Uncovering the hidden costs and benefits from Electric Vehicles

Final Report for the Electric Vehicle Council

Building a better working world

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Introduction

Background and Context

Electric vehicles (EVs) offer a range of environmental benefits, including the potential for reduced greenhouse gas (GHG) emissions, airborne particulates and other pollution from road transport, and would support Australia in achieving its international emissions targets. Despite this, support and demand for passenger EVs in the Australian market has historically lagged behind the rate of increase experienced in similar international markets. Outside of Australia, different policy incentives have made EVs a more attractive option to drivers and policy-makers, accelerating their uptake.

The Electric Vehicle Council (EVC) engaged EY to assess the costs and benefits associated with EVs displacing internal combustion engine vehicles (ICEVs) in Australia, separating these impacts into costs and benefits to government, and to society. Media reports have suggested that some State governments have considered implementing a tax on EV drivers out of concerns that EVs would reduce government revenue (through lower fuel excise revenue). However, EVs have broader economic, societal and environmental costs and benefits, and these need to be recognised and quantified as part of any discussion on the overall cost and benefits of EVs in Australia.

Analysis Performed

This analysis quantified the effects of EV uptake on direct government revenue (including fuel excise), together with the broader costs and benefits EVs bring to government and society. This analysis was carried out on a $AUD per-km ($/km) basis: that is, the costs and benefits per km travelled by an EV versus an equivalent fossil fuel vehicle. Our analysis (outlined in the table on page 4) has been grouped into two key categories for three differing ICEV categories (petrol cars, diesel cars, and diesel buses):

- Direct government revenue effects.
- Indirect costs and benefits to government and society.

The report also outlines the net per-km revenue effect of EVs to government and society.

EVs provide a net revenue benefit to government compared to the average fossil fuel vehicle

EY's analysis found that:

- EVs provide a net revenue benefit to government versus fossil fuel vehicles.
- EVs deliver significant additional net benefits to society, principally through avoided GHG emissions, avoided particulates and other pollutants (particularly when replacing diesel cars and buses), including noise.
- Electrification of buses has a net per-km benefit around 70% higher than replacing diesel cars with EVs, and more than double the benefit of replacing petrol cars with EVs.

$8,763
The average net benefit to government and society of an EV replacing an ICEV.

$40,051
The average net benefit to government and society of an electric bus replacing a diesel bus.

$0.011/km
The average net government revenue benefit of an EV replacing an ICEV.

Approach and method

The following approach was undertaken to quantify the net costs and benefits of replacing fossil fuel vehicles with EVs (on a per-km basis) by:

- Carrying out a detailed desktop assessment to provide qualitative and quantitative evidence demonstrating the contribution and value of each cost and benefit;
- Modelling of costs associated with EV uptake and loss of fuel excise revenue;
- Modelling of an indicative price of each cost and benefit, to quantify the environmental, economic, and societal effects of a transition to EVs at a government and societal level;
- Projecting the government's revenue losses and avoided externalities from EVs on a $AUD/km basis for three passenger vehicle types (petrol car, diesel car, and diesel bus), and the net revenue impact of EVs;
- Engaging with EVC stakeholders to discuss method, assumptions and validate outcomes of the analysis; and
- Refining and finalising analysis following engagement and feedback from EVC stakeholders.

EY's detailed approach and key assumptions are detailed in Appendices A and B.

Effect	Cost/Benefit	Purpose of analysis
Government revenue	Capital expenditure taxation and registration	To quantify the difference in sales tax revenue generated for the government between an EV and small ICEV (manufacturer list price, Luxury Car Tax, registration, stamp duty, GST)
	Operational GST	To quantify the impact of increased household discretionary spend due to lower running costs of EVs displacing ICEVs
	Income tax effects	To quantify the income taxation impact from additional electricity generation and spending diversion from fuel retailing to the broader economy
	Fuel excise	To quantify the revenue impact per unit distance for petrol cars, diesel cars and diesel buses
	Strategic fuel reserve	To quantify the impact on strategic fuel reserve (SFR) costs from increasing EVs and lowering demand for fuel
Market externality	Greenhouse gases (GHG) emissions	To price the impact of altered GHG emissions due to EVs displacing ICEVs
	Air pollutants	To price the impact of altered air pollution (excluding GHGs) from EVs displacing ICEVs
	Noise	To price the impact of altered noise levels from EVs displacing ICEVs
Private revenue	Grid resource	To quantify the benefits of EV batteries as a resource to the electricity grid

