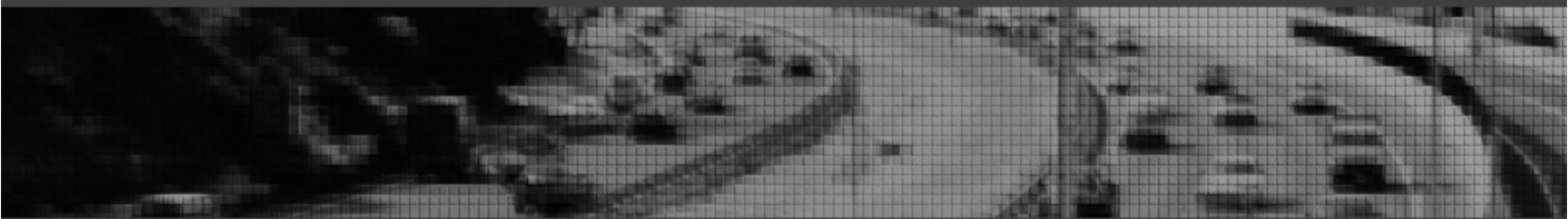

New Vehicle Efficiency Standard (NVES) Design Options and Estimated Impacts on Lifetime CO_2 Exhaust Emissions from New Australian Light-Duty Vehicles

Transport Emission Energy Research

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Executive summary

Purpose: This study has quantified the CO_2 emission impacts of the introduction of two versions of the NVES, the originally preferred option by the Federal Government (Option B) and the latest version (Draft Bill), which is based on Option B, but with a number of changes, namely a shift of specific large SUVs to the more lenient LCV standard, as well as reducing the overall stringency of the standard for LCVs.

Method: TER has recently developed a bespoke NVES design tool and an associated input data file for vehicle model year (MY) 2022 to assess the emission impacts of different standard design options. TER has used the tool in this study to estimate (changes in) total real-world (on-road) lifetime exhaust CO_2 emissions from new Australian light-duty vehicles for five future vehicle model years, MYs 2025 to 2029, which are the years for which targets have been set by the Federal Government.

Input data: In contrast to the EU where emissions and sales data are publicly available for transparency and accountability, this is not the case in Australia. TER therefore reconstructed an input file using publicly available data and information. Comparison with high level statistics suggest that the reconstructed input file could be a reasonably accurate representation of the actual data used by the Federal Government for the purposes of this study.

Scope: The estimated emission impacts are based on reconstructed MY 2022 input data and they assume no change in total vehicle sales and no change in fleet average mass (mass in running order, MIRO) in future years. Electrification and any other measures that a manufacturer may choose to improve the future (2025-2029) emissions performance of their newly sold vehicles (e.g. hybridisation, engine downsizing) are reflected in the modelling by assuming that all vehicle brands will meet their respective MY-specific and brand-specific targets, whilst keeping their average MIRO the same. As a consequence, the simulation does not yet account for the potential increase in the sales of larger and heavier vehicles (car obesity) that has been observed over time, or alternatively, lightweighting of vehicles, both of which could change fleet average MIRO values and therefore the brand-specific targets.

Main findings:

The Federal Government estimated a total NVES emissions abatement in 2050 of 369 Mt (million metric tonnes) in 2050 (Option B) and 321 Mt (Draft Bill). The abated emissions predicted in this study are substantially lower with 103 Mt (Option B) and 87 Mt (Draft Bill), 27-28% of the estimates made by the Federal Government. In a relative sense, the predictions are more similar. The Federal Government estimates that the change from Option B to the Draft Bill reduced the total abated emissions with 13%, whereas this study estimates a total emission abatement loss of 16%. Without a clear understanding how the Federal Government modelled the NVES impacts, it is not possible to explore the reasons for these differences, but Section 5.3 suggests a number of possible reasons.

The introduction of the NVES (Draft Bill) in 2025 will provide significant reductions in real-world lifetime CO_2 emissions for newly sold vehicles after 2025, as compared with the baseline scenario. In 2025 the estimated reduction in real-world emissions is only 2%, but this is increasing to about 50% in 2029. Compared to Option B, the changes proposed in the NVES (Draft Bill) have weakened the standard and have increased real-world lifetime CO_2 emissions for newly sold vehicles with 5% in 2025 (2,671 ktonne), increasing to 16% (3,856 ktonne) in 2029.

The inclusion of the credit-debit system increases lifetime CO_2 emissions in the NVES (Draft Bill) with 4.5% in 2025, reducing to 2.3% in 2029. A restriction of the credit-debit system to apply to internal credits only (i.e. the transfer option for credits between manufacturers for monetary gains would be removed from the NVES) will result in an additional real-world emission reduction.

In terms of the NVES impacts by vehicle brand, the results are only indicative, as there are a number of caveats, as discussed in the report (e.g. use of MY 2022 reconstructed sales data, pre-pooling). Most manufacturers - but not all - in the debit group seem to have benefitted from the changes made in the Draft Bill in terms of a reduction in emission debits and their associated (potential) costs. However, a small number of manufacturers seem to have benefitted substantially more than others, with reductions in their debit potential between 44-95% (ranked: Toyota, Isuzu Ute, Land Rover, Ford, Ssangyong and LDV). Toyota is the only manufacturer that changed from the debit group to the credit group.

NVES recommendations:

The study made a number of recommendations to ensure that the NVES will be effective:

1. The NVES should adopt the WLTP test protocol from 2025 onwards.
2. The NVES should include on-board fuel consumption monitoring (OBFCM).
3. The NVES should include safeguard mechanisms to prevent adverse effects.
4. The NVES should include a robust evaluation and correction mechanism.
5. Improve transparency regarding NVES performance and input data.
6. Expand from exhaust to lifecycle emissions in future NVES design.
7. Reduce the adverse impact of the credit-debit system on emissions abatement.

Recommendation for further work:

Finally, there appears to be a significant risk that car obesity will be promoted with the currently proposed NVES design, therefore continuing the increased sale of large and heavy passenger vehicles, with detrimental effects on energy consumption and greenhouse gas emissions from the Australian road transport sector. It is therefore recommended that the NVES design tool is used to further analyse this issue and assess the potential risks for an effective operation of the NVES. It is also suggested that the results from this study are compared with a follow-up study that uses the actual input data used by the Federal Government.

Glossary of terms

- **BEV** - Battery electric vehicle (see Appendix B for further explanation).
- **Breakpoint** - Breakpoints are specific MIRO values (kg), which adjust the limit curve. Upper breakpoints create mass-independent (constant) limit values above the breakpoint, making the limit curve more stringent for heavier vehicles and effectively placing a cap at the higher end of the limit curve. In contrast, lower breakpoints create mass-independent limit values below the breakpoint, effectively making the limit curve more lenient for lighter vehicles.
- (**Vehicle**) **Class** - The vehicle class was originally defined as passenger vehicle (PV), which includes cars and SUVs (MA, MB, MC or light off-road passenger vehicle), and light-commercial vehicles (NA, NB1) up to 4.5 t GVM[1] (LCV).[1,2] In the draft Bill, the definition was changed to Status Type 1 (MA, MB, MC or light off-road passenger vehicle) and Type 2 LDVs (NA, NB1, MC2 or heavy off-road passenger vehicle with a GVM ≥ 3 t and a body-on-frame chassis), which roughly corresponds to passenger cars and light/medium sport utility vehicles or SUVs (Type 1) and light commercial vehicles or LCVs and heavy SUVs (Type 2).[2,3] Appendix A contains a list of make-models that shifted from Status Type 1 to 2.
- **Credit-debit system** (**units**) - The NVES allows for the production of (emission) credits. If the interim emission value for a supplier is less than zero (overperformance), a number of units (credits) will be issued and registered, equal to the absolute value of the interim emissions value (g/km). These credits remain valid for 3 years, after which they will lapse. The supplier may extinguish some or all of those credits to reduce their final emissions value for another year. Alternatively, they may transfer some or all of those credits to another supplier who may extinguish them to reduce their own final emissions value for that year or another year. A supplier must ensure that the final emission value for a particular year is zero or less, a little over two years later.[2] If this is not the case, a civil penalty will apply which is the final emission value for the particular year multiplied by (AUD) $100. In comparison, EU Regulation 2019/631 focuses on debits and refers to the 'excess emissions premium', which is a positive number of grams/km by which a (pooled) supplier's average specific CO_2 emissions exceeded its specific emissions target. It is computed as the difference between the specific emission target in the calendar year and the fleet-average emissions, multiplied with the number of newly registered vehicles and 95 Euros.
- **Emission number** (**E**) - The CO_2 exhaust emissions performance (g/km) of a new vehicle as determined by the official laboratory test procedure that is based on the New European Drive Cycle (**NEDC**). The NEDC value is the same as the emission number in the draft NVES Bill, or *E*, which is the NEDC value entered on the RAV.[3] For comparison, in EU Regulation 2019/631 this is referred to as the 'average specific CO_2 emissions'.
- **FCAI** - Federal Chamber of Automotive Industries.
- **FCEV** - Fuel cell electric vehicle (see Appendix B for further explanation).

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[1] The NVES includes heavier LDVs (≤ 4.5 t GVM), whereas the EU is limited to LDVs ≤ 3.5 t GVM. This ensures that heavy LDVs used in Australia do not escape regulation.

[2] Specifically, the final reconciliation day for a particular year is the 3rd 1 February after the end of the year (e.g. for 2025 it would be 1 February 2028).

- **Final emission value** - In the draft NVES Bill the final emission value for a supplier in a particular year is computed as the interim emissions value minus the number of units that were extinguished for the purpose of reducing their final emission value.[3]
- **GVM** - Gross vehicle mass (kg).
- **Headline target** (**HLT**) - The NVES NEDC-equivalent CO_2 target (g/km) for a vehicle class in a particular year. In the draft NVES Bill this variable is referred to as the headline limit or HL.[3] For comparison, in EU Regulation 2019/631 this is referred to as the fleet-wide target.
- **HEV** - Hybrid electric vehicle (see Appendix B for further explanation).
- **ICEV** - Internal combustion engine vehicle (see Appendix B for further explanation).
- **Interim emission value** - In the draft NVES Bill the interim emission value for a supplier is computed as the difference between the emissions number *E* and the emissions target *ET*, i.e. *E* - *ET*, multiplied by the number of covered vehicles. It quantifies the performance against the applicable targets. A positive value indicates that the vehicles have collectively underperformed against their targets, whereas a negative value indicates overperformance, leading to the issuing of credits, which are called units in the Draft NVES Bill.[3]
- **Lifecycle emissions** - Estimate of the total CO_2 emissions from a new vehicle sold in the future (2025-2029) over its entire 'cradle-to-grave' lifecycle, accounting for both fuel-cycle emissions (well-to-wheel) and vehicle-cycle emissions (material and vehicle production, as well as end of life, recycling or scrapping).
- **Lifetime emissions** - Estimate of the total exhaust (tailpipe) CO_2 emissions from a new vehicle sold in the future (2025-2029) over its entire useful life.
- **Limit curve** - The mathematical relationship between the sales-weighted average vehicle mass in running order (kg) and the applicable NEDC-equivalent CO_2 emission target (g/km). The curve is defined in terms of the reference mass, the slope and break points.
- **Limit value** (**ET**) - The NEDC-equivalent annual CO_2 emission target that applies to the supplier within each vehicle class. The limit values are derived from the limit curve, after determination of the sales-weighted MIRO and sales-weighted NEDC value. In the draft NVES Bill the limit value is called *ET*, the emission target for the vehicle for the year.[3] For comparison, in EU Regulation 2019/631 this is referred to as the 'specific emissions target'.
- **MIRO** (**DM**) - The vehicle mass in running order (kg), declared by the vehicle supplier, which is the mass of a vehicle with fluids, accessories, plus the weight of one person in the vehicle. In the draft NVES Bill MIRO is called *DM*, the 'designated mass' for the vehicle class and for a particular year.[3] For comparison, in EU Regulation 2019/631 this is referred to as the mass in running order as stated in the Certificate of Conformity.
- **NEDC** - New European Drive Cycle.
- **NVES** - New Vehicle Efficiency Standard.
- **Off-cycle credits** and **eco-innovation** - The off-cycle crediting program in the USA identifies and rewards technologies that deliver real-world benefits, but are insufficiently accounted for in the official test cycle. EU Regulation 2019/631 and 2023/851 (Article 11) include the concept of eco-innovation, which are CO_2 emission savings achieved through the use of innovative technologies or a combination of these technologies. They include things like the use of LED lights, solar roof battery charging and innovative and improved mobile air-conditioning systems. Eco-innovation reduces the average specific CO_2 emissions of a supplier

in the EU and it is capped at a maximum of 7 g CO_2/km (until 2024) reducing to 4 g CO_2/km (2030-2034). It is noted that technologies considered here can become mainstream and the industry standard. Off-cycle credits and eco-innovation are not included in the Draft Bill.

- PHEV - Plug-in hybrid electric vehicle (see Appendix B for further explanation).
- PV - passenger vehicle, including cars and SUVs.
- RAV - Register of Approved Vehicles, which has the same meaning as in the Road Vehicle Standards Act 2018.
- Reference mass (RM) - The sales-weighted average vehicle mass of all vehicles sold two years prior in each vehicle class. In the draft NVES Bill MIRO is called RM, the reference mass for the vehicle class and for a particular year.[3]
- Slope - The slope of the limit curve (SLC). In the draft NVES Bill slope is called MAF, the mass adjustment factor for the vehicle class and for a particular year.[3]
- Supercredits - In EU Regulation 2019/631, supercredits allowed suppliers to count ZLEVs at a higher rate by using a year-specific multiplier, therefore reducing their average specific CO_2 emissions and making the regulation more lenient. Supercredits applied until 2022, but not beyond. They are also not included in the NVES.
- SUV - Sport Utility Vehicle. The FCAI defines SUVs as passenger vehicles with a 2/4 door wagon body style and elevated ride height, typically featuring some form of 4WD or AWD.
- WLTP - Worldwide harmonized Light-vehicles Test Procedure.
- ZLEV - Zero- and low-emission vehicle. In EU Regulation 2019/631 this is defined as an LDV with official exhaust emissions between 0 and 50 g CO_2/km (WLTP).

