THE PLUG-IN HYBRID ELECTRIC VEHICLE IN REMOTE AUSTRALIA: A FURTHER CASE STUDY 2016-21

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This paper builds on research conducted in 2017 and published in an article by Lex Fullarton in the *Journal of Australian Taxation* in 2018[†]

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[†] Alexander Robert Fullarton, 'The Impact of the Changing Technology of Motor Vehicles on Road Tax Revenue' (2018) 20(1) *Journal of Australian Taxation* 26.

ABSTRACT

Since the beginning of the 19th century, the natural environment of the planet has been placed under the dire threat of climate change. This has been caused by greenhouse gas (GHG) emissions from the burning of fossil fuels. GHG emissions threaten to alter the planet's ecosystems disastrously and permanently.

Statistics reveal that Australian individuals are among the highest GHG emitters on the planet, and that the transport sector contributes nearly one-fifth of the nation's GHG emissions. It is suggested that significant reductions in Australian GHG emissions are urgently required, and it is considered that those reductions might be helped by a transition to electric vehicles (EVs) in the transport sector.

This paper looks at the consumption of motor vehicle fuels in Australia's transport sector and suggests how a reduction in GHG emissions might be achieved. It suggests that the electrification of Australian motor vehicles could eliminate up to 20 per cent of existing Australian GHG emissions.

The paper presents further findings from a case study that was conducted on a Mitsubishi Outlander Plug-in Electric Hybrid Vehicle (PHEV) in remote Western Australia from 2016–17. That study is updated and extended in this paper to October 2021.

The paper uses published statistical data from the Organisation for Economic Co-operation and Development (OECD) and Australian government agencies to support its findings, conclusions and suggestions for further research. It looks at the rate of transition to electric vehicles and concludes that, while the transport sector's growing contribution to Australia's overall GHG emissions could be significantly reduced by the transition to electric vehicles, there is some way to go.

The paper suggests that there are significant economic factors inhibiting the adoption of electric vehicles in Australia. However, rising fuel prices could encourage the transition away from vehicles powered by environmentally damaging internal combustion engines towards electric vehicles in Australia.

Keywords: Electric Vehicles, Fuel Excises, Renewable Energy Sourced EV Charging, Motor Vehicle Expenses.

I AIM AND PURPOSE

Greenhouse gas (GHG) emissions threaten to alter the planet's ecosystems disastrously and permanently. Despite its relatively small total population, Australia is one of the highest per capita emitters of GHGs in the world. Therefore, Australia needs to reduce its carbon emissions substantially.

This paper builds on a previously published paper and uses the same research approach.[1] It continues the aim of encouraging the transition in Australia's transport sector from internal combustion engines to electrically powered vehicles, in order to reduce the nation's GHG emissions. It also aims to encourage road users, governments and tax administrators to become aware of the impact of changing road tax revenue structures to fund the development and maintenance of road networks. To fulfil those aims it reviews the impact electric powered vehicles might have on the tax revenue currently raised through the fuel excises levied on the owners of motor vehicles powered by fossil fuels.

The purpose of this paper is to review and update the research data and findings of the case study conducted in 2017 that was previously published in this journal in 2018.[2] It further investigates the rate of adoption of electric vehicles on Australian roads and compares that take-up rate with the rate forecast in the previous paper. It suggests how electricity from renewable energy sources might promote the transition from fossil-fuelled internal combustion engine vehicles to electric vehicles to reduce GHG emissions from the transport sector of the Australian economy.

It acknowledges, but does not address, the social and environmental impacts or benefits of the transition from internal combustion engines to vehicles powered by electric motors, which are beyond the scope of this paper.

II INTRODUCTION

Fullarton's previous paper acknowledged that the internal combustion engine has powered the world's motor vehicles for nearly 150 years. He noted that the atmospheric pollution caused by the burning of fossil fuels had reached unacceptable levels and was beginning to have a severe impact on the world's human and natural environments. It is possible that the respiratory disease known as Covid-19 could be attributed to a progressively polluted atmosphere, but detailed discussion of that is beyond the scope of this paper.