Summary of findings

The costs and benefits of an ICEV** being displaced by an EV for each of the cost and benefits analysed are shown in the graph on the right and summarised below. The overall impact on government is an increase in net revenue of $0.011/km, and the overall externality impact to government and society is a benefit of $0.058/km, contributing to an overall net benefit of $0.069/km ($8,763/vehicle over a 10 year life) for each km travelled by EV versus an ICEV.

Due to reduced fuel consumption, EVs impose net costs to government of

The average EV **imposes *net* costs to government** over its lifetime (10 years) of:

- $0.046/km, or $5,879 per vehicle, from lost fuel excise revenue
- $0.007/km, or $858 per vehicle, from lost GST revenue that would have been spent on liquid fuels

EVs provide a net government revenue benefit of

$0.011/km

$137/vehicle/year

The average EV **generates *net* government revenue** over its lifetime (10 years) of:

- $0.056/km, or $7,079 per vehicle, from additional GST, LCT* and stamp duty on capital cost as well as annual vehicle registration.
- $0.001/km, or $131 per vehicle, from additional income taxation due to a redistribution of expenditure to more jobs-intensive industries than fuel retailing

The average EV **avoids *net* government expenditure** of:

- $0.007/km, or $892 per vehicle, from reduced expenditure on Strategic Fuel Reserve (SFR) leasing

EVs provide a net market externality benefit of

$0.058/km

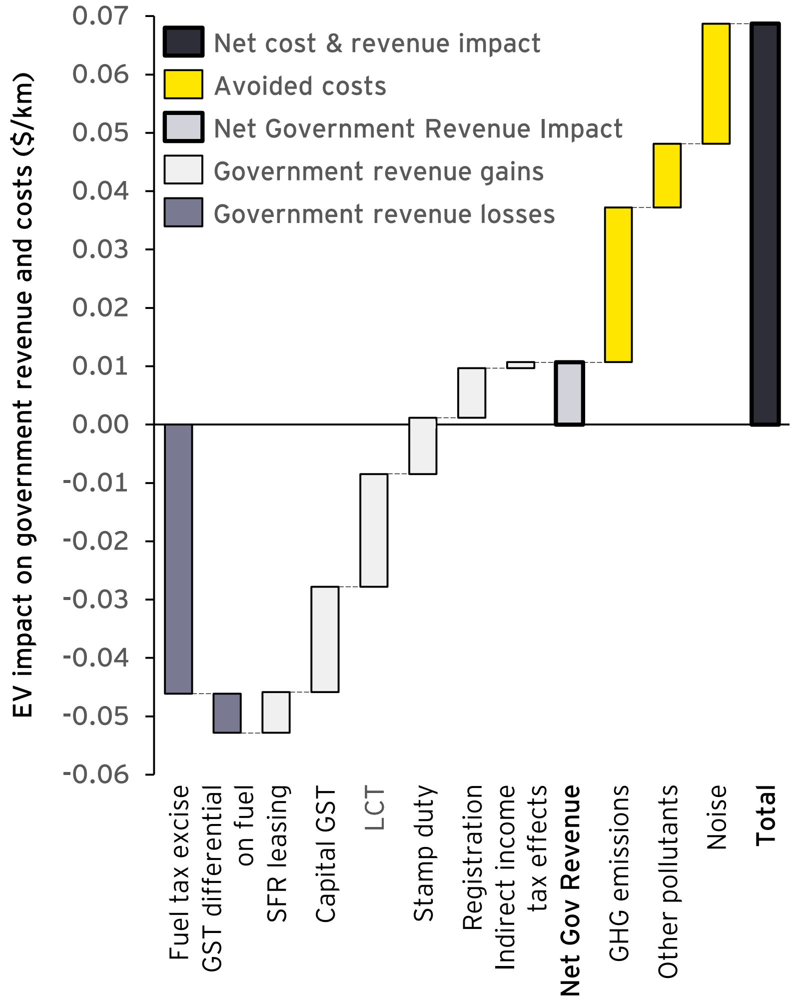
$740/vehicle/year

The average EV **avoids *net* market externality costs to government and society** over its lifetime (10 years) of:

- $0.026/km, or $3,377 per vehicle, from reduced GHG emissions
- $0.011/km, or $1,396 per vehicle, from reduced local air pollution
- $0.021/km, or $2,624 per vehicle, from reduced noise

*50% of cars were assumed to be captured by the LCT: see Appendix A.

Net per-kilometre revenue impact of electric vehicles to government and society



**Average vehicle weightings are by annual distance travelled (ABS, 2018): 84% petrol cars, 15% diesel cars, 1% diesel buses

Summary of findings

The costs and benefits of displacing petrol cars, diesel cars, and diesel buses by an equivalent EV are shown in the chart (right, by cost and benefit type), and summarised below. Note that the average net impact for each vehicle is calculated from the unique costs and benefits weighted by distance travelled. The major differences by vehicle type arise due to the higher particulate emissions from diesel vehicles, and higher per-km fuel use of buses.

Diesel and petrol car replacement

There are different costs and benefits for EVs replacing petrol and diesel cars due to fuel efficiency and emissions profile – hence a comparison outside of the average vehicle is needed.

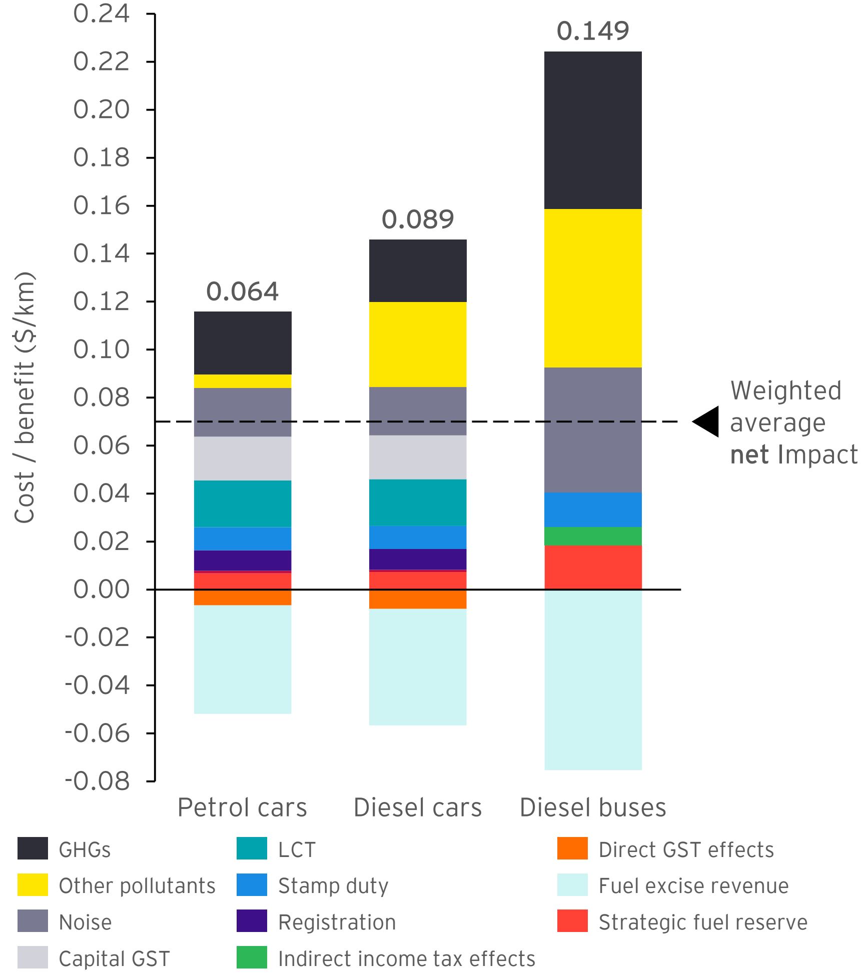
- Diesel car replacement imposes a slightly greater gross government revenue loss through lost fuel excise ($0.003/km) and GST on fuel ($0.001/km) due to petrol being a more efficient fuel
- Diesel car replacement avoids significantly more health costs to government and society ($0.030/km) from air pollution, predominantly due to avoided particulate emissions
- Diesel car substitution creates a net benefit to government and society of $0.089/km or $11,227 over a 10 year life (versus $0.064/km or $8,056 when replacement is for a petrol car)