1. Introduction

Road transport is a large and growing source of carbon dioxide (CO_2) emissions around the world. In Australia, CO_2 emissions from the road transport sector increased by more than 50% between 1990 and 2020, and during that time the contribution of road transport to Australia's greenhouse gas (GHG) emissions increased from 8% to 16%.[4] Australia needs real and rapid reductions in CO_2 emissions from the transport sector. Recent (joint) studies published by, for instance, Transport Energy/Emission Research (TER) and the International Council on Clean Transportation (ICCT) have estimated that Australia will fall short of the net-zero target in 2050 for road transport by a large margin (a total emission reduction of 35-45% in 2050 compared to 2019) unless emissions-mitigation policies are intensified and a portfolio of supporting policies are implemented.[4,5]

A mandatory fuel efficiency or emission standard is an internationally recognised key policy tool that reduces fleet-average CO_2 emissions from newly sold vehicles and a fundamental building block for effective emission mitigation policies.[6-8] Australian policymakers have debated whether to implement a mandatory standard for light-duty vehicles for more than a decade. Since 2008, the Australian Government has released six public consultation documents related to a proposed fuel efficiency standard.[4] With the release of the proposed New Vehicle Efficiency Standard Bill 2024, Australia is now close to adopting a mandatory new vehicle standard.[2,3]

Greenpeace commissioned Transport Energy/Emission Research (TER) to perform an independent and impartial expert review of recent changes in the proposed design of the (Australian) New Vehicle Efficiency Standard (NVES) and to estimate the associated impacts on CO_2 emission from new light-duty vehicles (LDVs), using an emission standard design tool recently developed by TER. LDVs include cars, sport utility vehicles (SUVs) and light-commercial vehicles (LCVs).

2. The NVES

The analysis is based on review of the following fundamental documents:

- AG, 2024. *Cleaner, Cheaper to Run Cars: The Australian New Vehicle Efficiency Standard, (Consultation) Impact Analysis*, Australian Government (AG), Department of infrastructure, Transport, Regional Development, Communications and the Arts, February and March 2024.[1,2]
- PCA, 2024. *New Vehicle Efficiency Standard Bill 2024*, The Parliament of the Commonwealth of Australia (PCA), House of Representatives, 2022-2023-2024.[3]

These documents discuss the manner in which the NVES will function and they include a description and/or the definition of relevant terms for the NVES, which are included in the glossary of terms.

This study will investigate the emission impact of three different scenarios, specifically:

- **Baseline** - A baseline scenario where Australia continues to lack a mandatory NVES.
- **Option B** - The Federal Government stated that 'Option B' was the preferred approach for the NVES in February 2024, balancing ambition and achievability.[1,2]
- **Draft Bill**: This is the latest version of the proposed NVES, which is presented as the 'best final option' in March 2024 [2], and it reflects a number of changes to Option B.[2,3]

Table 1 (next page) presents an overview of relevant design specifications of the NVES and the different scenarios. The coloured cells highlight where changes in NVES design have been proposed in the Draft Bill. Please refer to the glossary of terms for the definitions and descriptions of the NVES variables and aspects.

Compared to Option B, the Draft Bill:

- changed the definitions of vehicle type 1 and 2 (i.e. shifting specific large SUVs to the more lenient LCV standard),
- increased the headline target for LCVs with 6% (2025) to 36% (2029), and
- increased the upper breakpoints with about 10%.

Regarding the first point, Appendix A contains a list of make/models that we have assumed will be shifted from the Type 1 to the Type 2 category.

Table 1 – NVES design specification by scenario and vehicle class (NEDC-equivalent CO_2, g/km).

NVES aspect *	Baseline		Option B		Draft Bill	
	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2
Category	-	-	Car, SUV	LCV	Car, SUV	SUV, LCV
HLT 2025 (NEDC, g CO_2/km)	-	-	141	199	141	210
HLT 2026	-	-	117	164	117	180
HLT 2027	-	-	92	129	92	150
HLT 2028	-	-	68	94	68	122
HLT 2029	-	-	58	81	58	110
Reference Mass 2022 → 2025 ** (kg)	-	-	1,723	2,155	1,723	2,155
SLC/MAF 2022 → 2025 **	-	-	0.0663	0.0324	0.0663	0.0324
Lower breakpoint 2025 (kg)	-	-	1,500	1,500	1,500	1,500
Upper breakpoint 2025 (kg)	-	-	2,000	2,200	2,200	2,400
Credit banking/trading (units)	-	-	Yes	Yes	Yes	Yes
Civil penalty (AUD per g/km)	-	-	$ 100	$ 100	$ 100	$ 100
Manufacturer pooling	-	-	No	No	No	No
Supercredits	-	-	No	No	No	No
Off-cycle credits/eco-innovation	-	-	No	No	No	No

* **HLT** = headline target/limit, **SLC/MAF** = slope limit curve/mass adjustment factor. ** These values are based on fleet data for vehicles sold in 2022 (MY) and they will apply to vehicles that will be sold in 2025. These values will be updated on a rolling annual basis during the operation of the NVES and may be adjusted for years after 2025, with the condition that headline limits must decrease over time or reflect a more stringent test procedure (Draft Bill Section 31).

3. The NVES design tool

TER has recently developed a NVES design tool and an associated input data file for model year (MY[3]) 2022. The tool is designed to quantify and assess the impacts of different NVES design options on real-world emissions. TER has used the tool in this study to estimate (changes in) CO_2 emissions from new Australian light-duty vehicles for each vehicle class. The assessment was carried out for five future years, MYs 2025 to 2029, which are the years for which targets have been set by the Federal Government.[1,2] This section will discuss the different aspects of the NVES design tool, the underlying method and assumptions that were made in the computation of the emission impacts for the three scenarios.

3.1 The NVES input file

In the EU, the European Environment Agency (EEA) makes new vehicle emissions and vehicle sales data publicly available for transparency and accountability.[9] The Federal Chamber of Automotive Industries (FCAI) is the custodian of these data in Australia, but these data are not publicly available.

TER has therefore created an input file for the NVES tool by combining various tables presented in the latest publicly available report published by the National Transport Commission (NTC). These tables[4] include sales and NEDC data for Australian LDVs that is specified by make and model.[10] These data were then supplemented with estimates of mass in running order (MIRO) using available online data,

[3] Also commonly referred to as year of manufacture.

[4] Tables 11, 12 and 27.

vehicle parameter data TER has collected over time (e.g. during vehicle emission measurement programs) and data that have been generated in ongoing collaborative research between TER and the EU's Joint Research Centre (JRC).[11, 12]

The input file for MY 2022 is effectively a reconstructed version of the complete, but not publicly available FCAI database. The input file provides critical input data on, for instance, vehicle brand (make), model, sales, market segment, emissions performance (NEDC, g CO_2/km), MIRO (kg), vehicle class (PC, SUV, LCV) and vehicle Status Type (1 or 2). The input file provides these input data for 302 make/model combinations, including battery electric vehicles (BEV). Comparison with publicly available analysis of FCAI's 2022 VFACTS data [13], shows that the input file captures 94% of total Australian LDV sales in 2022. The input file estimates that the number of (light-duty) BEVs sold in 2022 is 32,953 or 3.4% of total LDV sales. A comparison of total sales by vehicle brand [13], shows that:

- low-volume brands[5] (< 600 vehicles sold) are not included in the input file, as they are not included in the NTC tables, and
- a number of brands have a difference in total sales volume that exceeds 2,000 units.[6]

To ensure that the emission calculations reflect total sales, a brand-specific sales correction factor (δ_i) is used in the NVES design tool to ensure that total sales by brand align with summary sales data published by the FCAI, as will be discussed in the next section.[13]

3.2 How are emissions estimated in the NVES design tool?

The NVES tool calculates the sales-weighted CO_2 emissions performance for each vehicle brand and then compares this with the brand-specific targets, which are computed using the NVES design parameters presented in Table 1 (headline target, reference mass, mass adjustment factor, breakpoints). The detailed 2022 input file (Section 3.1) is processed to create an aggregated 2022 NVES input file listing total sales for each vehicle brand, as well as sales-weighted average values for 1) exhaust emissions performance, 2) mass in running order, 3) accumulated lifetime mileage, and 4) the real-world correction factor.

To prevent any confusion, the scope of this study is focused on estimation of real-world (on-road) *lifetime* exhaust emissions[7], but not the more comprehensive *lifecycle* emissions, as will be discussed in Section 3.3.

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[5] Alfa Romeo, Alpine, Caterham, Ferrari, Lotus, Mclaren.

[6] These include the German automaker brands Mercedes-Benz (56% included), BMW (59% included) and Audi (64% included) as well as Lexus (57% included) and Land Rover (49% included).

[7] Total exhaust (tailpipe) CO_2 emissions from a new vehicle sold in the future (2025-2029) over its entire useful life.

Total exhaust emissions for each vehicle make *i* in 2022 are estimated using the following formula:

$$e_{i,nedc} = \varepsilon_{i,nedc}\, m_i\, (\delta_i\, s_i) \qquad (1)$$

$e_{i,nedc}$: exhaust CO_2 emission for vehicle make *i* (g, NEDC)
$\varepsilon_{i,nedc}$: sales-weighted exhaust CO_2 emission rate for vehicle make *i* on the NEDC test cycle (g/km)
m_i : sales-weighted lifetime accumulated mileage for vehicle make *i* (km)
δ_i : sales correction factor for vehicle make *i* (-)
s_i : total number of annual vehicle sales of vehicle make *i* (-)

The variables $\varepsilon_{nedc,i}$, δ_i and s_i are retrieved from the aggregated NVES input file. For m_i the following values are used in this study:

- 200,000 km for cars
- 250,000 km for SUVs
- 300,000 km for LCVs

These input values were estimated after analysis of accumulated mileage data for different vehicles classes. The mileage data were collected as part of Australian vehicle emission measurement programs over time[8] and were supplemented with further analysis on other datasets to support the development of the Australian Fleet Model (AFM).

Total exhaust emissions for all newly sold vehicles in future years are then computed for the different scenarios and vehicle types (Status Type 1 and 2), both as NEDC-equivalents and as real-world (on-road) estimates:

$$E_{sxy,nedc} = \left(\gamma_{xy} \sum e_{i(y),nedc}\right)/1E9 \qquad (2)$$

$$E_{sxy,rw} = \varphi\, E_{sxy,nedc} \qquad (3)$$

$E_{sxy,nedc}$: total exhaust CO_2 emission (NEDC) for scenario *s*, year *x* and vehicle type *y* (ktonne)
$E_{sxy,rw}$: total exhaust CO_2 emission (real-world) for scenario *s*, year *x* and vehicle type *y* (ktonne)
$e_{i(y),nedc}$: exhaust CO_2 emission (NEDC) for vehicle make *i* belonging to vehicle type *y* (g)
γ_{xy} : BEV correction factor for year *x* and vehicle class *c* (-)
φ : fleet-average real-world driving correction factor (-)

The real-world correction factor φ will be discussed in Section 3.4.

For the baseline scenario, further penetration of BEVs in future years needs to be accounted for. This is done by introducing a year-dependent BEV correction factor γ_{xy}. By definition exhaust emissions from BEVs are 0 g/km.

So the impacts of electrification in the baseline scenario are captured by adjusting total emission estimates that are based on the MY 2022 input file (non-BEVs only), corrected for the share of BEVs. γ_{xy} is computed as $1-P_{bev,xy}$, where $P_{bev,xy}$ is the estimated proportion of new vehicles sales that are

[8] TER has collated these data into a comprehensive Australian emissions and vehicle parameter database.

BEVs for year *x* and vehicle type *y*. The values used for $P_{bev,xy}$ and γ_{xy} used in this study are discussed in Section 4.

For the NVES scenarios, the MY 2022 data are used to calculate the Option B and Draft Bill emissions for MYs 2025-2029. Electrification and a range of other measures that can improve the emissions performance of newly sold vehicles (e.g. hybridisation, lightweighting, engine downsizing, shift to selling smaller vehicles) are simulated by assuming that all vehicle brands will meet their respective brand-specific targets. The variable γ_{xy} is no longer relevant in the NVES scenarios and set to unity in the simulation.

The brand-specific targets are derived from the limit curve as defined in Table 1, using the estimated sales-weighted MIRO values for each supplier. The adjusted official emission rates will then be multiplied with total vehicle sales and estimated sales-weighted lifetime mileage to estimate total lifetime emissions for the newly sold vehicles for each MY in the 2025-2029 period. The estimation process is visualised in Figure 1 (next page). Using the sales-weighted real-world emission correction, an estimate will then be made for total (lifetime) real-world emissions.

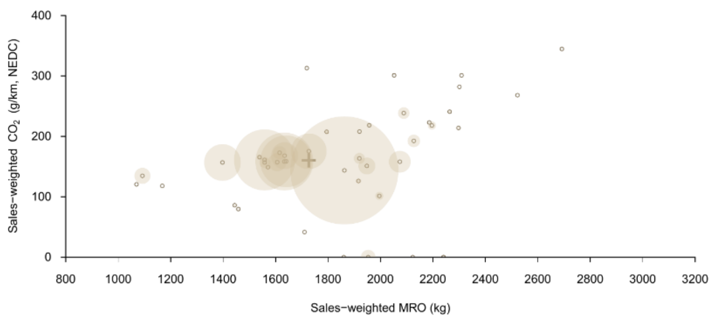
The impacts of the credit-debit system included in the NVES (Part 3 of the Draft Bill, “Units issued in respect of covered vehicles”) will largely depend how car manufacturers and suppliers will eventually wish to handle them, which is unknown at this stage. A supplier can use credits to offset its debits, it can bank them for later use or ‘transfer’ (sell) them to another supplier. They can also choose to pay a penalty when they fail to meet the emissions target. In the NVES tool the impact of the credit-debit system is simulated by making the following assumptions:

- Suppliers will avoid paying fines, so they will either meet their brand-specific target or use credits.
- Suppliers that have surplus credits will sell them and transfer them to other companies.

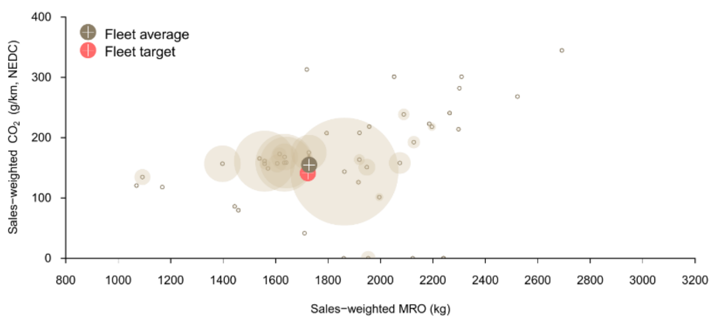
Although often used in similar international standards, the use and transfer of credits creates an emission abatement loss, because suppliers would have had to sell more zero- and low-emission vehicles (ZLEVs), if a credit-debit system would not have been part of the NVES. The emission abatement loss is further analysed by classifying suppliers into two groups.