This paper looks at the contribution of Australia's transport sector to the nation's GHG emissions. It examines further research data obtained from a case study of a Mitsubishi Outlander Plug-in Electric Hybrid Vehicle (PHEV), which was the focus of a Fullarton's previously published paper.

That earlier paper found that there has not been a hypothecation of road tax revenue for the construction and maintenance of Australia's roadways since 1959. The 'electrification' of Australia's road transport should therefore have no impact whatsoever on government expenditure on roadway construction and maintenance. This paper extends the research

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1 Alexander Robert Fullarton, 'The Impact of the Changing Technology of Motor Vehicles on Road Tax Revenue' (2018) 20(1) *Journal of Australian Taxation* 26.

2 Ibid.

findings of the case study of the previous paper to support or refute that conclusion, and suggests that existing and proposed federal and state taxes may be inhibiting, rather than encouraging, the 'electrification' of Australia's passenger vehicles.

The principal aims of transitioning from vehicles powered by an internal combustion engine to electric vehicles are as follows: to address Australia's contribution to the world's growing GHG emissions; to provide leadership to other nations; and to address the problem of GHG emissions and their contribution to a warming global atmosphere and climate change.

However, at very senior Australian government levels, there is a strong opinion that Australia makes a negligible contribution to GHG emissions and climate change generally. In 2019 the Prime Minister of Australia, Scott Morrison, expressed the opinion that:

> the suggestion that any way shape or form that with Australia, accountable for 1.3 per cent of the world's emissions, that the individual actions of Australia are impacting directly on specific fire events, whether it's here or anywhere else in the world, that doesn't bear up to credible scientific evidence either. Climate change is a global phenomenon and we're doing our bit as part of the response to climate change. We're taking action on climate change. But I think to suggest that with just 1.3 per cent of global emissions that Australia doing something differently, more or less, would have changed the fire outcome this season [2019-20] – I don't think that stands up to any credible scientific evidence at all.[3]

Detailed scrutiny of Australia's climate change policies is beyond the scope of this paper, which assumes that Australia can play a key role in reducing global GHG emissions.

To place Australia's GHG emissions in the global perspective, the following section looks at the nation's GHG emissions compared to those of other Organisation for Economic Co-operation and Development (OECD) nations, and the contribution that the transport sector makes to the nation's GHG emissions.

III AUSTRALIAN GHG EMISSIONS

Figure 1 shows Australia's ranking for the volume of GHG emissions per person in 2010, as shown in Fullarton's 2018 paper.[4] In 2010, each Australian citizen was contributing roughly twice the GHG emissions of the average fellow citizen of an OECD member country.[5]

3 Radio interview with Scott Morrison, Prime Minister of Australia, (Sabra Lane, ABC AM, 21 November 2019) <https://www.pm.gov.au/media/radio-interview-sabra-lane-abc-am-0>. Written verbatim from the transcript.

4 Fullarton (n 1).

5 Organisation for Economic Co-operation and Development (2021), Air and GHG emissions (indicator). doi: 10.1787/93d10cf7-en, (Web Page, 2021) <https://data.oecd.org/air/air-and-ghg-emissions.htm>.