Diesel bus replacement

There are different costs and benefits for electric buses replacing diesel buses as opposed to electric cars replacing ICE cars due to operational patterns, fuel efficiency and emissions profile – hence a comparison outside of the average vehicle is needed.

- Imposes a net government revenue loss ($0.035/km) due to GST rebates, no LCT and no registration income differential
- Avoids significant net costs to government from local air pollution ($0.066/km), GHG emission ($0.066/km) and noise ($0.052/km), predominantly due to poorer fuel efficiency, operation patterns and diesel combustion's larger particulate emissions profile
- Substitution creates a net benefit to government and society of $0.149/km or $40,051 over a 10 year life

Net per-km revenue & cost impact of electric vehicles to government and society by vehicle type



Government revenue effects

Electric car substitution generates a net weighted government revenue increase of $0.011/km, or $137/vehicle/year (table, below). EV buses result in a reduction in government revenue of around 17% (chart, right-hand side), but they deliver substantially higher societal benefits (next page).

Fuel excise, GST on fuel, and strategic fuel reserve costs

- Lost fuel excise and GST revenue on fuel has the largest revenue loss effect
- This is due to EVs generating zero fuel excise revenue, a lower average GST rate incurred on diverted spending in the broader economy compared to fuel, and a fraction of operational cost saving for EV owners directed to consumption as opposed to saving or reducing debt.
- Avoided strategic fuel reserve costs from EVs reducing IEA petroleum import requirements have a modest, though pivotal, contribution ($0.007/km).

Capital taxation and registration

- GST on capital, LCT, stamp duty and registration marginally offsets lost fuel excise and GST revenue on fuel ($0.003/km difference) while indirect income tax effects from shifts in employment had a minor net benefit (0.001/km).
- This is predominantly due to a $15,000-$25,000 price differential between equivalent ICEV and electric cars (not representative of extra luxury) as well as EVs incurring additional registration costs due to a heavier mass from the batteries.

