.02%	0.02%	0.02%	0.02%	0.15%	0.17%	**-3.44%**	0.89%	0.79%	0.32%	0.49%	0.24%	0.10%	0.07%	0.02%	0.00%
141 to 150	0.06%	0.06%	0.06%	0.06%	0.06%	0.20%	0.20%	0.47%	**-2.87%**	0.72%	0.23%	0.43%	0.22%	0.09%	0.07%	0.02%	0.00%
151 to 160	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.13%	0.40%	0.67%	**-3.22%**	0.37%	0.51%	0.28%	0.15%	0.18%	0.07%	0.01%
161 to 170	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%	0.13%	0.34%	0.44%	0.73%	**-3.47%**	0.67%	0.37%	0.23%	0.20%	0.09%	0.01%
171 to 180	0.00%	0.00%	0.00%	0.00%	0.00%	0.07%	0.11%	0.32%	0.49%	0.65%	0.47%	**-3.43%**	0.30%	0.22%	0.20%	0.08%	0.01%
181 to 190	0.01%	0.01%	0.01%	0.01%	0.01%	0.05%	0.09%	0.23%	0.38%	0.54%	0.37%	0.46%	**-3.42%**	0.19%	0.24%	0.10%	0.03%
191 to 200	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.05%	0.13%	0.20%	0.37%	0.29%	0.43%	0.22%	**-2.86%**	0.28%	0.12%	0.06%
201 to 225	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%	0.05%	0.09%	0.26%	0.15%	0.23%	0.15%	0.17%	**-2.33%**	0.16%	0.09%
226 to 250	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.04%	0.06%	0.19%	0.13%	0.17%	0.12%	0.14%	0.31%	**-2.55%**	0.10%
< 251	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%	0.01%	0.03%	0.04%	0.07%	0.18%	0.11%	**-1.83%**

Note: Percentage change in sales for row category from 1% change in price in column category

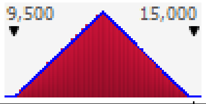
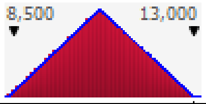
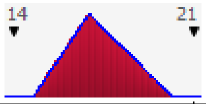
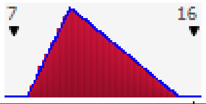
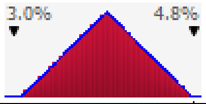
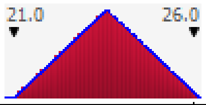
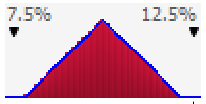
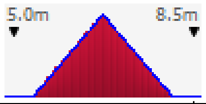
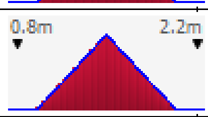
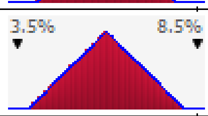
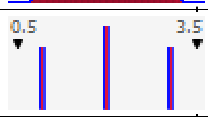
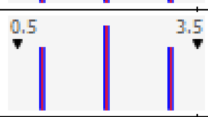
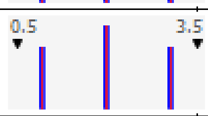
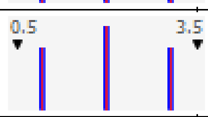
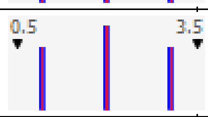
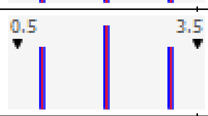
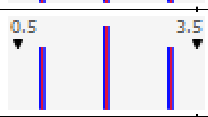
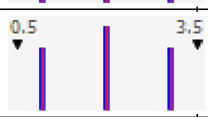
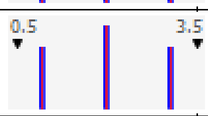
Annex 2 – Annual Costs and Benefits