1. The suppliers that have a sales-weighted emissions performance above the target will have to reduce their average emissions to meet the target (debit group).
2. Suppliers that have a sales-weighted emissions performance below the target (credit group), have a choice. They can sell and transfer their (net) credits to suppliers in the debit group and create additional profit, or they can do nothing and keep performing at their baseline 2022 level, thereby generating an environmental (greenhouse gas emissions) benefit for the on-road fleet.

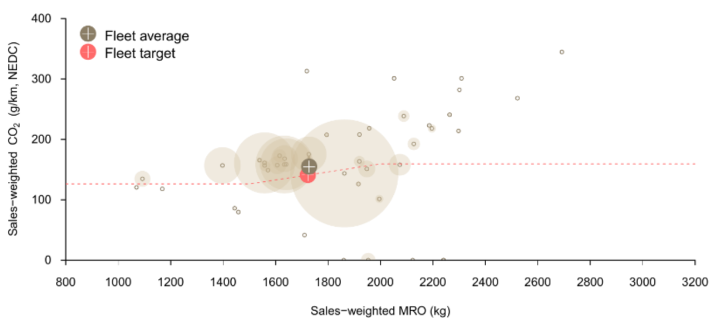
Emission abatement loss (ktonne CO_2) is then calculated as the grand total of the sum of (net) emission credits for each supplier belonging to the credit group, multiplied with their total sales and sales-weighted accumulated lifetime mileage.



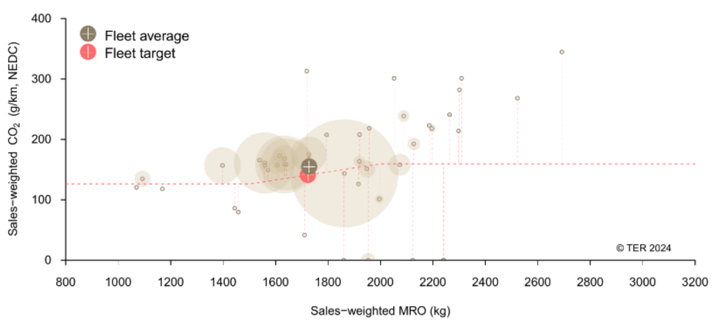
This chart visualises the aggregated NVES input file for Type 1 Vehicles. It shows the sales-weighted average MIRO and NEDC values for each supplier. The size of the semi-transparent circles reflect the relative number of vehicles sold by each supplier. A large polygon shows a relatively large number of vehicles sold.



In this chart the fleet-average NEDC and MIRO are added for 1) the NVES reference mass and headline target for 2025 as presented in Table 1 (large red dot and + symbol), and 2) the fleet average MIRO and NEDC value as calculated with the data in the NVES input file (large brown dot and + symbol).



In this chart the mass-dependent NVES limit curve for 2025 (Option B) is added as a red dotted line reflecting the design specifications outlined in Table 1 (headline target, mass adjustment factor, breakpoints).



Finally, the supplier-specific targets are computed by intersecting the sales-weighted average MIRO for each supplier with the limit curve. This is visualised with the vertical red dotted lines. Suppliers that fall above the limit curve belong to the debit group and the ones below the curve belong to the credit group.

Figure 1 – Visualisation of NVES design tool calculations for one example: MY 2025, Type 1 vehicles and the Option B Scenario.

The sales-weighted and fleet-average MIRO values computed using the NVES input file can now be compared with in the reference MIRO values reported in (Consultation) Impact Analysis published by the Federal Government (Table 3 [1] and Table 2 [2]). If the values are close, this suggests that the NVES input file replicates the input data used by the Federal Government reasonably well. The results are:

- Type 1 vehicles - The NVES tool predicts an average MIRO value of 1,728 kg, which is 0.3% higher than the value reported in Table 3 in the Consultation Impact Analysis (1,723 kg).
- Type 2 vehicles - The NVES tool predicts an average MIRO value of 2,104 kg, which is 2.4% lower than the value reported in Table 3 in the Consultation Impact Analysis (2,155 kg).

This comparison suggest that the reconstructed NVES input file could be a reasonably accurate representation of the actual data used by the Federal Government for the purposes of this study.

3.3 Lifetime emissions versus lifecycle emissions

This study estimates exhaust (tailpipe) emissions for new LDVs sold in the period in 2025-2029, since the NVES only considers this type of emission. However, all vehicles generate emissions at other stages, for instance, during vehicle manufacturing or the production of fuels (petrol, diesel, electricity, hydrogen, etc.). It is increasingly recognised that a fair assessment of the emissions performance of on-road vehicles requires a so-called life-cycle assessment or LCA[9].

For instance, EU Regulation 2023/851 states: "*The Commission shall by 31 December 2025 publish a report setting out a methodology for the assessment and the consistent data reporting of the full life-cycle CO_2 emissions of passenger cars and light commercial vehicles that are placed on the Union market. From 1 June 2026, manufacturers may, on a voluntary basis, submit to the Commission the life-cycle CO_2 emissions data for new passenger cars and new light commercial vehicles using the methodology.*"

TER has conducted detailed LCA studies (open access) for Australian passenger vehicles and trucks, and the emission estimation can be expanded in a follow-up study to account for all life-cycle aspects.[14,15] For now it is important to state that the emissions estimated in this study are exhaust emissions only. To prevent any confusion, the scope of this study is restricted to estimation of *lifetime* exhaust emissions[10], but not the more comprehensive *lifecycle* emissions.

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[9] The scope of greenhouse gas emissions estimation and the associated terminology can be confusing. For instance, 'well-to-wheel' (WTW) greenhouse gas emissions include all emissions related to fuel production – often referred to as the fuel-cycle – in other words, processing, distribution (fossil transport fuels, electricity, hydrogen) and on-road use. An even more comprehensive scope is included in a life-cycle assessment (LCA), which estimates 'cradle-to-grave' emissions and accounts for both fuel-cycle emissions (WTW) and vehicle-cycle emissions (material and vehicle production as well as end of life, recycling or scrapping).

[10] Total exhaust (tailpipe) CO_2 emissions from a new vehicle sold in the future (2025-2029) over its entire useful life.

3.4 On-road (real-world) emissions

For effective emissions reduction policy, it is critical that the NVES reflects real-world fuel consumption and emissions as closely as possible. The proposed NVES standard is based on the NEDC (New European Drive Cycle) test procedure. The NEDC test procedure was developed in the early 1970s, when test facilities could not simulate significant changes in speed.[4] There is an abundance of overseas and also Australian studies that have demonstrated that real-world emissions and fuel consumption deviate substantially – and increasingly – from the NEDC laboratory tests.[16-20] This discrepancy is often referred to as ‘the gap’.[11] Due to this widening gap between NEDC and real-world emissions, the European Union replaced the NEDC test procedure in 2017 with the Worldwide harmonized Light-vehicles Test Procedure (WLTP). WLTP type-approval CO_2 emissions are (on average) about 20% higher (cars) and almost 30% higher (vans) than those of the NEDC.[19] The WLTP test procedure, however, still significantly underestimates real-world and on-road emissions, as is now becoming clear through analysis of on-board fuel consumption monitoring (OBFCM) data that has been collected in the EU for new LDVs sold since 2021.[20,21]

Figure 2 - On-road emissions testing in Sydney.[11,18]

It is also clear that the gap can vary greatly for individual vehicles in the real-world. For instance, on-road measurements in Europe, using the same vehicle but different drivers and different driving conditions found a gap between the NEDC and real-world driving that varied from 16% to 106%.[22] In a recent on-road emissions study in Australia (Figure 2), five SUVs with a portable emission monitoring system were driven around Sydney in various real-world situations, such as in the city and on the freeway.[11] Compared to official NEDC values published in the Green Vehicle Guide [25] , the measurements of fuel consumption and CO_2 emissions were consistently higher, as expected. But they also varied significantly from 16% to 65%, depending on the vehicle and driving conditions. On average, real-world fuel consumption and CO_2 emissions were both 27% higher than NEDC values for these five SUVs.[18]

[11] There are various reasons for this gap, such as the laboratory test protocol itself, and strategies used by car manufacturers (and allowed by the test) to achieve lower emissions in laboratory conditions. The official test that uses the New European Drive Cycle (NEDC) consists of mild accelerations and constant speeds that do not reflect modern driving. The test procedure also uses dynamometer vehicle mass settings that are not representative of on-road vehicles and too low. In addition, the test procedure allows for several ‘tolerances’ and ‘flexibilities’ that have been increasingly used by car manufacturers to get favourable results in the laboratory. For instance, it allows manufacturers to define resistances for the official test for a pre-production vehicle. Such a vehicle may be stripped from auxiliaries, use low-resistance and overinflated tires, use high-performance lubricants, and carefully select a favourable test track for coast down tests, among other options. This has led to unrealistically low fuel and emission test results in the laboratory.

A recent and ongoing collaborative study between TER and EU's Joint Research Centre (JRC) similarly estimated that the gap between the NEDC and real-world driving for Australian passenger vehicles varied significantly between 18 and 45%.[12]

Since Australian real-world emissions data are not yet available for individual make and models, a fleet-average real-world correction factor is applied in this study to correct NEDC emissions. The Federal Government assumed a generic real-world correction factor of 1.39.[1,2] A recent TER-ICCT study estimated fleet-average real-world correction factors of 1.46 and 1.29 for passenger vehicles (cars, SUVs) and LCVs, respectively, in 2021.[4] The TER-ICCT correction factors are used in this study.

4. The baseline scenario (no mandatory standard)

The year 2022 is taken as the starting point for the emissions simulation, which means that total vehicle sales and the sales fleet mix have been kept constant for future years. The only change that was modelled in the baseline scenario is the expected increase in the sale of zero-emission (exhaust) BEVs in 2025-2029, as was discussed in Section 3.2. The year 2022 is assumed to reflect the absence of mandatory standards[12], it is the most recent year for which input data are available, and it is the year used by the Federal Government in their modelling.[1,2] It is noted that the baseline scenario reflects a situation that cannot be known and cannot be verified, as it is unlikely there will be no mandatory standard. The emissions estimated for the baseline scenario should therefore be considered indicative, with a higher level of uncertainty.

The Federal Government defined a business-as-usual scenario in its Consultation Impact Analysis and presented an EV uptake chart (Figure 10).[1] However, these data are not provided in table format and are not split by vehicle type (PC, SUV, LCV).

For this study, $P_{bev,xy}$ values are therefore extracted from detailed fleet modelling that underpinned a recent (2023) TER study.[5] This study used the Australian Fleet Model (AFM) to simulate future fleet growth and fleet turnover (scrappage) for the Australian on-road fleet out to 2060 and estimated vehicle population and total travel activity, expressed as vehicle kilometres travelled (VKT). AFM simulates complex patterns in the fleet turnover processes through consideration of vehicle class specific on-road population, vehicle sales data, vehicle usage profiles, population growth and scrappage rates. The model considers 15,200 individual vehicle classes.

The penetration of new vehicle technologies into the Australian on-road fleet was assumed to follow a 10-year delayed but ambitious EU scenario with a natural fleet turnover process, i.e. no policy interventions like scrappage programs.

[12] It is likely that BEV sales in 2022 were already influenced by the Government's statements in mid 2022 regarding its intention to introduce a mandatory standard. However, for the purposes of this study we have assumed that MY 2022 reflects the absence of mandatory standards.

The penetration trajectories considered historic vehicle sales data and estimated future sales out to 2060, using the AFM scenario builder option[13] that deploys a broad range of functions to produce plausible and adaptable penetration trajectories. Figure 3 shows the results for the two vehicle classes of interest in this study (passenger vehicles, which include cars and SUVs, and light commercial vehicles) and five fundamental technology types.[14]

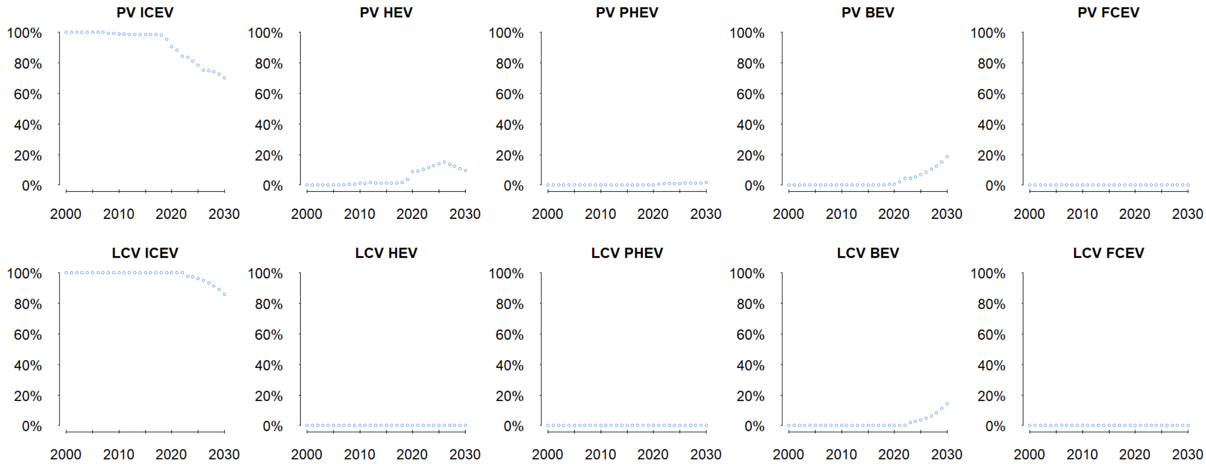

Figure 3 – Share (expressed as a percentage) of new vehicle sales in the period 2000-2030 by vehicle class, technology type and year of manufacture, as predicted with the Australian Fleet Model (AFM).[5]

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[13] Since 2022, AFM has incorporated a statistical method to forecast plausible technology penetration trajectories for the on-road vehicle fleet. The starting point is the diffusion of innovation theory, which describes the uptake of new technology over time with a typical sigmoid adoption function (logistic growth curve). This approach has been regularly used to successfully predict the penetration of a broad range of technologies, for instance, EV technology. However, the diffusion of innovation can fail for various reasons, for instance, due to a lack of supporting infrastructure, lack of (sustained) government support or simply technological reasons. This means that the typical S-curve is not always the most plausible trajectory for new vehicle technologies entering the on-road fleet. AFM therefore considers a broad range of functions to produce plausible and adaptable penetration trajectories. The plausible trajectory method includes the logistic, modified logistic and Gompertz curves, which represent potential choices for vehicle technologies that are not expected to peak, but instead reach an equilibrium. For situations where a peak is expected, followed by a decline, piece-wise functions are included to allow for the change in direction. The method also includes piece-wise linear, piece-wise quadratic, as well as more flexible curve types such as the polynomial and natural splines. The best fitting curves are found through parameter optimisation and minimising of the sum of squared errors between the curve trajectories, sales data and forecasted values, as well as expert judgement. Some further modifications were made to reflect the Australian situation. For instance, the proportion of PHEVs in EU vehicle sales has been significant (due to fiscal measures), but the relative proportion of PHEVs in Australian EV sales is small and falling with increased popularity of BEVs. Recent research has shown that PHEVs can have extremely large gaps between the official and real-world emissions, up to 3 times [27], for reasons outlined in Appendix B. PHEVs are generally regarded as a transitionary technology for those vehicle segments where fit-for-purpose BEVs are not yet available, or where public charging infrastructure is not yet adequate.