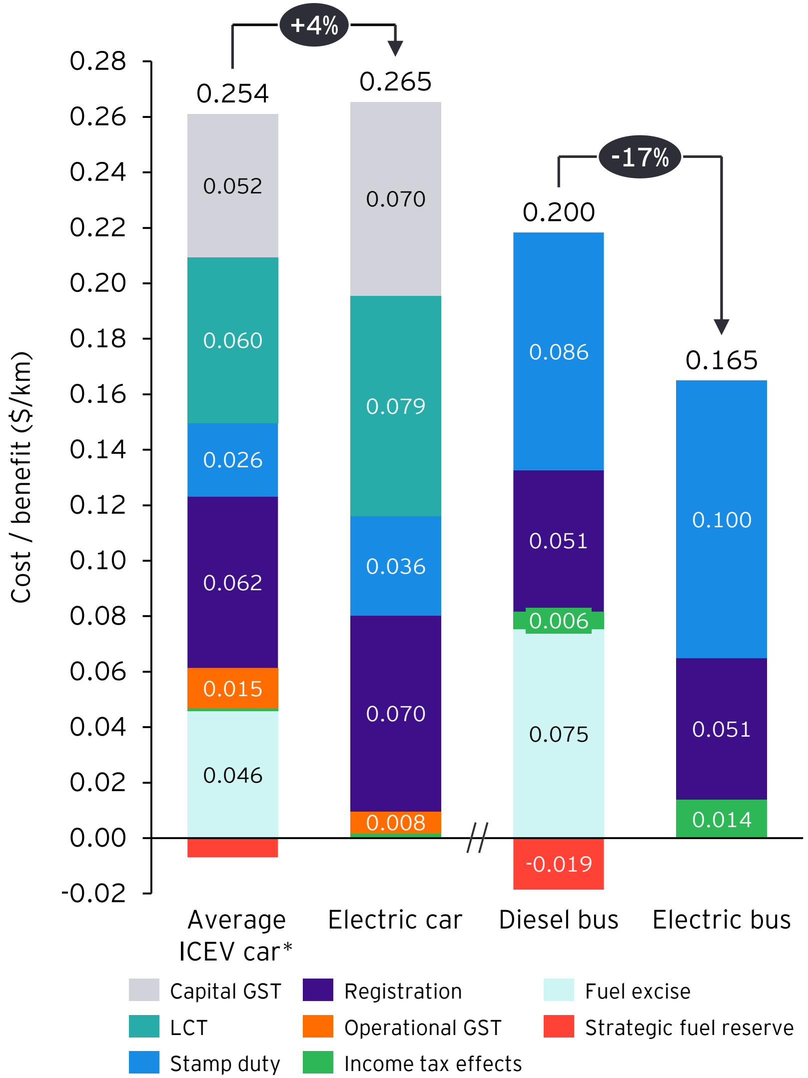
Avoided health costs

- Studies have estimated approximately 80% of the health costs of air pollution from ICEV's (see next slide) are incurred by government (or via health insurance) (EPHA, 2018).
- For buses, avoiding these costs could therefore result in a further benefit to government of up to $0.053/km. This would result in bus electrification delivering a 9% net revenue benefit to government (versus the 17% decrease shown in the chart, right).

Average ICEV replacement	Net benefit ($/km)	Net benefit ($/vehicle/year)
Fuel excise and GST on fuel	-0.053	-674
Capital taxation and registration	0.056	708
Strategic fuel reserve	0.007	89
Income tax effects	0.001	13

Comparison of ICEV and EV net weighted government revenue benefits

Left-hand side average car, right-hand side average bus



*Average ICE car weightings are by annual distance travelled (ABS, 2018): 84% petrol cars, 16% diesel cars.

Market externality effects

Electrification of cars avoids significant GHG, local air and noise pollution costs to government, society and private individuals totalling $0.057/km (chart, left-hand side). Electrification of buses delivers more than three times this benefit (on a per-km basis), with avoided air pollution costs a major contributor (chart, right-hand side).

GHG emissions

- GHG emissions are the largest contributor with avoided costs accounting for 46% of net market externality benefits.
- This is due to much larger emissions from liquid fuel combustion compared to electricity generation – of which the majority used for EV charging is either rooftop PV or marginal utility renewable electricity (RE).
- A social cost of carbon of just over $80/tCO_2e$ was used, based on an international ANU literature review as detailed in Appendix A.