Table 7: Annual Costs and Benefits

Financial Year	Implementation Year	Undiscounted Costs & Benefits								Discounting Factor @	Discounted Costs & Benefits							
		Costs ($mln)				Benefits ($mln)			Net Benefit ($m)		Costs ($mln)				Benefits ($mln)			Net Benefit ($mln)
		Technology Cost	Deadweight Loss (Proxy)	Implementation Cost	Total	Fuel Savings	GHG emissions	Total		6%	Technology Cost	Deadweight Loss (Proxy)	Implementation Cost	Total	Fuel Savings	GHG emissions	Total	
2019	0	-	-	6.75	6.75	-	-	-	(6.75)	1.00	-	-	6.75	6.75	-	-	-	(6.75)
2020	1	36.84	0.42	1.50	38.76	-	-	-	(38.76)	0.94	34.75	0.40	1.42	36.56	-	-	-	(36.56)
2021	2	115.09	1.44	1.50	118.04	27.16	0.74	27.89	(90.14)	0.89	102.43	1.28	1.33	105.05	24.17	0.66	24.83	(80.23)
2022	3	202.20	2.03	1.50	205.72	75.24	1.92	77.16	(128.56)	0.84	169.77	1.70	1.26	172.73	63.17	1.61	64.79	(107.94)
2023	4	271.90	2.22	1.50	275.62	148.77	4.19	152.96	(122.66)	0.79	215.37	1.75	1.19	218.32	117.84	3.32	121.16	(97.16)
2024	5	333.99	2.28	1.50	337.77	242.92	7.34	250.26	(87.52)	0.75	249.58	1.71	1.12	252.40	181.52	5.49	187.01	(65.40)
2025	6	429.08	2.51	1.50	433.08	358.45	11.36	369.81	(63.28)	0.70	302.48	1.77	1.06	305.31	252.69	8.01	260.70	(44.61)
2026	7	-	2.72	1.50	4.22	511.30	16.72	528.02	523.80	0.67	-	1.81	1.00	2.81	340.05	11.12	351.16	348.35
2027	8	-	2.88	1.50	4.38	531.26	17.71	548.97	544.59	0.63	-	1.81	0.94	2.75	333.32	11.11	344.43	341.68
2028	9	-	2.91	1.50	4.41	552.65	18.60	571.25	566.84	0.59	-	1.72	0.89	2.61	327.11	11.01	338.12	335.51
2029	10	-	2.87	1.50	4.37	575.79	19.40	595.19	590.82	0.56	-	1.60	0.84	2.44	321.52	10.83	332.35	329.91
2030	11	-	2.81	1.50	4.31	578.45	19.49	597.94	593.63	0.53	-	1.48	0.79	2.27	304.72	10.27	314.99	312.72
2031	12	-	-	1.50	1.50	551.08	18.96	570.04	568.54	0.50	-	-	0.75	0.75	273.87	9.42	283.29	282.55
2032	13	-	-	1.50	1.50	498.61	17.71	516.32	514.82	0.47	-	-	0.70	0.70	233.77	8.30	242.07	241.37
2033	14	-	-	1.50	1.50	423.91	16.13	440.03	438.53	0.44	-	-	0.66	0.66	187.49	7.13	194.63	193.96
2034	15	-	-	1.50	1.50	324.98	13.94	338.92	337.42	0.42	-	-	0.63	0.63	135.60	5.82	141.42	140.79
2035	16	-	-	1.50	1.50	182.54	10.82	193.36	191.86	0.39	-	-	0.59	0.59	71.86	4.26	76.12	75.53
2036	17	-	-	1.50	1.50	177.62	11.06	188.68	187.18	0.37	-	-	0.56	0.56	65.96	4.11	70.07	69.51
2037	18	-	-	1.50	1.50	161.35	10.51	171.86	170.36	0.35	-	-	0.53	0.53	56.53	3.68	60.21	59.68
2038	19	-	-	1.50	1.50	138.60	9.42	148.01	146.51	0.33	-	-	0.50	0.50	45.81	3.11	48.92	48.42
2039	20	-	-	1.50	1.50	109.09	7.71	116.80	115.30	0.31	-	-	0.47	0.47	34.01	2.40	36.42	35.95
2040	21	-	-	1.50	1.50	76.15	5.58	81.73	80.23	0.29	-	-	0.44	0.44	22.40	1.64	24.04	23.60
2041	22	-	-	1.50	1.50	40.92	3.10	44.02	42.52	0.28	-	-	0.42	0.42	11.35	0.86	12.22	11.80
Total		**1,389.10**	**25.09**	**39.75**	**1,453.93**	**6,286.83**	**242.39**	**6,529.22**	**5,075.29**	**13.04**	**1,074.39**	**17.03**	**24.81**	**1,116.23**	**3,404.77**	**124.16**	**3,528.93**	**2,412.70**