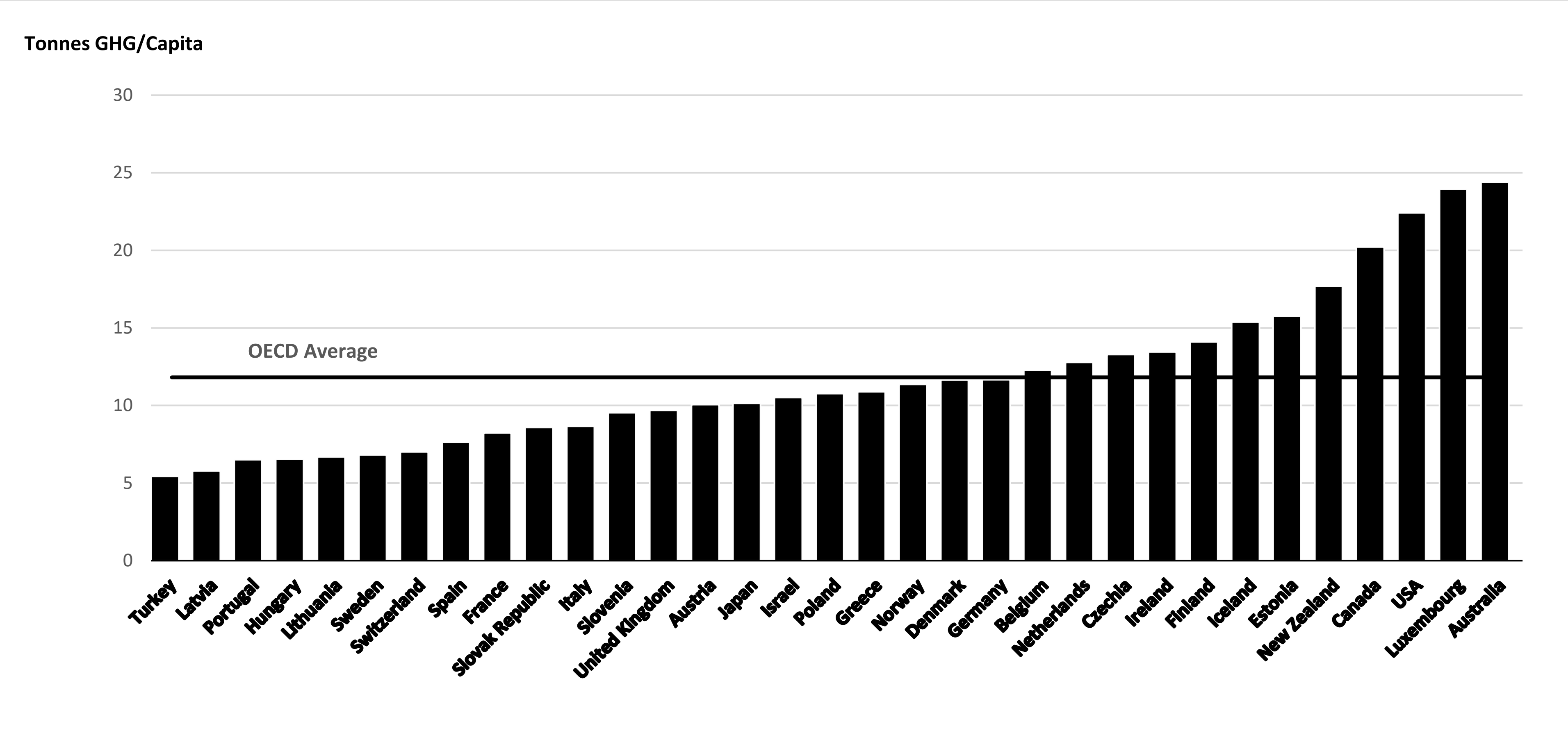

Figure 1: OECD national greenhouse gas emission intensities per capita, 2010.[6]

6 Ibid.

It was concluded by Oliphant in 2009 that '[a]lthough [Australia's] responsibility for 1.2 per cent of global [greenhouse gas] emissions seems small, it is not. In both gross emissions and emissions per capita, Australia is in the world's top 10 per cent'.[7] However, Oliphant is not correct. Australia was not in the world's top 10 per cent in gross emissions, but, more significantly, figure 1 reveals that in 2010, Australia was the highest emitter of greenhouse gases per capita of all of the OECD nations and figure 2 shows that in 2018 that ranking remained unchanged.

Therefore, it is suggested that, despite Australia's relatively small total contribution to world atmospheric pollution, its position as a developed nation that proposes to lead the world in economic and social issues means that the contribution by each Australian citizen of nearly twice the volume of GHG emissions of the average world citizen must be addressed.

Figure 2 shows that by 2018 the average Australian had reduced his/her GHG emissions from 24.4 tonnes in 2010 to 22.4 tonnes. However, Australians remain the highest ranked atmospheric polluters among all the OECD nations.