[14] ICEV = internal combustion engine vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, BEV = battery electric vehicle, FCEV = hydrogen fuel-cell electric vehicle (refer to Appendix B).

Table 2 shows the input values that were extracted from the TER road transport emissions study for use in the NVES design tool.

Table 2 – Estimated proportion of new vehicles sales in the baseline scenario that are BEVs and the associated BEV correction factor by year and vehicle class.

Year	Passenger vehicle (car, SUV)		Light Commercial Vehicle (LCV)	
	$P_{bev,xy}$	γ_{xy}	$P_{bev,xy}$	γ_{xy}
2025	0.07	0.93	0.04	0.96
2026	0.08	0.92	0.05	0.95
2027	0.10	0.90	0.07	0.93
2028	0.12	0.88	0.08	0.92
2029	0.15	0.85	0.11	0.89

Figure 4 shows the emissions results for the baseline scenario. The charts show the total lifetime emissions in ktonnes for all vehicles sold in a particular year (model year, MY), using the official NEDC emission rates (left chart) and the estimated real-world emissions (right chart). Without a mandatory standard, lifetime emissions for newly sold LDVs are estimated to reduce with 12% in the period 2022-2029, due to the progressive increase in the uptake of battery electric vehicles.

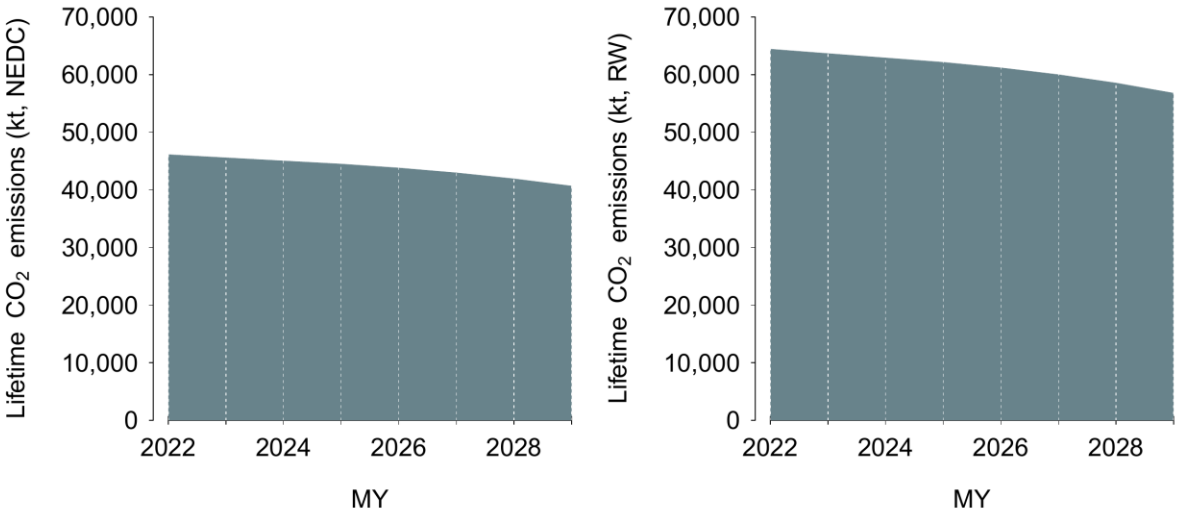

Figure 4 – Lifetime CO_2 emissions for all vehicles sold in a particular model year (MY) for the baseline scenario, the left chart shows emission estimates based on NEDC values declared by vehicle manufacturers, the right chart shows the emissions estimated for real-world and on-road conditions.

It is emphasised that the baseline emission scenario reflects the MY 2022 sales and emissions performance data, which is the latest year for which these data are available. As a consequence, any future shifts in the characteristics of the new vehicle fleet are not reflected in the estimates. They include, but are not limited to, any changes in the percentage of HEV and PHEV sales, increasing sales of heavier and 4WD vehicles (which will increase emissions), engine downsizing and the use of Continuously Variable Transmission (which will reduce emissions), as has been discussed in another TER study.[17]

5. The NVES scenarios (Option B and Draft Bill)

This section presents the results for the NVES scenarios using the NVES design tool. The NVES results include the (no standard) baseline scenario, that was discussed in the previous section. Similar to the baseline scenario, the MY 2022 is taken as the starting point for the emissions simulation, which means for each manufacturer:

- no change in total vehicle sales (MY 2022 is used), and
- no change in fleet average MIRO (MY 2022 is used).

The average emissions performance, however, is changed, depending on the MY 2022 emissions performance, the future MY and NVES scenario. Electrification and any other measures that a manufacturer may choose to improve the emissions performance of their newly sold vehicles (e.g. hybridisation, engine downsizing) - and meet their future targets - are reflected in the modelling by assuming that all vehicle brands will meet their respective brand-specific targets, whilst keeping the fleet average mass (MIRO) the same.

As a consequence, the simulation does not account for the sustained increase in the sales of larger and heavier vehicles that has been observed over time (car obesity), as will be discussed further in Section 7, or alternatively, lightweighting of vehicles, both of which could change fleet average MIRO values and therefore the brand-specific targets.

5.1 Option B

Figure 5 and 6 visualise the calculations that were made using the NVES design tool for Scenario Option B and for MYs 2025 and 2026. Although calculations were also made for MYs 2027-2029, and are included in the overall emission results (shown later), they should be considered preliminary, because years beyond 2026 may be based on adjusted NVES design parameters (headline target, reference mass, mass adjustment factor, breakpoints).[15]

Figure 7 shows the emission results for both the baseline scenario and the Option B scenario. The charts show the total lifetime emissions in ktonnes for all vehicles sold in a particular model year (MY), using the official NEDC emission rates (left chart) and the estimated real-world emissions (right chart). Figure 7 shows that the introduction of the NVES (Option B) in 2025 will provide significant reductions in real-world lifetime CO_2 emissions for newly sold vehicles, as compared with the baseline scenario. In 2025 the estimated reduction in real-world emissions is 6%, increasing to almost 60% in 2029.

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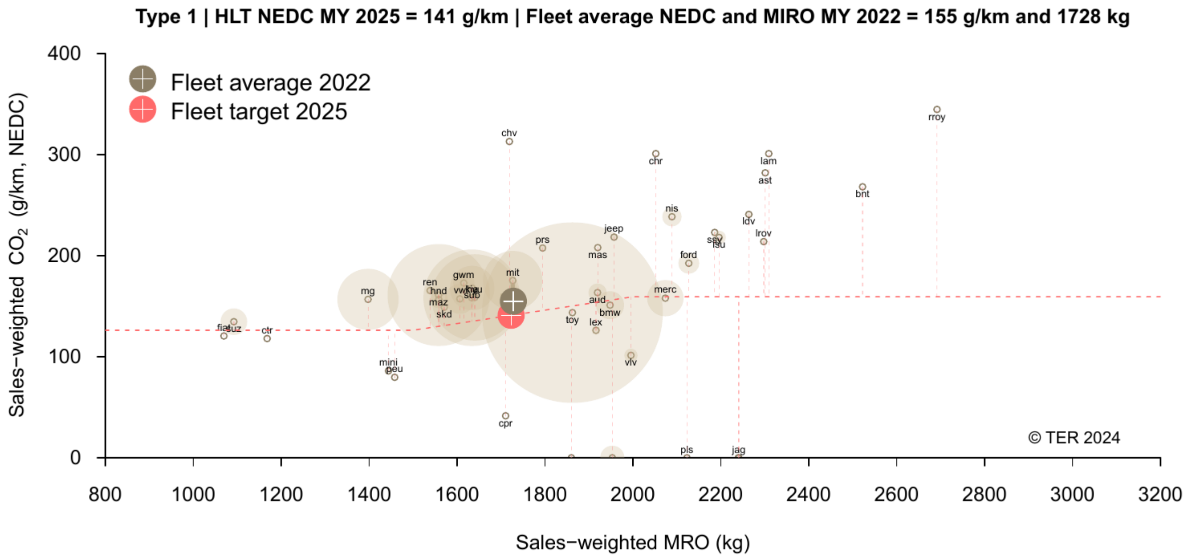
[15] The Draft Bill states in Section 93: "*The Minister must cause a review of the operation of this Act to be 8 commenced before 31 December 2026*." In Section 28-32, it states: "*The Minister may, by legislative instrument, determine a number for any of the following, for type 1 or type 2 vehicles, for a particular year: the headline limit; the lower breakpoint; the upper breakpoint; the mass adjustment factor; the reference MIRO*". In addition, the Minister can change vehicle allocation to Status Type 1 and 2. Section 31 states: "*Headline limits must decrease or be worked out using more stringent test procedure*", so in principle the headline limit cannot increase.[3]

The emissions predicted for NVES Option B are also split into two categories, i.e. with and without the inclusion of the credit-debit system. Figure 7 shows that the inclusion of the credit-debit system increases lifetime CO_2 emissions with 3.8% in 2025, reducing to 2.6% in 2029. This increase is based on the assumption that all credits will be used to offset any debits across all vehicle manufacturers in the same MY. If suppliers would decide to not use their emission credits, they would contribute to a significant reduction in greenhouse gas emissions for new vehicles sold in 2025 and beyond.



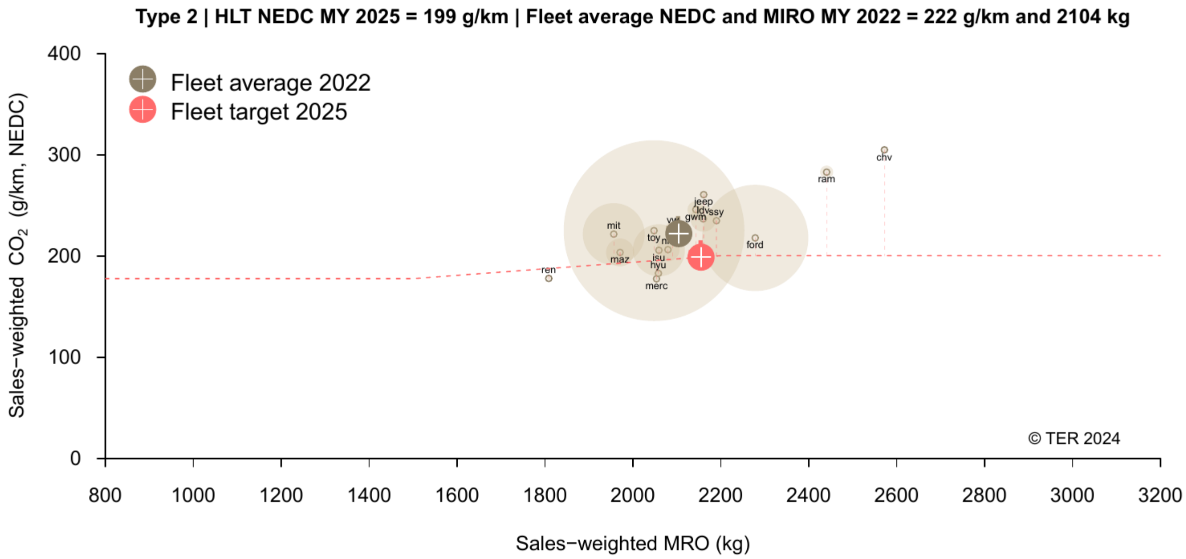
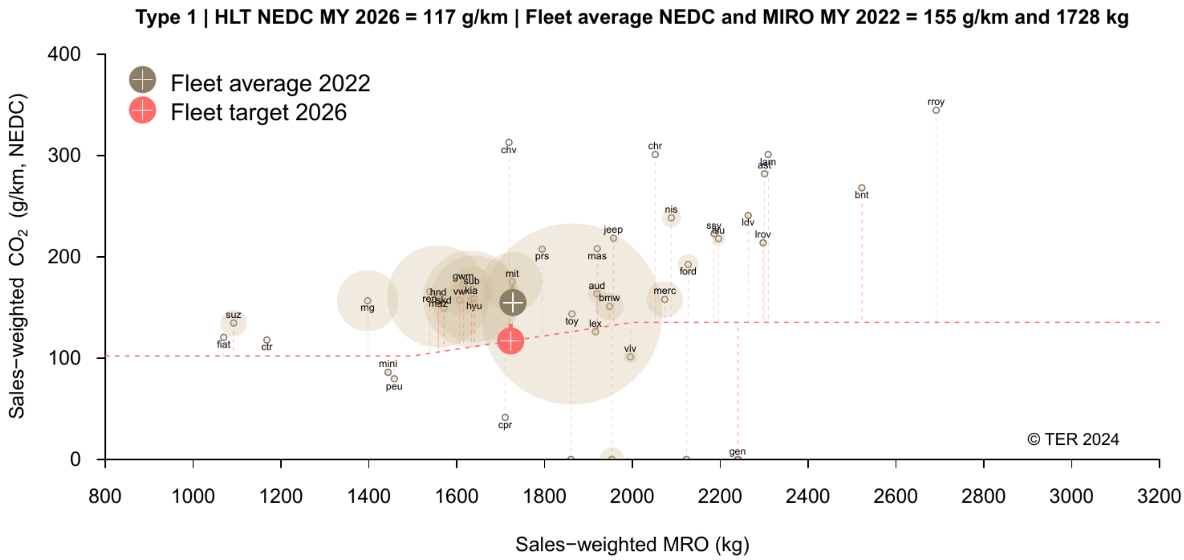


Figure 5 – NVES design tool calculations for MY 2025 and scenario Option B, showing the MY 2022 sales and emissions performance values versus the 2025 targets.