Annex 3 – Monte Carlo Simulation: Key Input Parameters

Table 8: Key Input Parameters

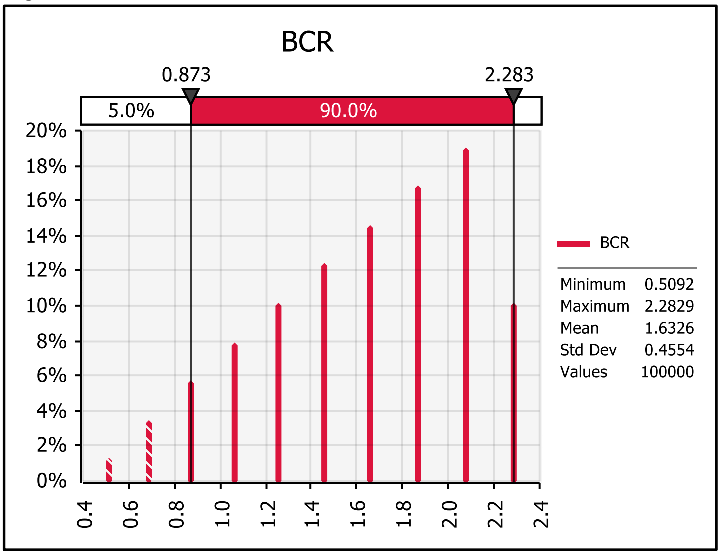
Name	Graph	Min	Mean	Max	5%	95%
Average VKT driven by a new vehicle		9798	12238	14676	10564	13911
Average VKT driven by a used vehicle		8561	10692	12829	9230	12154
Average lifetime of a new vehicle		15	17	20	16	19
Average lifetime of a used vehicle		8	11	15	9	14
Annual decrease in VKT decrease		3%	4%	5%	3%	4%
Fuel Emission Factor		21.24	23.60	25.95	21.98	25.21
Rebound Effect		8%	10%	12%	9%	11%
Implementation cost (CAPEX)		5,504,901	6,750,000	7,994,816	5,895,280	7,604,711
Implementation cost (OPEX)		1,000,825	1,500,000	1,999,097	1,158,100	1,841,879
Discount Rate (Policy)		4%	6%	8%	5%	7%
Fuel Price		1	2	3	1	3
Electricity Price		1	2	3	1	3
Carbon Price		1	2	3	1	3
Average VKT driven by an ICE vehicle		1	2	3	1	3
Technology Cost of ICE Vehicles		1	2	3	1	3
Technology Cost of Hybrid Vehicles		1	2	3	1	3
Technology Cost of Electric Vehicles		1	2	3	1	3
Growth Rate in Vehicle Imports		1	2	3	1	3
Average VKT driven by an electric/hybrid vehicle		1	2	3	1	3

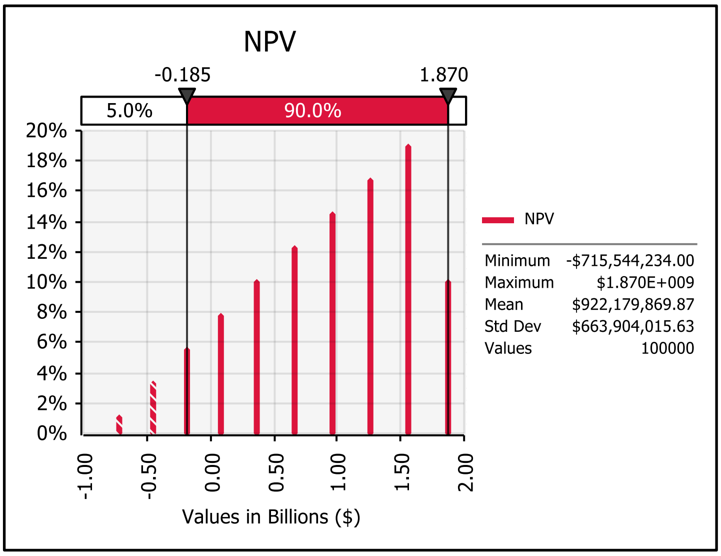
Annex 4 - Monte Carlo Simulation on "Internalisation of Fuel Cost" Parameter

Table 9: Results of the Monte Carlo Simulation on "Internalisation of Fuel Cost" Parameter

	Lower	Upper
Change in Output Statistic for BCR	0.87	2.28
Change in Output Statistic for NPV	-$715,544,234	$1,870,301,410

Figure 11: Confidence Levels of the "Internalisation Fuel Cost" Parameter





Annex 5 – Comparison of Economic Indicators from applying different Social Cost of Carbon

The monetary benefits from CO_2 savings depend on the social cost of carbon that is used to convert the estimated impacts from tonnes to the dollar values. In this analysis, carbon price has been used as a proxy and was taken from New Zealand's Seventh National Communication to the UNFCCC [15] as shown in Table 10. A linear extrapolation was used to obtain figures for the interim years while for post-2030, the price was maintained at $25/tCO_2e.

Table 10: Carbon Prices

	$ per tCO_2e
2010	19.50
2015	15.21
2016	17.15
2020	19.57
2025	22.58
2030	25.00

Various 'carbon prices' or social cost of carbon exist both in New Zealand publications and from literature around the world. In NZTA's EEM, a social cost of $40/tonne [4] is recommended while the current NZ ETS price is $21.50/tonne [19] and is expected to increase to around $27/tonne in 2023 [19]. The recently published NZ Productivity Commission report [20] models three Options that estimate a carbon price ranging from $55 -$80/tonne in 2030 to $150-$250/tonne in 2050. In the EU, the traded ETS price stood at €13/tonne ($22/tonne @ 0.58 exchange rate) [21] while the EPA recommends a price of US$105 ($150/tonne @ 0.71 exchange rate) [22].