Local air pollution

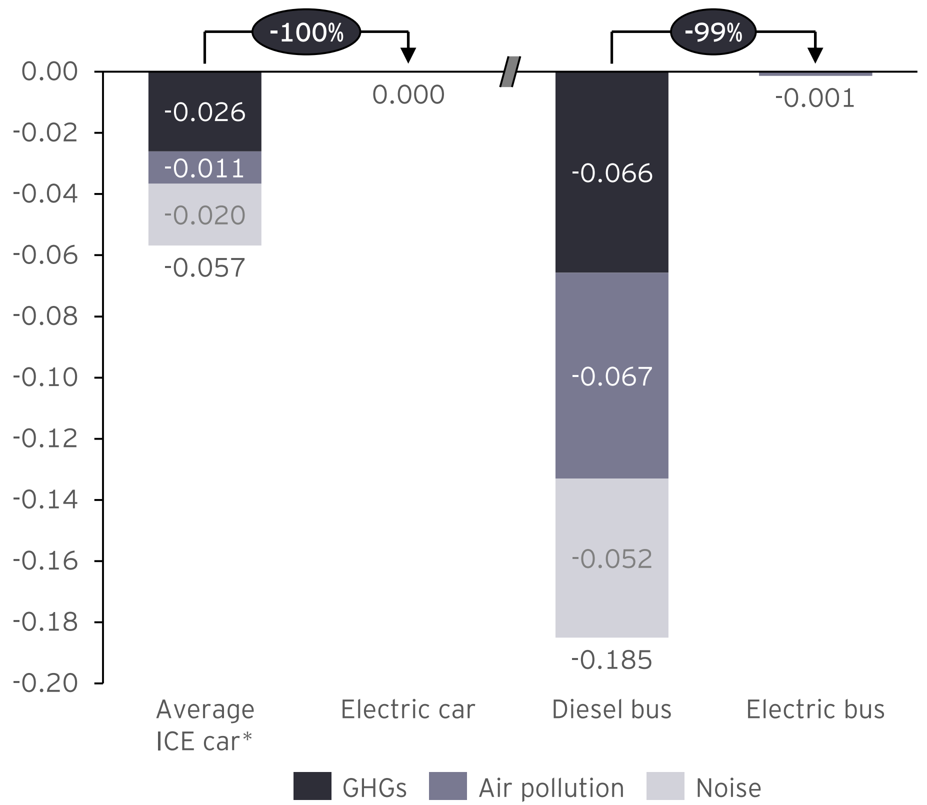
- Local air pollutions costs account for around 20% of externality costs, with literature attributing the majority (~80%) to government (EPHA, 2018).
- This is due to the hazardous emissions profile of ICEV exhausts close to human centres compared to the geographically distant electricity generation – of which the majority used for EV charging is either rooftop PV or marginal utility RE (firming thermal generation required for RE integration is accounted for*).

Noise pollution

- Noise pollution avoided costs are the 2nd largest contributor, accounting for 35% of the net market externality benefit.
- This is the result by (effectively) zero noise from EVs compared to ICEVs – the cost of which is distributed between private individuals (e.g. decreased property prices), society (e.g. lower productivity) and government (e.g. greater health public costs).

Comparison of ICEV and EV weighted externality costs

Left-hand side average car, right-hand side average bus (all units $/km)



*Average ICE car weightings are by annual distance travelled (ABS, 2018): 84% petrol cars, 16% diesel cars.

Average ICEV replacement	Net benefit ($/km)	Net benefit ($/vehicle/year)
GHG emissions	0.026	338
Local air pollution	0.011	140
Noise pollution	0.021	262

Conclusion

This analysis has found that the uptake of EVs (displacing ICEVs) would have revenue benefits to government, and cost benefits to government and society. This is quantified by the average net benefit of $8,549 for government and society when replacing an ICEV for an EV car and $40,051 average net benefit to government and where an EV bus replaces a diesel bus (both on an average vehicle age of 10 years).

Further, market externality effects highlight that discussion and consideration of mechanisms that may disincentivise EV uptake (such as an EV tax) in Australia do not consider that there are large government and societal benefits to be gained via improved health and environmental outcomes arising from replacing ICEVs with EVs. EVs currently contribute more to government revenue than ICEVs per vehicle, even when accounting for losses of fuel tax excise and GST.

Overseas experience has shown that government incentives and support act as key drivers of EV uptake, particularly when the existing market is small. The results of this analysis suggest there is an opportunity to align the policy and support framework for EVs in Australia to better reflect the government and societal benefits of EV uptake.

Limitations and considerations

Changes in external factors, such as Australian transport and taxation policy, energy costs, electric vehicle technology and vehicle costs, and costs attributed to environmental and health impacts, could materially alter the outcomes of this analysis and engagement. The assumptions used in undertaking this engagement are referenced in Appendix B.