7 Monica Oliphant, 'Australia's Emissions Contribution: Does It Matter?' in John O'Brien (ed), *Opportunities Beyond Carbon: Looking Forward to a Sustainable World* (Melbourne University Publishing, 2009) 328. Monica Oliphant is an experienced research scientist with expertise in renewable energy who specialises in solar energy, as well as in improved energy efficiency and reductions in greenhouse emissions. She has a Master's degree in physics from the University of London and worked for almost 20 years as an energy research scientist for the Electricity Trust of South Australia. She is an Adjunct Associate Professor at the University of South Australia and a University Fellow at Charles Darwin University. She also runs her own consultancy, Monica Oliphant Research Scientist.

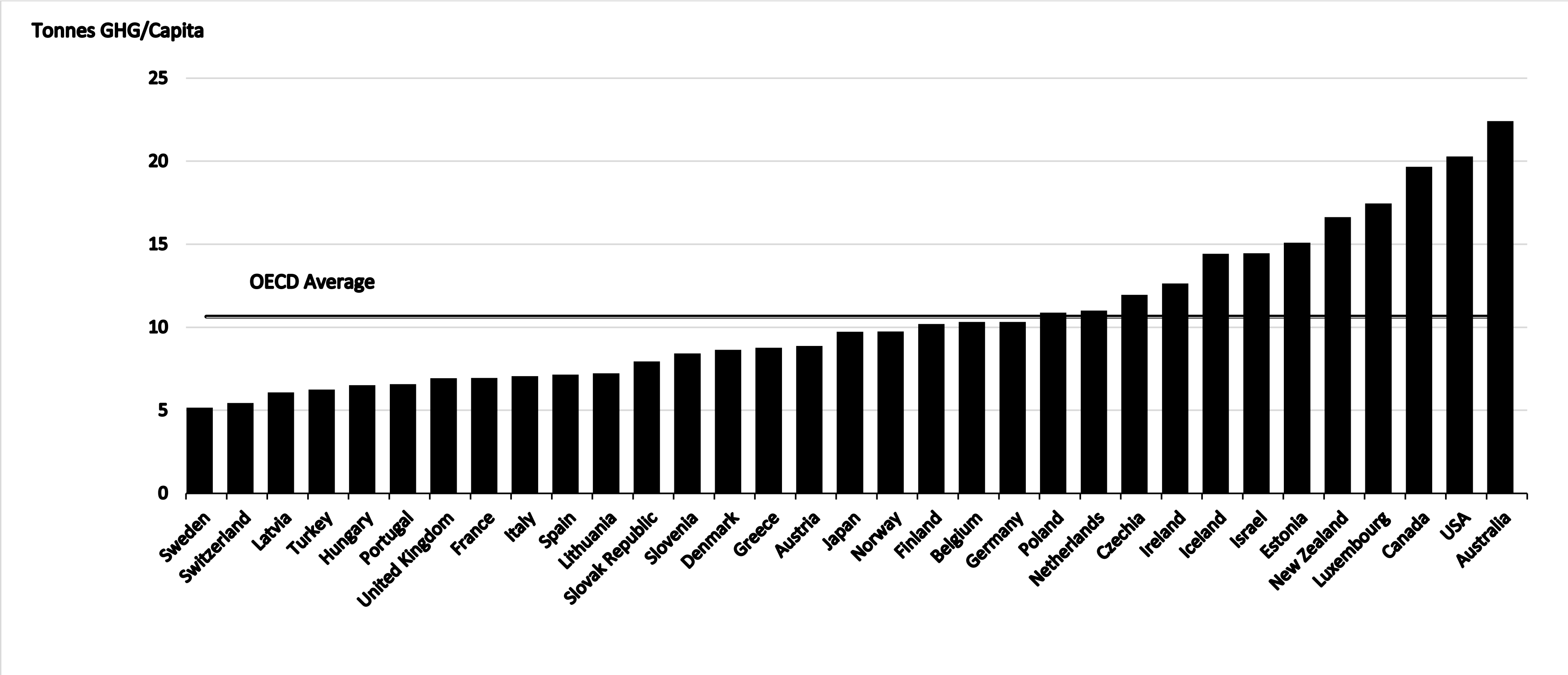

Figure 2: OECD national greenhouse gas emission intensities per capita, 2018.[8]