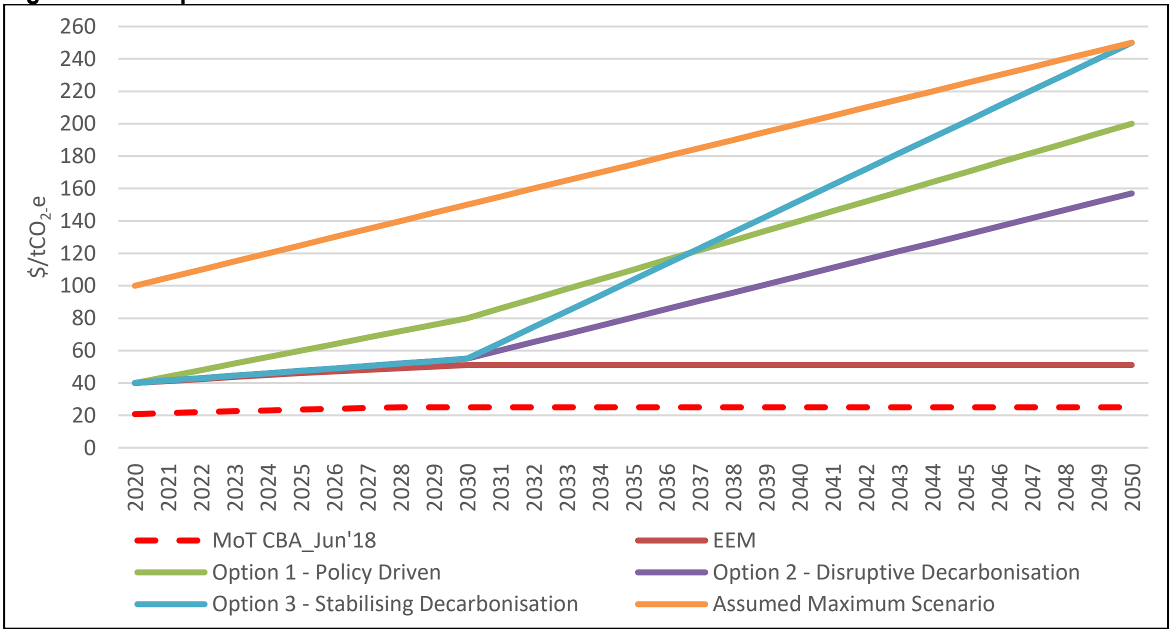
The uncertainty in the carbon price necessitates a comprehensive sensitivity analysis to determine the impact of different price scenarios on the economic indicators. The modelled social cost of carbon/carbon prices are shown in Table 11 and
Figure 12.

Table 11: Comparison of different Carbon Prices and Social Cost of Carbon Values

Social cost of carbon $ per tonne of CO_2 in real terms	MoT CBA_Jun'18 (source: Mfe – 7th NC to UNFCCC)	NZTA - EEM	Prod Comm - Option 1 - Policy Driven	Prod Comm - Option 2 - Disruptive Decarbonisati on	Prod Comm - Option 3 - Stabilising Decarbonisation	MoT - Assumed Scenario
2020	20.77	40.00	40.00	40.00	40.00	100.00
2021	21.38	41.23	44.00	41.50	41.50	105.00
2022	21.98	42.46	48.00	43.00	43.00	110.00
2023	22.58	43.69	52.00	44.50	44.50	115.00
2024	23.06	44.92	56.00	46.00	46.00	120.00
2025	23.55	46.15	60.00	47.50	47.50	125.00
2026	24.03	47.14	64.00	49.00	49.00	130.00
2027	24.52	48.13	68.00	50.50	50.50	135.00
2028	25.00	49.12	72.00	52.00	52.00	140.00
2029	25.00	50.11	76.00	53.50	53.50	145.00
2030	25.00	51.10	80.00	55.00	55.00	150.00
2031	25.00	51.10	86.00	60.10	64.75	155.00
2032	25.00	51.10	92.00	65.20	74.50	160.00
2033	25.00	51.10	98.00	70.30	84.25	165.00
2034	25.00	51.10	104.00	75.40	94.00	170.00

Social cost of carbon $ per tonne of CO_2 in real terms	MoT CBA_Jun'18 (source: Mfe – 7th NC to UNFCCC)	NZTA - EEM	Prod Comm - Option 1 - Policy Driven	Prod Comm - Option 2 - Disruptive Decarbonisation	Prod Comm - Option 3 - Stabilising Decarbonisation	MoT - Assumed Scenario
2035	25.00	51.10	110.00	80.50	103.75	175.00
2036	25.00	51.10	116.00	85.60	113.50	180.00
2037	25.00	51.10	122.00	90.70	123.25	185.00
2038	25.00	51.10	128.00	95.80	133.00	190.00
2039	25.00	51.10	134.00	100.90	142.75	195.00
2040	25.00	51.10	140.00	106.00	152.50	200.00
2041	25.00	51.10	146.00	111.10	162.25	205.00
2042	25.00	51.10	152.00	116.20	172.00	210.00
2043	25.00	51.10	158.00	121.30	181.75	215.00
2044	25.00	51.10	164.00	126.40	191.50	220.00
2045	25.00	51.10	170.00	131.50	201.25	225.00
2046	25.00	51.10	176.00	136.60	211.00	230.00
2047	25.00	51.10	182.00	141.70	220.75	235.00
2048	25.00	51.10	188.00	146.80	230.50	240.00
2049	25.00	51.10	194.00	151.90	240.25	245.00
2050	25.00	51.10	200.00	157.00	250.00	250.00