Three key considerations for this work in the future are:

- The decreasing capital cost of EVs as technology further matures will close the price gap between ICEVs and EVs, reducing the net capital taxation benefit to government.
- The decreasing cost of battery replacement and increased cyclability as the technology develops could make EVs a valuable grid resource both for direct private benefit but also indirectly for society though lower electricity costs and for government through increased consumption expenditure and indirect taxation revenue. This has the potential to shift energy consumption, movement and production patterns profoundly.
- When considering the strict government revenue change of EVs replacing ICEVs, there is a benefit to government in reduced health costs from lower air pollution and reduced climate mitigation expenditure and less taxation losses from adverse economic impacts of climate change due to lower GHG emissions.

Appendices

Appendix A - Methodology and assumptions

Government revenue effects

Capital expenditure taxation and registration

- Average net government revenue generated at the time of sale for car EVs and ICEVs was calculated by averaging the differential in capital expenditure taxation and registration of a high and a low case of equivalent petrol and electric SUVs. The average net revenue was utilised in the final results as the Federal Luxury Car Tax of 33% (on pre-GST value) only applies to cars over of $75,526 for fuel efficient vehicles and $67,525 for other vehicles (in FY20). The two cases were calculated as follows:
  - A high case was calculated using the difference in revenue (the NSW manufacturers list price, LCT, GST, stamp duty and registration costs) between equivalent vehicles – the Audi Q8 55 quattro (ICEV) and E-tron 55 quattro (EV).
  - A low case was calculated using the difference in revenue (NSW manufacturers list price, GST, stamp duty and registration costs) between the equivalent vehicles of the Nissan Leaf (EV) and Toyota Corolla (ICEV).
  - The net government revenue generated from diesel and electric buses was calculated by applying NSW stamp duty rates to the capital expenditure differential and registration costs over a 10 year lifetime between a BYD K9 (EV) and average diesel bus (calculated from 10 buses in the market published in Volgren's Life Cycle Cost Analysis of Australian Buses). Registration (NSW costs) calculated based on the assumption all buses a 2 axle type 2 with a higher GVM limit.
- A ten year vehicle lifespan was used to calculate the total capital taxation and registration paid over the lifetime of each ICEV and EV.

Fuel excise levy

- Published government fuel excise rates ($0.423/L) including the rebate for buses ($0.258/L) and ABS fuel efficiencies were combined to yield a per unit distance lost fuel excise revenue.

GST on fuel

- Lost GST revenue on petrol (charged at a 10% rate) was applied to a per km fuel cost, obtained by combining a $1.36/km fuel price from Australian Petroleum Statistics 2019 and ABS fuel efficiencies.
- An average GST rate of consumption in the broader economy of 7% was applied to the diverted spending, assumed to be 50% of operational savings (slightly less than the 67% ABS data indicates) and a GST rate of 10% was applied to the cost of electricity.

Strategic fuel reserve

- The storage cost of fuel was taken from the Louisiana Offshore Oil Port (LOOP) just after April 2020 (post oil crash) in USD, converted to AUD using current RBA exchange rates and converted to a per km basis from ABS fuel efficiencies.
- The finance cost was calculated using the CPI rate at the end of FY19 of 1.6% on storage costs (as above) and the cost of oil from the Singapore oil market at the end of FY20, converted to AUD using current RBA exchange rates and converted to a per km basis from ABS fuel efficiencies.

Government revenue effects (continued)

Indirect income effects

- Gross employment gains in the electricity sector due to increased electricity demand were calculated using EY multipliers, converted to a per km basis from EV fuel efficiencies. ATO income tax rates were applied to the average electricity supply salary from ABS data.
- Net employment change (gain) from diverted spending in fuel retailing to the broader economy was calculated using EY employment multipliers (of sales and service income) from ABS industry data, converted to a per km basis from EV fuel efficiencies. The marginal ATO income tax rate was applied to the differential between average salaries in the fuel retailing industry compared to the broader economy.