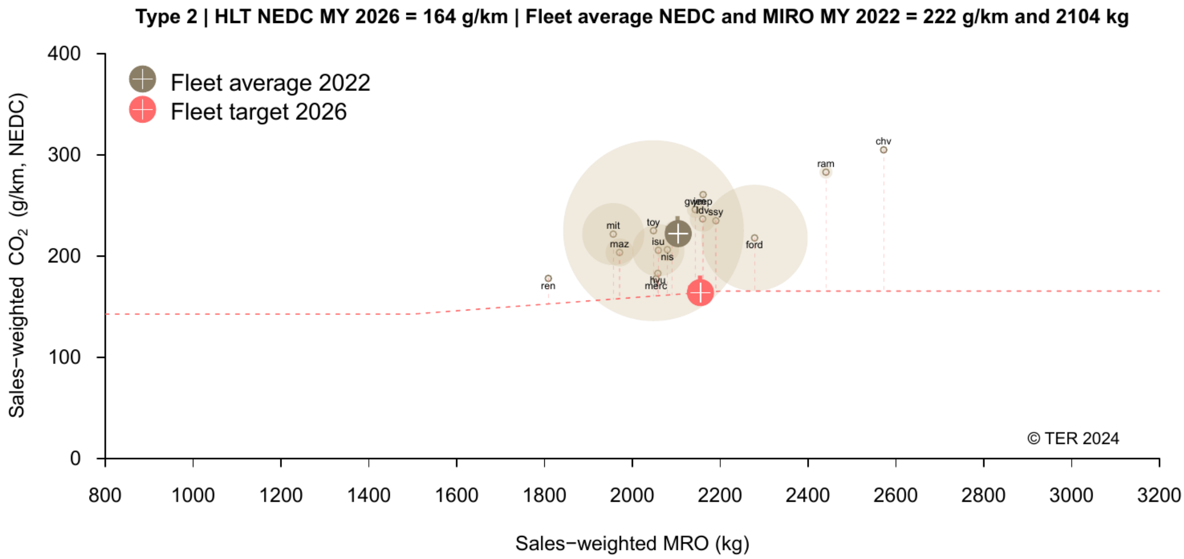


Figure 6 – NVES design tool calculations for MY 2026 and scenario Option B, showing the MY 2022 sales and emissions performance values versus the 2026 targets.

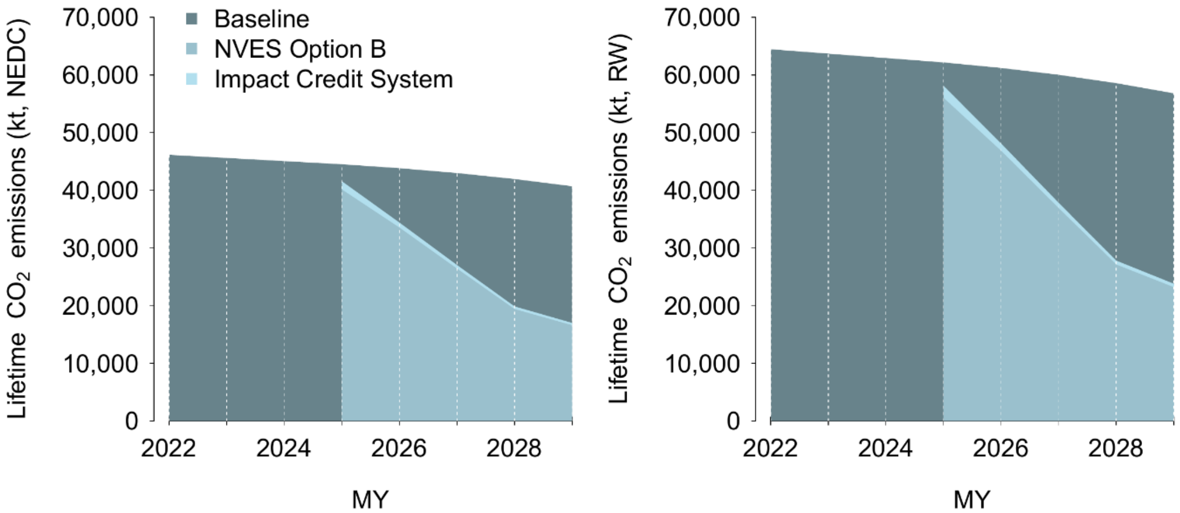


Figure 7 – Lifetime CO_2 emissions for all vehicles sold in a particular model year (MY) for both the Baseline and Option B scenarios. The left chart shows emission estimates based on NEDC values and declared by vehicle manufacturers and the right chart shows the emissions estimated for real-world and on-road conditions.

5.2 Draft Bill

Figure 8 and 9 visualise the calculations that were made using the NVES design tool for Scenario Draft Bill and for MYs 2025 and 2026.

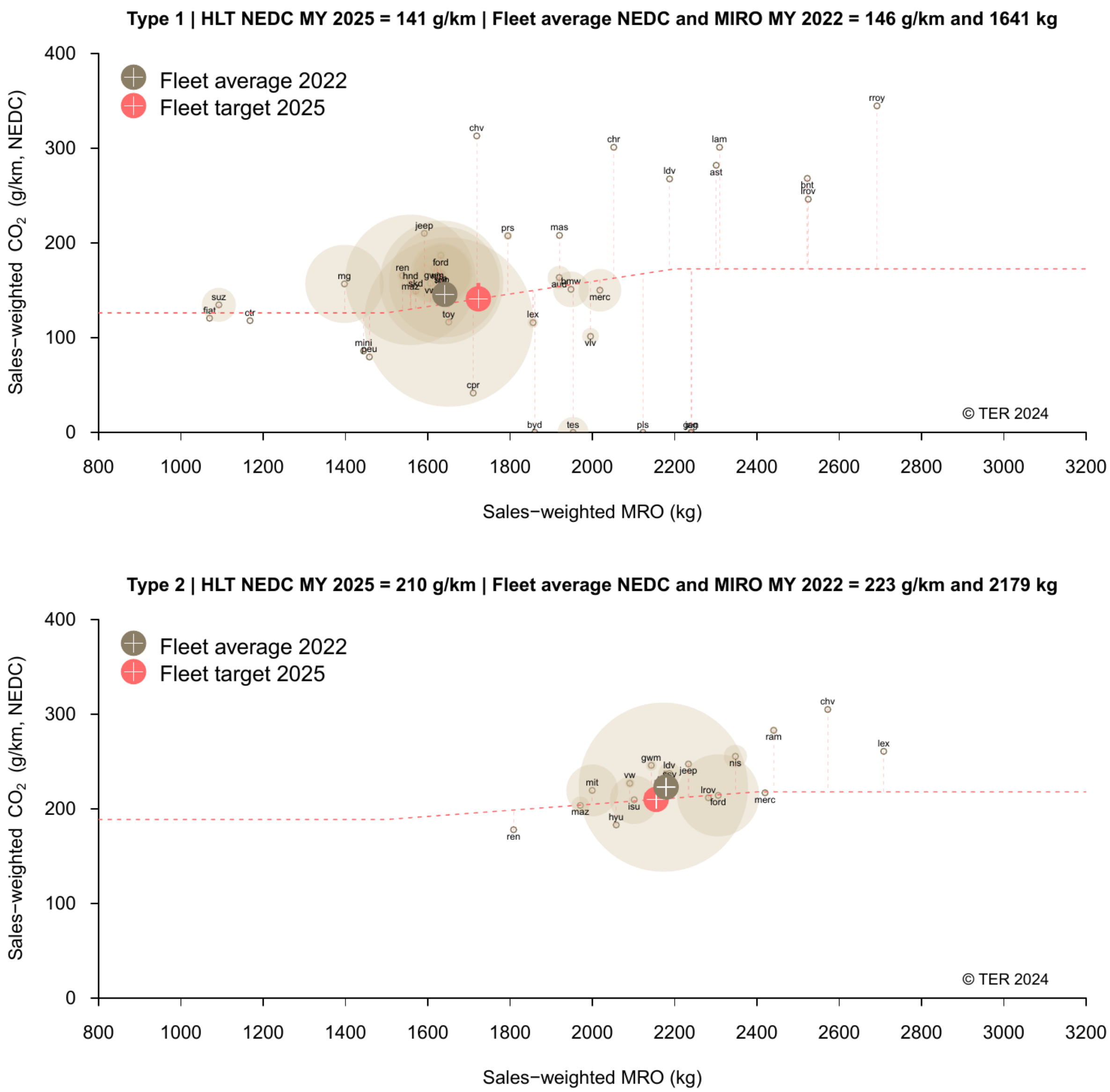
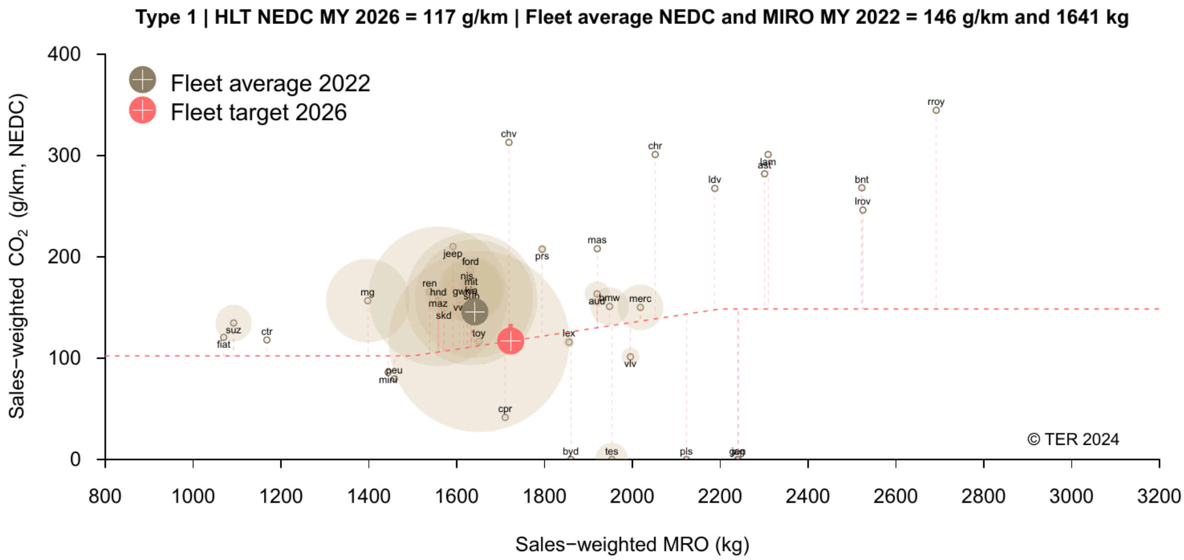


Figure 8 – NVES design tool calculations for MY 2025 and scenario Draft Bill, showing the MY 2022 sales and emissions performance values versus the 2025 targets.



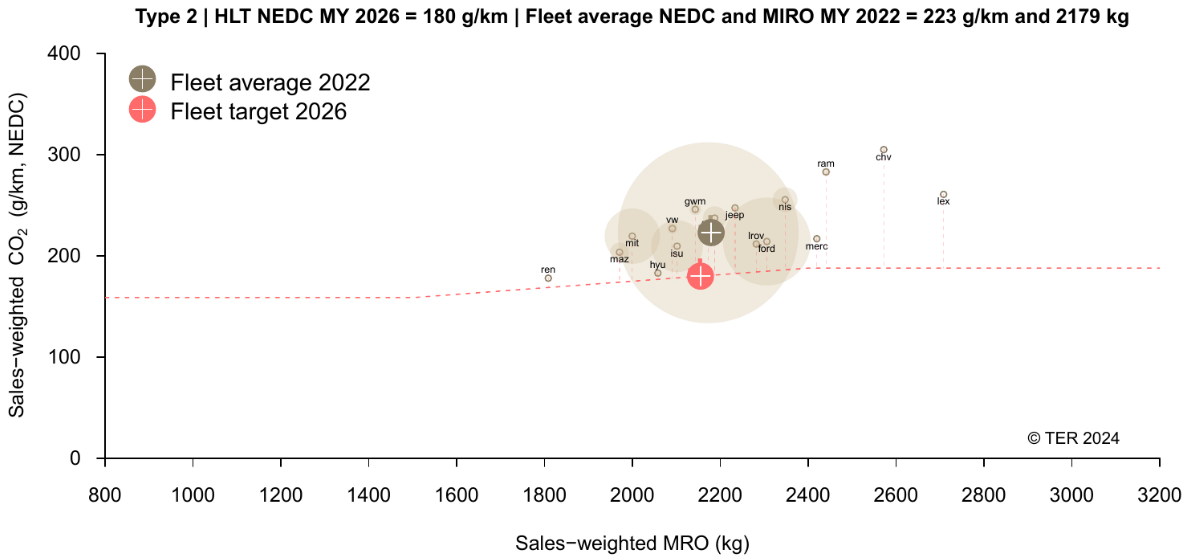


Figure 9 – NVES design tool calculations for MY 2026 and scenario Draft Bill, showing the MY 2022 sales and emissions performance values versus the 2026 targets.

Figure 10 shows shows the emissions results for both the baseline scenario and the Draft Bill scenario. The charts show the total lifetime emissions in ktonnes for all vehicles sold in a particular model year (MY), using the official NEDC emission rates (left chart) and the estimated real-world emissions (right chart).