8 Ibid.

While a reduction of two tonnes per capita has been achieved, it appears that the total national emissions have plateaued rather than declined. Gains achieved in some sectors, such as through the roll-out of dispersed solar photovoltaic electricity generation that has displaced fossil fuels in the electricity generation sector, appear to be negated by the rise in GHG emissions in others.

It should be noted that, while Australians may contribute just over 1 per cent of the world's GHG emissions,[9] they make up just 0.33 per cent of the world's population.[10] That compares to the United Kingdom's (UK's) contribution of just under 1 per cent of the world's GHG emissions.[11] However, the UK has nearly three times the population (0.87% of the world's population).[12]

The comparison with the UK reflects poorly on Australia in terms of combatting GHG emissions, but figure 3 reveals a possible key influencing factor and an explanation of why road transport emissions make up such a significant proportion of Australian per capita GHG emissions.

Physically, Australia is some 32 times larger than the UK. The area of Australia is approximately 7,741,220 sq km, while that of the UK is approximately 243,610 sq km.[13] Therefore, there is a significant difference between the population densities of the two nations. For illustrative purposes, figure 3 positions the outline of the UK near the middle of Australia.

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9 Hannah Ritchie and Max Roser, 'Greenhouse Gas Emissions', *Our World in Data*, (Web Page, 2020) <https://ourworldindata.org/greenhouse-gas-emissions#annual-greenhouse-gas-emissions-how-much-do-we-emit-each-year>; Oxford University, 'Total Greenhouse Gas Emissions, 2016' *Our World in Data*, (Web Page, 2021) < https://ourworldindata.org/grapher/total-ghg-emissions?tab=chart&time=latest&country=USA~GBR~CHN~IND~BRA~AUS>.

10 Worldometer, *Countries in the World by Population (2021)* (Web Page, 2021) <https://www.worldometers.info/world-population/population-by-country/>.

11 Oxford University (n 9).

12 Worldometer (n 10).

13 My Life Elsewhere, *Country Size Comparison*, United Kingdom compared to Australia (Web Page, 2021) <https://www.mylifeelsewhere.com/country-size-comparison/united-kingdom/australia>.

Figure 3: The Australian landmass compared to that of the United Kingdom[14]

To provide some background to the distribution of the Australian population and the extent of the transport network, figure 4 shows how the population is concentrated along the southeastern and eastern coasts of Australia and the southwestern coast of Western Australia. If we consider the comparative road lengths of the two nations, in 2018 the UK government estimated the total road length in Great Britain to be 246,700 miles (or 397,000 km)[15] while for the same year Australian government statistics showed Australia's total road length to be over twice that of Great Britain, at 545,347 miles or 877,651 km.

In summary, Australia has roughly a third of the population of the UK, about 32 times the area, and two and one fifth times the road length.

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14 Australian Government, Geoscience Australia, *Australia's Size Compared* (Web Page, 2021) <https://www.ga.gov.au/scientific-topics/national-location-information/dimensions/australias-size-compared>.

15 Government of the UK, *Road Lengths in Great Britain:2018* (Web Page, 2021) <https://www.gov.uk/government/statistics/road-lengths-in-great-britain-2018>.