Market externality effects

GHG emissions

- Emissions intensities for petrol and diesel from the National Greenhouse Accounts (NGA) Factors were applied to fuel efficiencies from the latest ABS Motor Vehicle Survey to calculate the per kilometre GHG emissions intensity of each ICEV class.
- Emissions intensities of electricity generation from the latest NGERS dataset were applied to the marginal build of electricity generation over the next 20 years from AEMO's latest Integrated System Plan (ISP) central scenario generation outlook by technology to calculate an average marginal emissions intensity of grid electricity less rooftop solar PV.
- A weighted average of grid and net-zero electricity emissions intensities was used based on the EVC's latest EV owner survey on charging source.
- The \$82/tCO_2-e carbon price used was an average excluding high and low outliers from an ANU literature review of 11 different prices from 9 countries estimated from both abatement and damage cost methodologies (\$91/tCO_2-e with outliers).

Local air pollution

- The cost of local air pollution from electricity for EVs is taken from a Victorian Government study, originally from a Harvard Kennedy School of Government report. The different charging sources for EVs have been considered as above with an adjustment to account for air pollution of thermal reserve capacity that may be needed to assist in grid integration costs.
- The cost of local air pollution for ICEVs is from a Victorian Government study, originally from a 2016 review of the Fuel Quality Standards Act 2000 prepared for the Department of the Environment. The same review has been used for the split in costs between particulate air pollution and other forms. The cost has been corrected for the relative particulate emissions intensity of diesel to petrol combustion from the BTRE economic costing of the health impacts of transport emissions in Australia, adjusted for buses and weighted proportional to distance travelled for all vehicles from ABS fuel efficiency data.

Noise

- The cost of noise pollution for petrol and diesel cars is taken from the EVC's Cleaner and Safer Roads for NSW, originally from the Victorian EPA.
- The cost of noise pollution for diesel buses is from The KTH Royal Institute of Technology, originally from the Victorian Transport Policy Institute, and is updated for inflation.
- EVs are assumed to emit no noise.

Appendix A - Methodology and assumptions

Further assumptions

- 2018 ABS motor vehicle survey data is used for petrol car, diesel car, and diesel bus fuel efficiency and distance travelled
- The Nissan Leaf is used for electric car efficiency
- BYD K9 (electric bus operational in Beijing) is used for electric bus efficiency
- RBA data is used for market exchange rates, inflation, and interest rates
- Average bus and car lifetime is 10 years
- AEMC 2019 market review is used for electricity price (31c/kWh)
- ATO income tax rates are used including the 2% Medicare levy
- Average vehicle weightings are by annual distance travelled (ABS, 2018): 84% petrol cars, 15% diesel cars, 1% diesel buses
- 2019 National Government Account (NGA) factors are used for petrol and diesel emissions intensity of combustion
- EVC 2019 survey results are used for EV charging electricity source
- Marginal NEM emissions intensity of generation is an average from 2020-2040 from AEMO's 2018 ISP central scenario generation outlook to 2040 and 2019 NGERS emissions intensity of gird connected generation
- An average of seven carbon prices from seven countries was calculated using abatement and damage cost methods from an ANU literature review (outliers excluded) to yield a carbon price of ($83/t$CO_2$e)

Private benefits

Grid resource

- The benefit of EVs as a grid resource was modelled as below though ultimately was not included due to the high cost of battery depreciation in the present and uncertainty over availability arising from consumer behaviour (i.e. how often the battery will be connected to the grid and how engaged consumers will be) and existing market structures (or lack there of for small market participants).
- The benefit of EVs as a grid resource was proxied off Neon's Hornsdale Power Reserve's FY19 operating income relative to its 100MW capacity (the assumption being revenue is largely due to FCAS services as opposed to arbitrage). This was converted to a per km basis from EV battery capacities and annual distances travelled from ABS data.
- The EV battery was assumed to be available 50% of the time, with a further 50% of consumers opting not to partake and a 20% discount applied for not providing full availability (as is often required in FCAS markets).
- Battery depreciation and use is based on Nissan Leaf battery efficiency and replacement costs.
- Peer reviewed conference proceedings from the 9th International Scientific Conference Transbaltica are used for electric bus battery depreciation.

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