Figure 12: Comparison of different Carbon Prices and Social Cost of Carbon Values



The results of the sensitivity analysis indicate that the use of a higher carbon price has a moderate impact on the net benefits and a very small impact on the benefit-to-cost ratio. This is partly because of the diluting effect of discounting and partly due to the lower mitigation potential in the future due to the decreasing impact of the policy intervention itself. Table 12 below compares the results of the economic indicators from applying different carbon prices.

Table 12: Comparison of Economic Indicators from the application of different Carbon Price

	MoT CBA_Jun'18 (source: Mfe – 7th NC to UNFCCC)	NZTA - EEM	Prod Comm - Option 1 - Policy Driven	Prod Comm - Option 2 - Disruptive Decarbonisation	Prod Comm - Option 3 - Stabilising Decarbonisation	MoT - Assumed Scenario
BCR	2.07	2.12	2.15	2.13	2.13	2.27
NPV ($million)	1,566	1,632	1,683	1,641	1,649	1,857
MAC ($/ton of CO_2)	-326	-340	-350	-342	-343	-387
CO_2 savings as a share of Net Benefits	2.1%	4.0%	5.4%	4.3%	4.5%	9.7%

Annex 6 – Additional Information on the Marginal Abatement Cost

A marginal abatement cost is a measure of the cost-effectiveness of the policy measure in reducing GHG emissions. It is calculated by dividing the net present value (NPV) of the measure with its GHG abatement potential i.e. the expected reduction in emissions that this measure would achieve if it is implemented as intended. The calculation may be shown by the following notation.

$$NPV_m = \sum_{t=0}^{n} \frac{(b-c)_{m,n}}{(1+r)} \qquad (1)$$

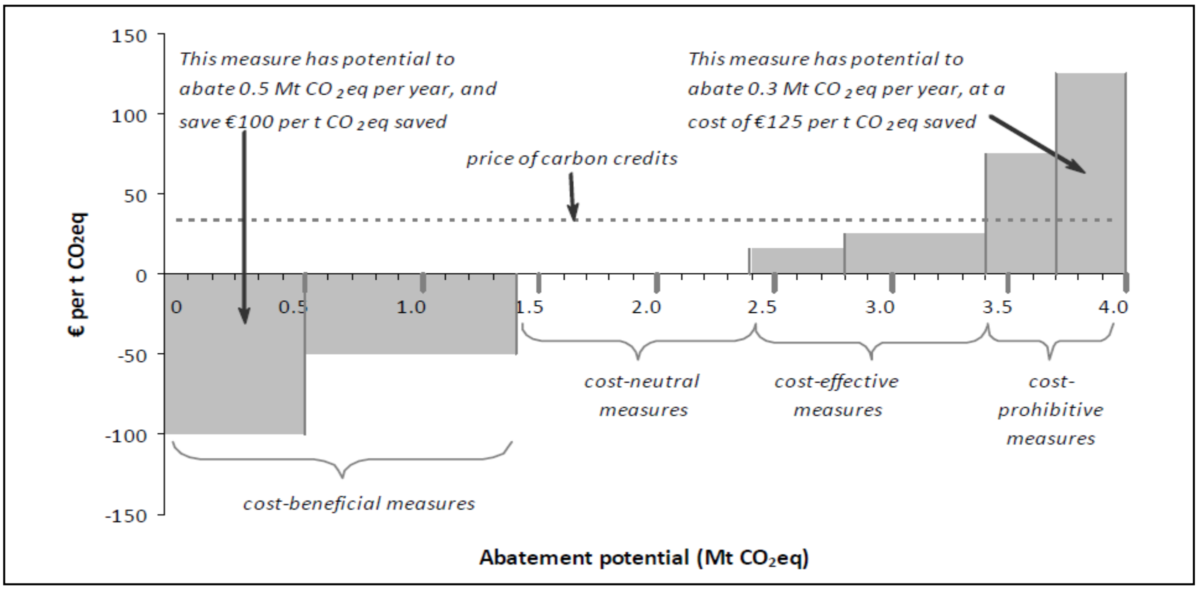
$$MAC_m = \frac{-NPV_{m,n}}{CO_{2\ m,n}} \qquad (2)$$

Where:

(1) NPV_m is the net present value from implementing the measure (m), b denotes the benefits derived from implementing the measure (m) whilst c denotes the costs incurred from implementing measure (m). 1+r denotes the discount rate, n represents the lifetime of measure (m) and t represents the implementation year.
(2) MAC_m is the marginal abatement cost from implementing measure (m), NPV_m is the net present value from implementing measure (m) and CO_{2m} represents the emissions in CO_2 equivalent saved from implementing measure (m) over n years.