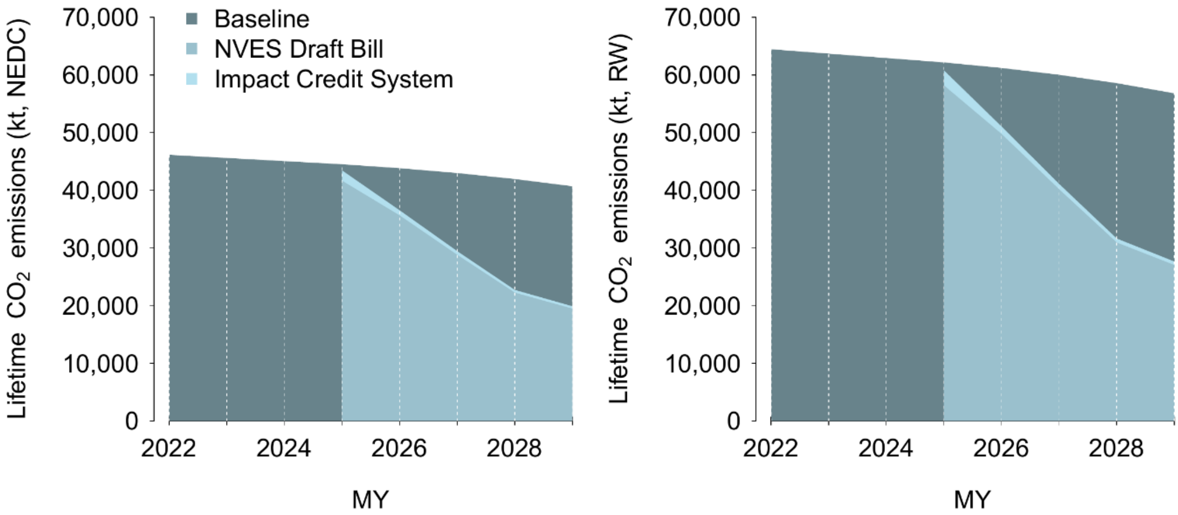


Figure 10 – Lifetime CO_2 emissions for all vehicles sold in a particular model year (MY) for both the Baseline and Draft Bill scenarios. The left chart shows emission estimates based on NEDC values and declared by vehicle manufacturers and the right chart shows the emissions estimated for real-world and on-road conditions.

Figure 10 shows that the introduction of the NVES (Draft Bill) in 2025 will still provide significant reductions in real-world lifetime CO_2 emissions for newly sold vehicles after 2025, as compared with the baseline scenario. In 2025 the estimated reduction in real-world emissions is only 2% compared with the baseline scenario (6% in Option B), but this is increasing to 51% in 2029 (58% in Option B). Compared to Option B, the changes proposed in the NVES (Draft Bill) have weakened the standard and have increased real-world lifetime CO_2 emissions for newly sold vehicles with 5% in 2025, increasing to 16% in 2029. Figure 10 shows that the inclusion of the credit-debit system increases lifetime CO_2 emissions with 4.5% in 2025, reducing to 2.3% in 2029.

5.3 Emission reduction and abatement loss

Sections 5.1 and 5.2 quantified the estimated real-world exhaust CO_2 lifetime emissions for new vehicles sold in the period 2025-2029. Table 3 presents the predicted total emissions for each scenario and MY in the period 2025-2029. These values have been used to produce Figures 4, 7, 10 and 11. Table 3 also includes the total cumulative emissions for the period 2025-2029.

Table 3 – Estimated total real-world lifetime exhaust CO_2 emissions (ktonne) for Australian LDVs by future model year (MY), by (NVES) scenario and with/without credit-debit system (CDS).

MY	Baseline	Option B		Draft Bill	
		With CDS	Without CDS	With CDS	Without CDS
2025	62,175	58,137	56,034	60,808	58,184
2026	61,214	48,119	46,837	51,076	49,768
2027	60,029	37,830	36,899	41,105	40,162
2028	58,576	27,812	27,121	31,640	30,937
2029	56,813	23,796	23,191	27,652	27,035
Σ	298,806	195,694	190,081	212,282	206,087

Table 3 can now be used to quantify the emission abatement loss due to the change from NVES Option B to NVES Draft Bill (both including a debit-credit system). The results are shown in Figure 11.

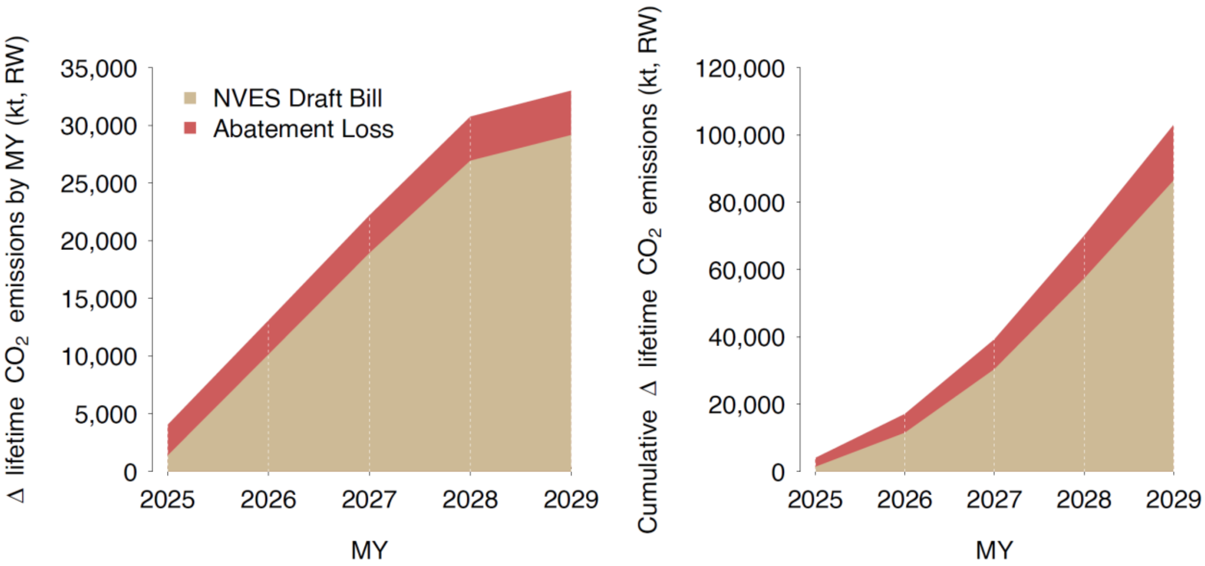


Figure 11 – The reduction (Δ) in lifetime real-world CO_2 emissions for all new vehicles sold in a particular model year (MY) due to implementation of the NVES Draft Bill scenario and the emission abatement loss associated with the changes made in NVES Option B (left chart). The right chart presents the same data, but now as a time-series, showing cumulative emissions as time progresses from MY 2025 to 2029.

Figure 11 (left chart) shows that the estimated reduction in lifetime CO_2 emissions through implementation of the NVES Draft Bill (Draft Bill with CDS minus Baseline in Table 3) starts at 1,367 ktonne for MY 2025, quickly increasing to 10,139 ktonne for MY 2026 and eventually to 29,161 ktonne for MY 2029. This corresponds to a relative reduction of -2% for MY 2025, -17% for MY 2026 increasing to -51% for MY 2029.

The abatement loss due to the changes made to Option B (Draft Bill with CDS minus Option B with CDS in Table 3) is estimated to be 2,671 ktonne for MY 2025 (5% increase), 2,957 ktonne for MY 2026 (6% increase), increasing to 3,856 ktonne in 2029 (16% increase). This suggests that the NVES has been weakened from a real-world emissions perspective, when compared with Option B.

The emissions presented in Table 3 include the total emissions over the useful life for all new vehicles sold in a particular MY in the period 2025-2029. This means that the vehicles sold in this time period will have reached an age between 22 and 26 years in 2050. In a previous study for the Federal Government, TER developed survival curves for passenger vehicles and LCVs, which showed that most vehicles will be scrapped when they reach an age of 22 years or older.[28] The total cumulative emissions included in Table 3 can therefore be used to provide a reasonable estimate of the total abated emissions by the different NVES design options in 2050. These are also shown in Figure 11 (right chart) and correspond to the values for MY 2029 (i.e. cumulative emissions for MY 2025-2029). The estimated total abated emissions are:

- 103 Mt for Option B (∑ Baseline minus ∑ Option B with CDS in Table 3).
- 87 Mt for Draft Bill (∑ Baseline minus ∑ Draft Bill with CDS in Table 3).

In comparison, the Federal Government estimated a total NVES emissions abatement in 2050 of 369 Mt in 2050 (Option B) and 321 Mt (Draft Bill). The abated emissions predicted in this study are substantially lower (27-28% of the estimates made by the Federal Government). In a relative sense, the predictions are more similar. The Federal Government estimates that the change from Option B to the Draft Bill reduced the total abated emissions with 13%, whereas this study estimates a total abatement loss of 16% (17 Mt).

Without a clear understanding how the Federal Government modelled the NVES impacts, it is not possible to explore the reasons for these differences. Differences in method and underlying assumptions are expected to contribute, as well as differences in the input data. A possible explanation is that this study estimated lifetime emissions for all vehicles sold in the period 2025-2029, whereas the Federal Government may have included the 'knock-on' effects of the NVES for vehicles sold after 2029 (presumably using 2029 NVES targets). The Federal Government may also have modelled an increase in future sales volumes, whereas this study assumed constant (MY 2022) LDV sales in the period 2025-2029.

5.4 The NVES impacts by vehicle brand

In this section, the credit and debit *potential* are estimated for each vehicle brand for the 2025 NVES targets, using the MY 2022 input data file. This provides insight in the current compliance gap and an indication of how close each brand is to meeting the 2025 NVES targets for Type 1 and Type 2 vehicles combined, when their (historic) 2022 sales profile is considered. It also provides insight into which vehicle brands 'overperformed' in 2022, for instance, by already selling a large proportion or 100% ZLEVs. It is noted that the results are indicative since several brands have started to offer more ZLEVs since 2022. The assessment can be updated with MY 2023 and MY 2024 input data and it is suggested these data will be made available by the Federal Government.

Using the estimated difference between the 2025 NEDC emissions targets and the sales-weighted MY 2022 NEDC emissions performance for each vehicle category (Status Type 1 and 2), each NVES design option and for each supplier, the number of credits/debits can be estimated per newly sold vehicle and for all vehicles sold through multiplication with the total number of sales. Figure 12 shows the estimated credit-debit potential by brand for the NVES Draft Bill option, which is ranked from largest credit to largest debit form left to right.

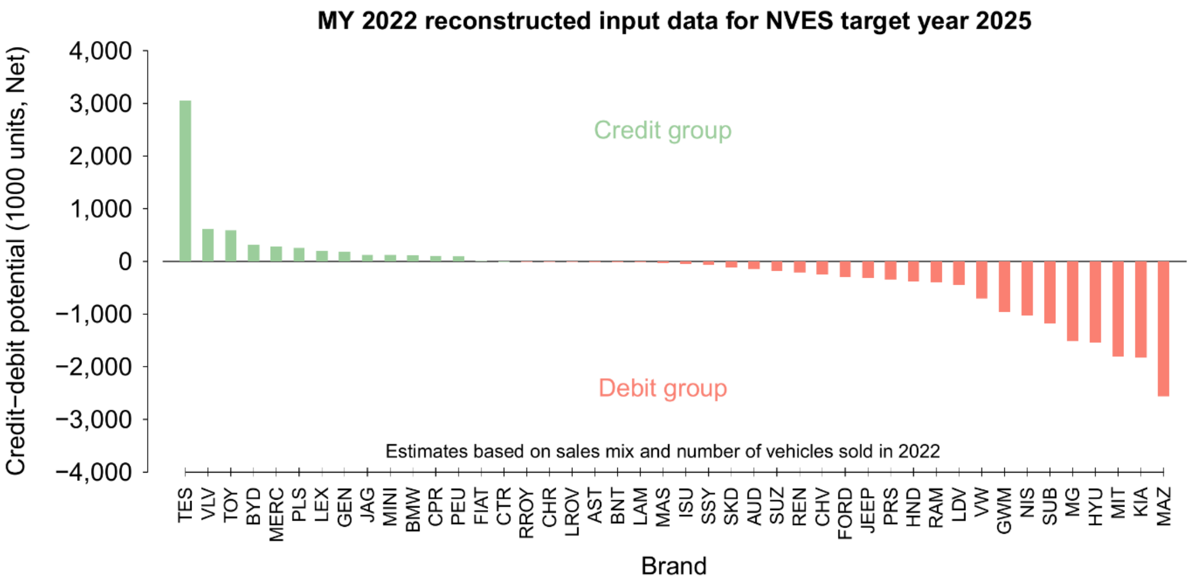


Figure 12 – Current compliance gap: the NVES Draft Bill credit-debit potential by vehicle manufacturer (before pooling) using MY 2022 sales-emissions performance data and the NVES MY 2025 targets. Ranking: manufacturers with the largest estimated potential credits are shown on the left, progressively reducing from left to right with those with the largest potential debits on the right.

In the Draft Bill, the simulation suggests that the majority of credits will be held by a select group of manufacturers, namely Tesla (50%), Volvo (10%), Toyota (10%), BYD (5%) and Mercedes-Benz (5%). These manufacturers are shown on the left side of the chart in Figure 12. Two categories can be distinguished in the credit group:

1) manufacturers that use credits to offset their own debits, which includes banking them for later use (internal use), and
2) manufacturers that transfer and sell surplus credits to other manufacturers to create extra profit (external use).

The NVES could restrict the credit-debit system to internal use of credits only, i.e. the removal of the credit transfer option from the NVES. This change in NVES design will result in an additional real-world emission reduction, which can be quantified in future work. Figure 12 also shows that several manufacturers fall into the debit group, which means they will have to do something to improve their MY 2022 emissions performance. These companies will only have the estimated debit potential if they maintain exactly their 2022 sales profile in 2025.

It is interesting to examine the impact of the shift from NVES Option B to the Draft Bill on the credit-debit potential. This is shown in Figure 13, ranked from the largest change in the credit-debit potential (left) to the smallest change (right).

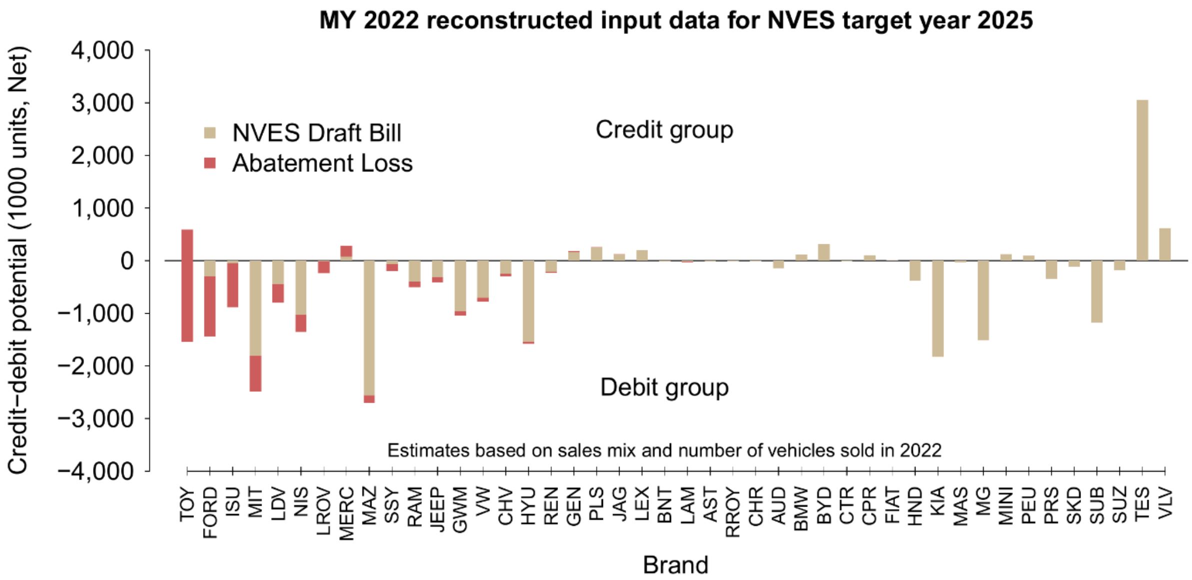


Figure 13 – The impact of the shift from the NVES Option B to the NVES Draft Bill on the credit-debit potential by vehicle manufacturer (before pooling) using MY 2022 sales-emission performance data and the NVES MY 2025 targets. Ranking: manufacturers with the largest estimated emission abatement loss are shown on the left[16], progressively reducing from left to right, with those with no change on the right.