The MAC of different measures may be ranked in ascending order from the least expensive to the most expensive in terms of GHG reductions to create a marginal abatement cost curve (MACC)[17], as stylised in Figure 13 below [23] [24].

Figure 13: Stylised Marginal Abatement Cost Curve



[17] A MACC represents the relationship between the quantity of abated emissions and the [incremental] price of CO_2 through the implementation of abatement measures.

The ‘low hanging fruit’ are those measures on the left hand side and below the horizontal axis since these measures are both financially worthwhile[18] and save emissions. Moving to the right of the horizontal axis would represent more costly measures. To determine which of the measures situated above the horizontal axis are still worthwhile to implement, a ‘social cost of carbon’ (SCC) is used as a benchmark [25]. Any measure whose bar is higher than the SCC line would be deemed to be too expensive to undertake and, in theory, it would therefore be cheaper to buy carbon allowances.

The total cost and emissions savings from the implementation of the measures are based on a number of underlying assumptions, including the emissions reduction potential, the behavioural changes that the measure might induce and the time period over which it would be effective. For example, an energy saving awareness campaign may be expected to induce a behavioural change in 10% of households which would subsequently reduce their energy consumption (and hence emissions) by 1% per year over the next 5 years. These assumptions are therefore crucial to obtain a meaningful MAC and a careful analysis is required when calculating the emissions saving potential and the cost of each measure. These estimations need to be sufficiently robust in the face of the uncertainties inherent in any analysis that requires some form of projections.

Moreover, the measures being considered are likely to have an impact on one, or more, of the other measures. These multi-measure interactions can be quite complex and it may be difficult to assess their overall effect. Hence, a careful examination of these interactions is required and detailed caveats would have to be made when drawing conclusions through the use of the bottom-up approach.

[18] As denoted by a positive NPV

Annex 7 – Contribution to New Zealand's GHG Emissions Reduction Targets

In 2020, the projected emissions from road transport are expected to reach 14.1 million tonnes of CO_2 equivalent with 8.5 million tonnes of CO_2 equivalent emitted by cars, SUVs and light trucks. The latter are projected to decrease to 7.1 million tonnes of CO_2 equivalent in 2040 under the most conservative scenario[19] [6].

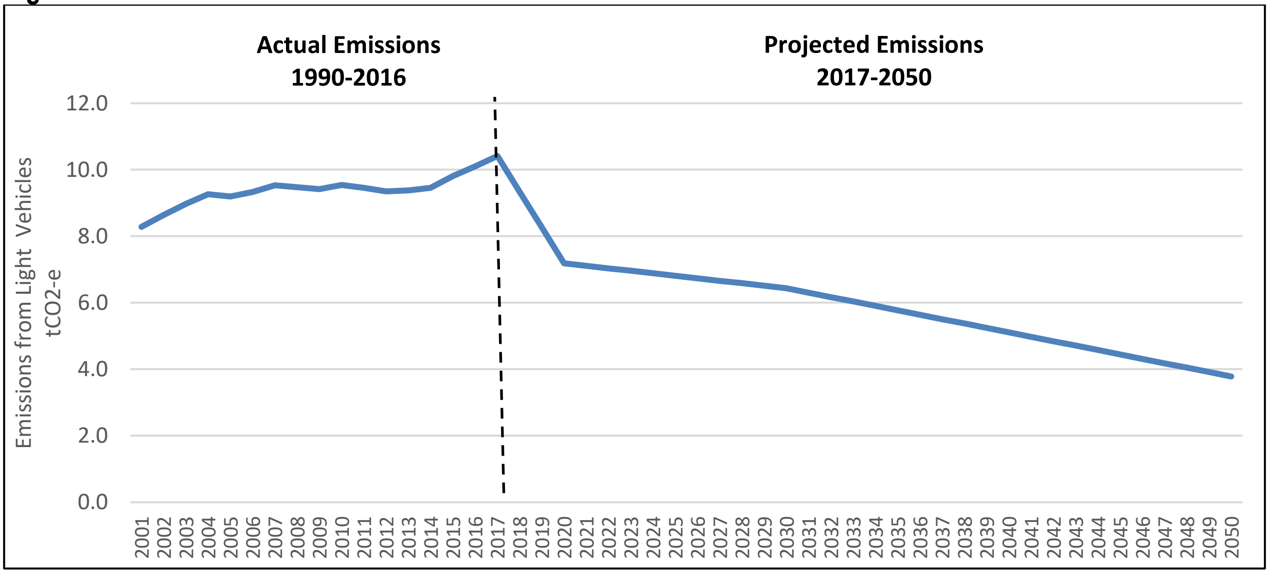
New Zealand's current GHG reduction targets [26] apply at the national level and are not sector-specific. Hence, there is no specific target for the transport sector. The GHG reduction targets are the following:

(1) 5% below 1990 levels by 2020
(2) 30% below 2005 levels by 2030 (equivalent to 11% below 1990 levels)
(3) 50% below 1990 by 2050

For the purposes of this analysis, these national level targets were applied to the road transport emissions[20] and a target trajectory was calculated for the period 2020 to 2050. A linear interpolation was used to obtain annual figures for the interim years.

To obtain a comprehensive time series of historic and projected emissions specifically from light vehicles, the historic emissions (2001-2016) from light vehicles were included with the target trajectory (2017-2050). These historic emissions were obtained from the National Inventory Submission under the Common Reporting Framework (CRF) as reported to the United Nations Framework Convention on Climate Change (UNFCCC) [27]. The resultant time series of road emissions covering 2001-2050 is shown in Figure 14.

Figure 14: Road Emissions from 2001 – 2050

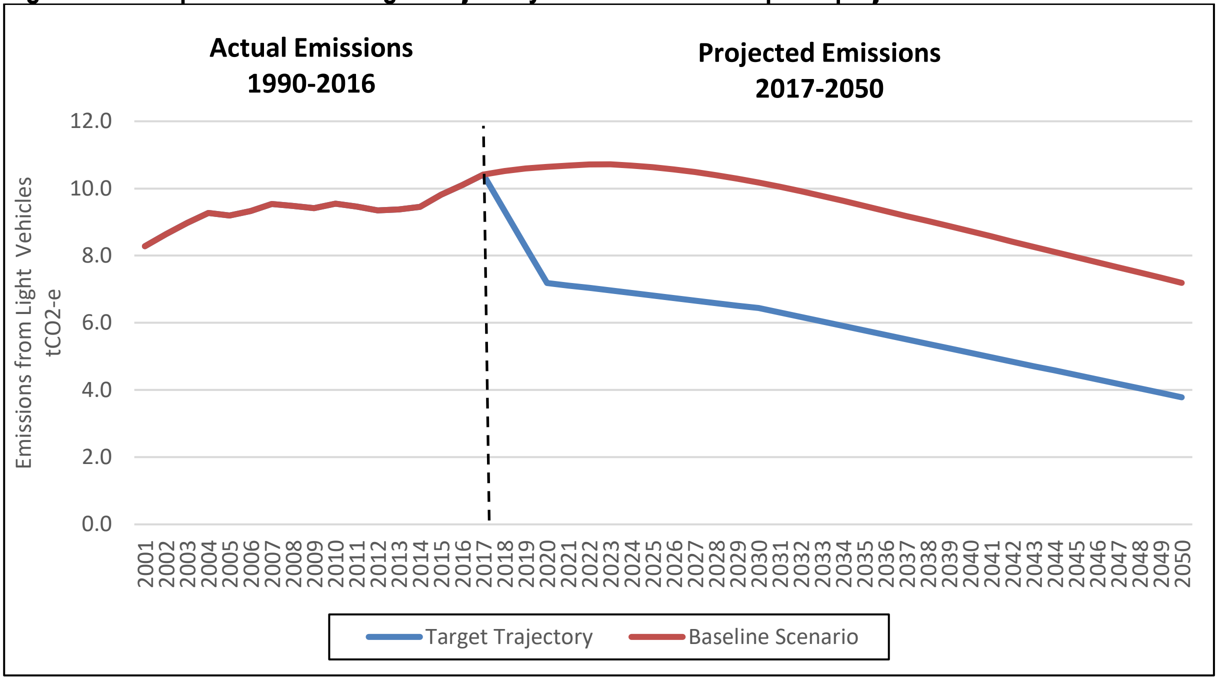


source: [6], [27]

[19] The MoT models a number of scenarios in the Future Outlook report. The most conservative is the 'Slow EV Uptake' scenario, which assumes a quasi-linear uptake in electric vehicles for the period 2020-2040.
[20] In theory, a sector-specific target should be based on the cost-effective mitigation potential of the particular sector.

Superimposing the projected emissions from light vehicles as estimated in the VFEM's Slow EV Uptake scenario [3] shows the 'target gap' between the projected scenario and the target trajectory. This gap therefore shows where New Zealand is expected to stand in relation to its GHG reduction targets at any given year and the effort needed to attain these targets. Figure 15 below compares the target trajectory with the Slow EV Uptake scenario.

Figure 15: Comparison of the Target Trajectory with the Slow EV Uptake projections



The annual CO_2 savings from the VFES are compared with both the emissions projections and with the observed target gap. In the latter case, this comparison provides an indication of how much this measure can contribute to help New Zealand remain within its annual carbon budget. Table 13 shows the contribution from the annual CO_2 savings from the VFES at the end of each decade. The year 2026 was included because the annual CO_2 savings from the VFES are at their highest in that year.