Figure 13 shows that the credit-debit potential did not change for 19 out of 44 manufacturers (43%). These are the manufacturers on the right side of the chart. Most manufacturers (but not all) in the debit group seem to have benefitted from the changes made in the Draft Bill in terms of a reduction in emission debits and their associated (potential) costs.

However, a small number of manufacturers seem to have benefitted substantially more than others. These are the manufacturers on the left side of the chart. The largest change in the estimated credit-debit potential is observed for Toyota. This is also the only manufacturer that changed from belonging to the debit group (NVES Option B) to belonging to the credit group (NVES Draft Bill). Mercedes-Benz increased its potential credit position with almost four times. Isuzu and Land Rover reduced their debit potential with 95%, Ford with 79%, Ssanyong with 66% and LDV with 44%.

[16] Please note that Toyota is a special case and the only manufacturer that changed from the debit group (-1.5 M units) to the credit group (+0.6 M units). As a consequence, the full extent of the credit-debit potential is shown as an abatement loss and the NVES Bill value of 589,000 is hidden behind the red bar and not visible.

In principle, the credit and debit potential could be converted to monetary values.[17] However, given the uncertainty and variability in the (future) monetary value of credits and debits, a conversion to dollar values was not considered to be appropriate in this study, but it can be considered at a later stage.

Although the analysis of the credit-debit impacts of the NVES on LDV manufacturers and suppliers is interesting, it is noted that these results are indicative and should be treated with care, as there are several caveats.

1. The simulation results are based on the MY 2022 sales numbers and sales profile for each manufacturer, which effectively assumes that the vehicle mix will remain the same in 2025 and beyond, which of course will not happen. Suppliers will be able to change their sales profile by including, for instance, more ZLEVs and smaller and lighter vehicles, thereby extinguishing or reducing their emission debits and associated monetary impacts.
2. In contrast to the EU where relevant input data are publicly available, the underlying database used by the Federal Government in the development of the NVES is not. Therefore the development of a 'reconstructed' input database was required, using publicly available data and information. Although a high level comparison of aggregated statistics with publicly available information suggest that the reconstructed input data could be reasonably accurate overall, there is no guarantee that significant differences at the model/make level are absent.
3. The NVES will apply to type approval holders, not individual manufacturers, which means that several manufacturers will be pooled based on (future) ownership and importing arrangements. For instance, Toyota, Mazda, Suzuki and Subaru were previously members of one manufacturer pool in the EU market. Further work is thus required to clarify this and to bundle manufacturers together accordingly, after which the credit-debit potential can be re-assessed more accurately for these pooled arrangements.
4. In future refinement work and updates, it would be useful to consider brand-specific sales forecasts (if available), or to at least use updated MY sales data (2023, 2024) to capture market change as Australia moves closer to the NVES start year of 2025.

[17] The NVES states that a supplier must ensure that their final emissions value for a particular year is zero or less and that failure to achieve this may result in a civil penalty. The penalty is calculated as the final emission value multiplied by $100 per g/$CO_2$ (Section 17), but Section 82 states a court can impose half the maximum penalty following an infringement notice.[3] The maximum monetary value for an emission credit-debit is therefore estimated to be $50 per g CO_2/km (NEDC), but it is likely significantly less when credits are negotiated and transferred between manufacturers.

6. Recommendations to ensure that the NVES will be effective

This section provides further discussion and recommendations in relation to an effective NVES design.

Recommendation 1 - *The NVES should adopt the WLTP test protocol from 2025 onwards.*

A discussed in Section 3.4, the proposed NVES is still based on an outdated emission test protocol, the NEDC, developed in the 1970s, whereas the EU is currently based on the WLTP. The continued use of NEDC emissions data in the NVES confuses the debate. Tracking NVES performance using the NEDC test can give the false impression that emissions are reduced, where in reality this is not the case, as previous Australian research has shown.[4,5,17]

The Federal Government mentioned that it will eventually adopt the WLTP in the NVES, but is suggesting to wait until at least July 2028, when the WLTP-based Euro 6d emission standards (air pollutants) will be mandated in Australia for all new LDVs. The Federal Government will then have to develop a rigorous target conversion procedure to enable a smooth transition from the NEDC to WLTP-based NVES standard.

This introduces a new risk to the NVES and can potentially undermine its effectiveness if the development of the target conversion procedure is not based on careful consideration and impartial and evidence-based information. An example is the specific use of *measured* WLTP values in the current EU emission standards, rather than manufacturer *declared* WLTP values. This was done specifically as manufacturer declared values[18] were found to artificially and significantly inflate the targets (by about 5% on average).

If the NEDC is retained in the NVES, it is recommended that a technical working group be established, including independent and impartial subject-matter experts, to ensure that a conversion mechanism is robust, learns from overseas experiences and accounts, as much as possible, for real-world emissions. It should also include consideration of specific (emerging) issues and assess their relevance for Australia (e.g. PHEVs). Moreover, it is recommended that onboard fuel monitoring is specifically considered by a technical working group (next recommendation).

Recommendation 2 - *The NVES should include on-board fuel consumption monitoring (OBFCM).*

Even when the Australian NVES is based on the WLTP and not the NEDC test protocol – whilst a definite improvement – there is still a fuel consumption gap, compared to real-world driving. This gap is expected to be in the order of about 20%.[26] This means that official WLTP based fuel consumption and CO_2 figures for new vehicle sales in Australia, underpinning the NVES and national climate policies, will still significantly underestimate actual on-road fuel use and GHG emissions with about 20%, moving us away from achieving net zero emissions in 2050.

So additional measures will be required to address this issue. The EU has already considered this issue and has taken action. To ensure CO_2 emissions from road transport are actually reduced in line with EU policies and regulations and to prevent the fuel consumption gap from increasing again, separate

[18] Manufacturers may do this for good reasons, e.g. to build in a safety margin for conformity of production testing of new vehicles.

EU regulation now requires monitoring of actual in-use fuel consumption. This means that new vehicles registered in the EU from 2021 onwards require the installation of onboard fuel consumption monitoring (OBFCM) devices.

EU Regulation 2019/631 relevantly states "*Furthermore, the Commission shall regularly collect data on the real-world CO_2 emissions and fuel or energy consumption of passenger cars and light commercial vehicles using on-board fuel and/or energy consumption monitoring devices, starting with new passenger cars and new light commercial vehicles registered in 2021. The Commission shall ensure that the public is informed of how that real-world representativeness evolves over time.*" This aligns with almost all of the Government's guiding principles Effective, Transparent, Enabling, Credible and Robust.[1,2]

A collaborative research project between TER and the EU's Joint Research Centre (JRC) is analysing the first round of EU OBFCM data and - although this needs to be confirmed - the initial findings indicate higher than expected on-road fuel consumption and CO_2 emissions for certain types of powertrains like PHEVs.[26,27] OBFCM is an essential component of an effective NVES. It will be required to track, monitor and report the effectiveness of the Australian NVES over the coming years and to reduce the opportunity for car manufacturers to exploit legislative loopholes.

On a final note, it is unlikely that the the current on-road emissions testing program that is being administered by the AAA, and will run for the coming years, will provide the empirical data and independent checks that the NVES requires. For instance, there are issues related to the relatively small sample size (compared to the on-road fleet and in consideration of inter-vehicle and regional variability in emissions that OBFCM will capture) and the (Melbourne-based) test protocol (RDE), which deviates from actual real-world driving (country-wide differences in ambient temperature and humidity, driving style, road gradient, fuel quality, etc.).

Recommendation 3 - *The NVES should include safeguard mechanisms to prevent adverse effects.*

There are specific design features in the proposed NVES that could trigger unwanted and adverse effects in relation to the reduction of emissions and improvement of fuel efficiency. One such topic is the impact of NVES design on a further increase in car obesity, which is discussed in more detail in Section 7.

When the current NVES design is compared internationally, it appears there is significant risk that car obesity will be promoted. In particular the relatively steep slope of the NVES suggests that it may be beneficial for manufacturers to sell more larger and heavier vehicles, as it would significantly increase their emission targets, reduce their emission debits and/or increase their emission credits, with potentially additional monetary gains.

For instance, a potential safeguard mechanism could be designed to ensure that the number of new passenger vehicles sold in 2025 and beyond that fall into the more lenient Type 2 standard does not increase beyond a certain point. If this point is reached, this could trigger certain changes to the vehicle allocation rules, the Type 2 limits, etc., potentially preventing the adverse effect.

Recommendation 4 - *The NVES should include a robust evaluation and correction mechanism.*

It will be critical that the NVES incorporates a robust evaluation and correction mechanism, which will allow the Federal Government to act if the measured real-world fuel efficiency and associated emissions show that actual improvements turn out to underperform or even be absent, something that is not beyond the realm of possibilities. It is noted that EU Regulation 2023/851 explicitly includes this aspect, including timelines.

- Article 14a: "*By 31 December 2025, and every two years thereafter, the Commission shall submit a report to the European Parliament and to the Council on the progress towards zero-emission road mobility.*"
- Article 15: "*The Commission shall, in 2026, review the effectiveness and impact of this Regulation …*"

Section 93 in the draft Bill states that a review of the Act will be commenced before 31 December 2026 and that a written report will be prepared that will be laid before each House of the Parliament.[3] It is unclear at this stage how this review will be conducted, who will do this and if the report will be made publicly available.

Recommendation 5 - *Improve transparency regarding NVES performance and input data.*

The EU has put specific requirements in place regarding transparency and accountability. For instance Regulation 2019/631 states that "*The Commission shall keep a central register, which shall be publicly available.*" The EU has put specific requirements in place regarding real-world CO_2 emissions and fuel or energy consumption, and its public availability. Regulation 2019/631 (Article 12) states: "*The Commission shall monitor and assess the real-world representativeness of the CO_2 emissions and fuel or energy consumption values determined pursuant to Regulation (EC) No 715/2007. Furthermore, the Commission shall regularly collect data on the real-world CO_2 emissions and fuel or energy consumption of passenger cars and light commercial vehicles using on-board fuel and/or energy consumption monitoring devices, starting with new passenger cars and new light commercial vehicles registered in 2021. The Commission shall ensure that the public is informed of how that real-world representativeness evolves over time.*"

As discussed in this study, the European Environment Agency publishes all relevant data in relation to the EU vehicle emission standards. The Federal Chamber of Automotive Industries (FCAI) is the custodian of these data in Australia, but to date has not made it publicly available. This has arguably reduced the transparency and accountability of the automotive sector in Australia and makes an independent assessment of the different NVES design options more difficult, as was found in this study.

The NVES will establish and maintain the New Vehicle Efficiency Standard Unit Registry to facilitate the credit-debit system. Public availability of these data would align with the federal Government's own guiding principles of e.g. transparency, credibility and robustness.[1,2] Section 86 in the draft Bill states that at least some of the relevant information will be published on the Department's website, including the vehicle manufacturer, the interim emissions value, the number of credits held and "*such other information as is prescribed by the rules*".[3] It appears that the publicly available data will be aggregated and would still miss essential information such as make/model specific sales and emissions performance.

Improved data transparency is strongly recommended for Australia. Detailed data on vehicle sales, relevant vehicle parameters and emissions performance (make/model level), as well as supplier-specific pooling arrangements (based on ownership/importing structures) and their targets should be public and freely available to inform Australian consumers, industry bodies, research organisations, NGOs and government.

Recommendation 6 - *Expand from exhaust to lifecycle emissions in future NVES design.*

As was discussed in Section 3.3, the NVES applies to exhaust (tailpipe) emissions only, but it is now widely acknowledged that CO_2 emissions should be based on a life-cycle assessment to provide a fair, holistic, balanced and evidence-based understanding of emissions performance. It is recommended that lifecycle emissions are included in the scope of the review of the Act that will start before 31 December 2026.

Recommendation 7 - *Reduce the adverse impact of the credit-debit system on emissions abatement.*

The NVES could restrict the credit-debit system to internal use of credits only, i.e. the removal of the credit transfer option from the NVES. This change in NVES design will result in an additional real-world emission reduction as was discussed in this study.

7. Recommendations for further work and refinement

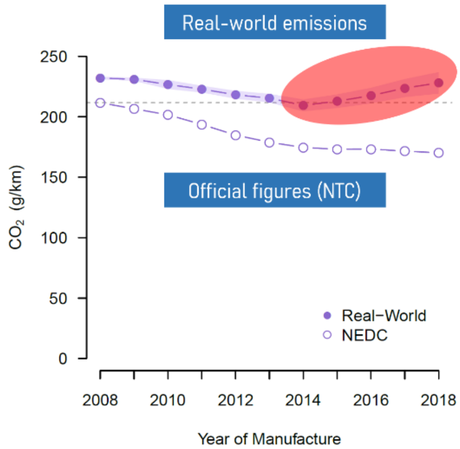
Recommendation 1 - *Further NVES design assessment*

This study presents a targeted analysis to quantify the emission impacts of the introduction of the two different version of NVES design, as detailed in two documents produced by the Federal Government, i.e. the (Consultation) Impact Analysis (Option B) and the New Vehicle Efficiency Standard Bill 2024.[1,2,3] The analysis can be expanded to estimate the emission impacts of several other (future) changes that could be of interest, for instance:

- further changes to the allocation of make/models to Status Type 1 and 2,
- removal or shifting of breakpoints,
- changing the headline target,
- changing the slope of the limit curve,
- introducing manufacturer pooling.