Table 13: Contribution to Target Trajectory and Target Gap

	Emissions from Light Vehicles (A)	Target Trajectory (B)	Target Gap (C = A - B)	Difference between Gap and Trajectory (C)/(B)	Annual Emissions Savings (D)	Share of Emissions Savings from Light Vehicles emissions (D)/(A)	Share of Emissions Savings from Target Gap (D)/(C)
	tCO_2-e	tCO_2-e	tCO_2-e		tCO_2-e		
2020	10.64	7.19	3.45	48%	-	-	-
2026	10.56	6.74	3.83	57%	0.49	5%	13%
2030	10.17	6.44	3.74	58%	0.41	4%	11%
2040	8.72	5.11	3.61	71%	0.06	1%	2%

Table 13 shows that the VFES would reduce the projected emissions from light vehicles by 5% in 2026. This figure falls to 1% by 2040 in-line with the decreasing impact of the VFES on the imported vehicles i.e. in that year, most of the imported vehicles would already be within the emissions standard, and hence, the impact of the measure will be much lower. Expressing these savings in terms of the target gap, this measure would reduce the gap by 13% in 2026 and decreasing to 2% in 2040.

Annex 8 – Equivalent Value of the Cumulative Emissions Savings

An 'equivalent value' compares the emissions savings from implementing a GHG reduction measure with an equivalent source that would need to be reduced or to an equivalent sink that would need to be introduced to offset the CO_2 emissions. This comparative exercise provides a sense of the scale of CO_2 savings from implementing a GHG reduction measure. In this analysis, the CO_2 savings are compared to the following equivalent sources or sinks:

(1) Power stations that would be taken off-line
(2) Vehicles that would be scrapped or lifetime emissions from the three most popular vehicles
(3) Trees that would be planted

Power stations taken off-line

The Ministry for Business, Innovation & Employment (MBIE) reports the GHG emissions from the energy sector [28] on an annual basis. A subset of this sector is electricity generation and the annual GHG emissions for 2011 to 2015 are shown in Table 14.

Table 14: GHG emissions from electricity generation

	kt CO_2-e
2011	5,012
2012	6,417
2013	5,198
2014	4,231
2015	4,041

The VFES is expected to save 5.1 million tonnes of CO_2 equivalent over its lifetime and therefore, it is equivalent to preventing nearly all the emissions that occur from electricity generation in a single year. A similar comparison with a 'standard' power station indicates that the CO_2 savings are approximately equivalent to:

- **5 years** of emissions from a large (400MW) efficient gas-fired power station operating for most of each year or;
- **1 year** of emissions from a large (750MW) coal fired power station operating for most of the year.

Vehicles that would be scrapped

A preliminary CBA carried out by the MoT on the implementation of a vehicle scrappage scheme in Auckland indicates that, on average, scrapping a vehicle (between 10 to 18 years) would save approximately 10.9 tonnes of CO_2 per vehicle (weighted by the level of travel to be expected by vehicle age over the remaining economic life time of the vehicle). This figure is based on a number of assumptions including the characteristics (age, fuel type, emissions rating etc.) of the scrapped vehicles. In general, these where based on historic data on the types of vehicles scrapped.

The VFES is expected to affect half a million vehicles imported over the five years to 2025 and save 5.1 million tonnes of CO_2 equivalent. The estimated CO_2 savings are equivalent to scrapping around

472,000 vehicles between 10 and 18 years of age from the existing fleet (excluding the emission effects from the purchase of any replacement vehicles).

Another approach is to base the equivalent value on the number of new vehicles that are imported in New Zealand. In 2017, the three most popular vehicles were the Ford Ranger, Toyota Hilux and Holden Colorado [29]. Their average emissions range from 191 gCO_2/km for a single cab to 223 gCO_2/km for a double cab. Taking the average of these two figures and the total VKT driven over their economic lifetime (17 years), the CO_2 savings from the VFES would be equivalent to lifetime emissions from 172,000 such vehicles.

Trees that would need to be planted

A report published by the Parliamentary Commissioner for the Environment [30] indicates that a hectare of pine trees would offset 31 tonnes of CO_2 emissions per year in the first 20 years of the tree's life. To retain the storage of 600 tonnes of CO_2 per hectare, the rotations need to continue indefinitely or an equivalent area will need to be planted. A hectare of pine trees can accommodate between 1,000 to 2,500 individual trees, depending on the number of rows and spacing in-between these rows, amongst others. The *annualised* savings from the VFES are expected to be 233,000 tons of CO_2 equivalent, and hence, these savings are equivalent to planting around 7.5 million trees every 20 years. This is equivalent to planting an area of 75 square kilometres (if a spacing of 1000 trees per hectare is assumed), which is roughly the size of Lake Wairarapa.

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