Recommendation 2 - *Assess the impact of NVES design on increasing car obesity.*

Of particular interest is the impact of the current NVES design on the growing issue of car obesity. This refers to the sustained and increasing proportion of large and heavy passenger vehicles (SUVs, utes) in on-road fleets around the world, and particularly in Australia. These vehicles have a detrimental effect on energy efficiency and greenhouse gas emissions. SUVs and utes are larger and heavier than conventional passenger cars and the laws of physics dictate they need substantially more energy and fuel per kilometre of driving, when compared with smaller and lighter vehicles.[5]



for new Australian passenger vehicles

TER research in 2019 estimated that on-road fleet-average CO_2 emissions rates (g/km) for Australian new passenger vehicles have not gone down as reported officially (NEDC), but are actually increasing with a few percent each year since 2015, rather than the annual reduction reported by the National Transport Commission, as is shown in in Figure 14.[17] A sustained increase in vehicle weight and a shift to the sale of more four-wheel-drive cars (in other words, SUVs and large utes) were found to be the main factors contributing to this undesirable outcome.

A recent joint TER-ICCT study confirmed the relatively stable or deteriorating real-world emissions performance of Australian LDVs due to the increase in car obesity (Figure 15).

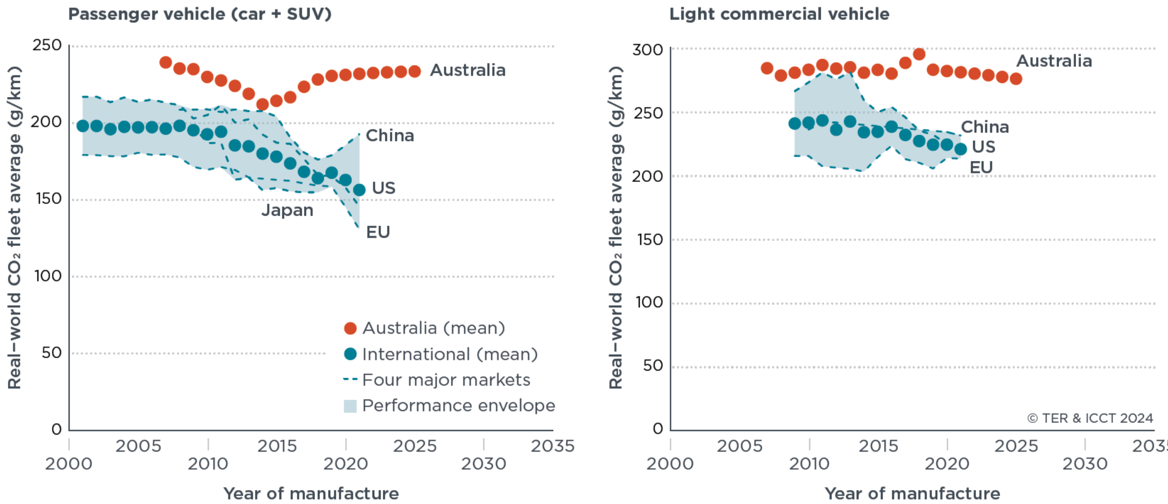


Figure 15 – Australian real-world fleet average LDV (exhaust) emissions performance in an international context; the blue polygon shows the combined real-world emissions data from the ICCT for the European Union, the United States, China, and Japan.[4]

The question is if the current NVES design will either promote or impede car obesity. When the current NVES design is compared internationally, as was recently done by ICCT, it appears there is significant risk that car obesity will be promoted.[29] In particular the steep slope of the NVES suggests that it may be beneficial for manufacturers to sell more larger and heavier vehicles, as it would significantly increase their emission targets, reduce their emission debits and/or increase their emission credits, with potentially additional monetary gains.

The NVES design tool can be used to analyse this issue, assess the risk and also compare with other standard settings around the world.

Recommendation 3 - *Update the results with the input data used by the Federal Government.*

To align with the Federal Government's own guiding principles of transparency, credibility and robustness, as stated in Table 2 [1] and Table 1 [2], it is recommended that the actual data used by the Government is requested and subsequently used to create an updated input file for use in the NVES design tool. This will then allow for an updated simulation with a complete data set and it will ensure consistency with the Government's calculations.

Recommendation 4 - *Use Probabilistic modelling.*

A probabilistic modelling approach could be used in the NVES design tool simulations. This method has been successfully used by TER in other studies.[14,15] This method provides an estimate of the most likely outcomes (emission predictions, monetary impacts), but also their associated variability and uncertainty (i.e. a plausible range in outcomes). It provides another layer of information for Greenpeace and policy-makers, where the uncertainty and the robustness (risks) of different NVES options can be assessed.

8. Conclusion

A mandatory fuel efficiency or emission standard is an internationally recognised key policy tool that reduces fleet-average CO_2 emissions from newly sold vehicles. Australian policymakers have debated whether to implement a mandatory standard for light-duty vehicles for more than a decade. With the release of the proposed New Vehicle Efficiency Standard Bill 2024, Australia is now close to adopting a mandatory new vehicle standard for light-duty vehicles (LDVs). LDVs include cars, sport utility vehicles (SUVs) and light-commercial vehicles (LCVs).

This study has quantified the CO_2 emission impacts of the introduction of two versions of the NVES, the originally preferred option by the Federal Government (Option B) and the latest version (Draft Bill), which is based on Option B, but with a number of changes, namely a shift of specific large SUVs to the more lenient LCV standard, as well as reducing the overall stringency of the standard for LCVs.

TER has recently developed a bespoke NVES design tool and an associated input data file for model year (MY) 2022 to assess the emission impacts of different standard design options. TER has used the tool in this study to estimate (changes in) total real-world (on-road) lifetime[19] exhaust CO_2 emissions from new Australian light-duty vehicles for five future years, MYs 2025 to 2029, which are the years for which targets have been set by the Federal Government.

In contrast to the EU where emissions and sales data are publicly available for transparency and accountability, this is not the case in Australia. TER therefore reconstructed an input file using publicly available data and information for 302 make/model combinations, including battery electric vehicles (BEV). The input file collates critical data, including vehicle brand (make), model, total sales, emissions performance, mass in running order, vehicle class and type. Comparison with high level statistics suggest that the reconstructed NVES input file could be a reasonably accurate representation of the actual data used by the Federal Government for the purposes of this study.

The main findings from this study are as follows.

- In the baseline scenario without a mandatory standard, lifetime emissions for newly sold LDVs are estimated to reduce with 12% in the period 2022-2029, due to the progressive increase in the uptake of battery electric vehicles.
- The estimated emission impacts of the two NVES options for MY 2025-2029 are based on the reconstructed MY 2022 input data and they assume no change in total vehicle sales and no change in fleet average mass (MIRO) in future years. Electrification and any other measures that a manufacturer may choose to improve the emissions performance of their newly sold vehicles (e.g. hybridisation, engine downsizing) are reflected in the modelling by assuming that all vehicle brands will meet their respective brand-specific targets, whilst keeping the fleet average mass (MIRO) the same.
    - The introduction of the NVES (Option B) in 2025 would provide significant reductions in real-world lifetime CO_2 emissions for newly sold vehicles, as compared with the baseline scenario. In 2025 the estimated reduction in real-world emissions is 6%, increasing to almost 60% in 2029, as compared with the baseline scenario.

[19] Total exhaust (tailpipe) CO_2 emissions from a new vehicle sold in the future (2025-2029) over its entire useful life.

- The introduction of the NVES (Draft Bill) in 2025 will still provide significant reductions in real-world lifetime CO_2 emissions for newly sold vehicles after 2025, as compared with the baseline scenario. In 2025 the estimated reduction in real-world emissions is only 2%, but this is increasing to about 50% in 2029.
- The inclusion of the credit-debit system increases lifetime CO_2 emissions in the NVES (Draft Bill) with 4.5% in 2025, reducing to 2.3% in 2029. A restriction of the credit-debit system to apply to internal credits only (i.e. the transfer option for credits between manufacturers for monetary gains would be removed from the NVES) will result in an additional real-world emission reduction.

- Compared to Option B, the changes proposed in the NVES (Draft Bill) have weakened the standard and have increased real-world lifetime CO_2 emissions for newly sold vehicles with 5% in 2025 (2,671 ktonne), increasing to 16% (3,856 ktonne) in 2029.
- The Federal Government estimated a total NVES emissions abatement in 2050 of 369 Mt (million metric tonnes) in 2050 (Option B) and 321 Mt (Draft Bill). The abated emissions predicted in this study are substantially lower with 103 Mt (Option B) and 87 Mt (Draft Bill), 27-28% of the estimates made by the Federal Government.[20] In a relative sense, the predictions are more similar. The Federal Government estimates that the change from Option B to the Draft Bill reduced the total abated emissions with 13%, whereas this study estimates a total emission abatement loss of 16% (17 Mt). Without a clear understanding how the Federal Government modelled the NVES impacts, it is not possible to explore the reasons for these differences. Section 5.3 suggests a number of possible reasons for the differences.
- In terms of the NVES impacts by vehicle brand, the results are only indicative, as there are a number of caveats, as discussed in the report (e.g. use of MY 2022 reconstructed sales data, pre-pooling). The simulation found the following:
    - Most manufacturers - but not all - in the debit group seem to have benefitted from the changes made in the Draft Bill in terms of a reduction in emission debits and their associated (potential) costs.
    - However, a small number of manufacturers seem to have benefitted substantially more than others, with reductions in their debit potential between 44-95% (ranked: Toyota, Isuzu Ute, Land Rover, Ford, Ssangyong and LDV). Toyota is the only manufacturer that changed from the debit group to the credit group.

The study made a number of recommendations to ensure that the NVES will be effective:

1. The NVES should adopt the WLTP test protocol from 2025 onwards.
2. The NVES should include on-board fuel consumption monitoring (OBFCM).
3. The NVES should include safeguard mechanisms to prevent adverse effects.
4. The NVES should include a robust evaluation and correction mechanism.
5. Improve transparency regarding NVES performance and input data.
6. Expand from exhaust to lifecycle emissions in future NVES design.
7. Reduce the adverse impact of the credit-debit system on emissions abatement.

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Finally, there appears to be a significant risk that car obesity will be promoted with the currently proposed NVES design, continuing the increased sale of large and heavy passenger vehicles with detrimental effects on energy consumption and greenhouse gas emissions. It is therefore recommended that the NVES design tool is used to further analyse this issue and assess the potential risk for effective operation of the NVES. It is also suggested that the results from this study are compared with a follow-up study that uses the actual input data used by the Federal Government.

9. Acknowledgements

TER is a research consultancy that operates independently, by not aligning with any political party or ideology. TER advice is based on robust, transparent and impartial research. TER has defined a research policy (https://www.transport-e-research.com/about) that applies to its business practices.

To address and mitigate any perceived conflict of interest or a perception of predetermined outcomes, this study has been reviewed by three independent experts.

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Appendix A. Make and models that are assumed to be shifted to Status Type 2

- Ford Everest
- Isuzu Ute Mu-X
- Isuzu Ute Mu-X
- Jeep Grand Cherokee
- Land Rover Defender 110
- Land Rover Discovery
- Land Rover Discovery Sport
- LDV D90
- Lexus Lx500d
- Lexus Lx600
- Mercedes-Benz G400d
- Mercedes-Benz Gls400d 4m
- Mercedes-Benz Gls450 4m
- Mercedes-Benz Gls600 4m
- Mercedes-Benz M-Amg G63 Fl
- Mercedes-Benz M-Amg Gls63
- Mitsubishi Pajero Sport
- Nissan Patrol
- Ssangyong Rexton
- Toyota Fortuner
- Toyota Landcruiser
- Toyota Prado

Appendix B. Fundamental vehicle technologies

- **Internal combustion engine vehicles (ICEVs)** represent the traditional vehicle technology. An internal spark-ignition or compression-ignition combustion engine ignites fuel to drive pistons and/or rotors to turn a driveshaft, and in turn, propel the vehicle forward. These vehicles can be powered using various liquid or gaseous fossil fuels (petrol, diesel, LPG, CNG), biofuels (bioethanol, biodiesel, etc.) or potentially e-fuels. Most of the energy stored in the fuel is lost making ICEVs a relatively energy inefficient technology. As a consequence, ICEVs generate significant amounts of greenhouse gases and air pollutant exhaust emissions. Typically about 20% of the available energy contained in fossil fuels is actually used to drive an ICEV.
- **Conventional hybrid vehicles (HEVs)** combine a combustion engine with an electric motor and typically use petrol fuel. HEVs still use an internal combustion engine like ICEVs, but also deploy regenerative braking for battery charging. The environmental performance of hybrids depends on (driving) behaviour and electric range of the vehicle. They exhibit the largest reduction in fuel consumption in low-speed urban conditions with smaller fuel reductions as vehicle speed increases.
- **Plug-in hybrid electric vehicles (PHEVs)** combine an electric and a conventional internal combustion engine powertrain, like HEVs. The difference is that PHEV batteries can also be charged with grid electricity in addition to the internal combustion engine and through regenerative braking while driving. They have the potential to reduce global greenhouse gas (GHG) emissions and local air pollution, if they drive mainly on electricity. So a critical factor is how much real-world driving occurs in electric mode, which depends on driving and charging patterns and vehicle characteristics (rated power, electric range, battery capacity). Recent overseas studies have shown that this real-world share is significantly lower than originally expected, in the order of only 20-40%. This means that PHEVs effectively operate as ICEVs most of the time. When PHEVs operate exclusively using electricity, their performance will align more with that of BEVs.
- **Battery electric vehicles (BEVs)** use a powertrain that consists mainly of an electric battery, charged from the electricity grid (power point or integrated system with solar panels), which in turn drives the wheels via an electric motor. BEVs are relatively energy efficient with about 80-90% of charged electricity consumption used to drive the vehicle. On a WTW basis a rule-of-thumb is that BEVs are about three times more energy efficient than ICEVs.
- **Fuel cell electric vehicles (FCEVs)** use hydrogen, stored in on-board tanks, in combination with a fuel cell stack to generate electricity, which in combination with a small battery, powers an electric motor. FCEVs are not plugged-in to charge, and are refilled with hydrogen in a similar manner to existing ICEVs. FCEV are less energy efficient than BEVs. About 50% of the available energy contained in hydrogen is used to drive a FCEV. On a WTW basis, FCEVs have a similar or slightly improved energy performance as ICEVs, i.e. typically losing 75-85% of (fuel) energy content in the process of production, transport and usage.