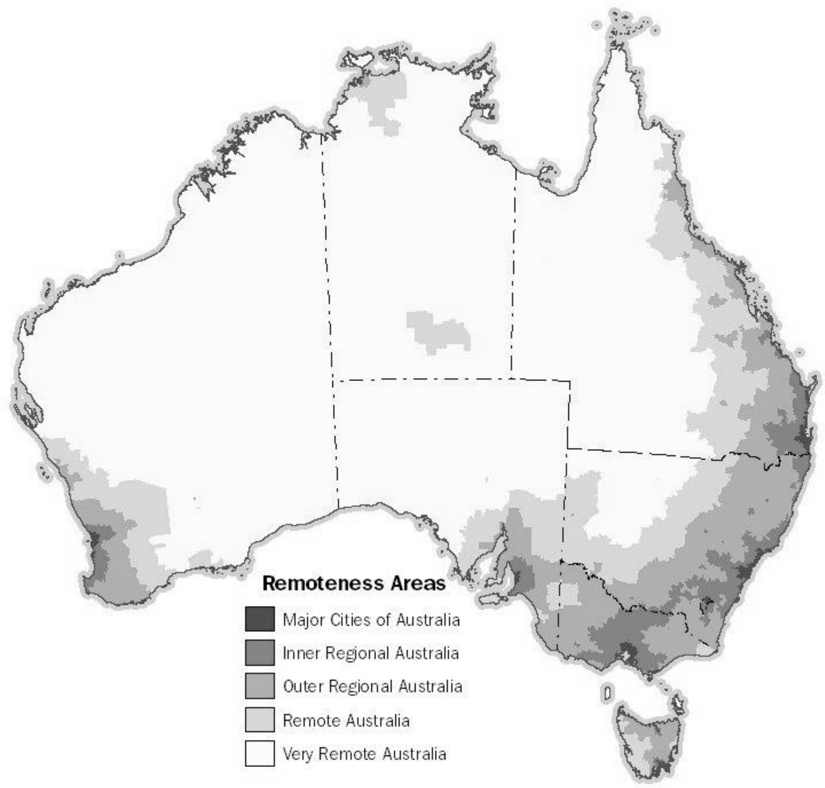

Figure 4: Map of the 2016 Remoteness Areas for Australia[16]

A detailed discussion of Australia's road networks is beyond the scope of this paper, but the maps and basic statistics provide an understanding of the vast distances between the population centres and the challenges faced by the Australian population in reducing the GHG emissions from Australia's transport sector. In addition, Australian decision-makers often point to the contribution made by other countries as some justification for the nation's lack of an incentive to reduce GHG emissions.

While a detailed analysis of that political philosophy is somewhat beyond the scope of this paper, the case of Luxembourg tends to support this assertion. The tiny population of Luxembourg, which has just over 600,000 people, makes a significant contribution to global GHG emissions.

However, the OECD notes that there may be an explanation for the apparently distorted per capita GHG emissions attributable to Luxembourg.

It notes that:

> Luxembourg has made progress in decoupling environmental pressures from economic growth, treating wastewater and managing waste and materials. It has also positioned itself as an international centre for green finance. Yet, it remains one of the most carbon- and material-intensive economies in the OECD. The country is a crossroads for freight traffic and attracts thousands of daily cross-border commuters. This exacerbates greenhouse gas emissions, air pollution and road congestion.[17]

16 Australian Bureau of Statistics, 'Remoteness Structure' *The Australian Statistical Geography Standard (ASGS) Remoteness Structure* (Web Page, 2016), <http://abs.gov.au/websitedbs/D3310114.nsf/home/remoteness+structure#Anchor2e>.

The apparent anomaly of Luxembourg, and the OECD's explanation, point to the contribution that the transport sector can make to overall national GHG emissions. Given its geographical location, and the fact that it shares the burden of its larger neighbours, the disproportionate GHG emissions attributed statistically to the people of Luxembourg may have a valid explanation.

However, Australia has no international land borders and so the contribution of foreign commuters refuelling their motor vehicles as they transit the nation does not apply to Australia. The example of Luxembourg does, however, highlight the contribution that the road transport sector can make to national GHG emission levels. Therefore, the following section looks at the contribution that the road transport sector makes to Australia's overall GHG emissions.

IV AUSTRALIAN ROAD TRANSPORT GHG EMISSIONS

Figure 5 shows the total Australian GHG emissions and the percentages attributable to the road transport sector from 1990 to 2018. It shows that GHG emissions from the transport sector of the Australian economy continue to rise, in terms of both their volume and as a proportion of the overall national GHG emissions.

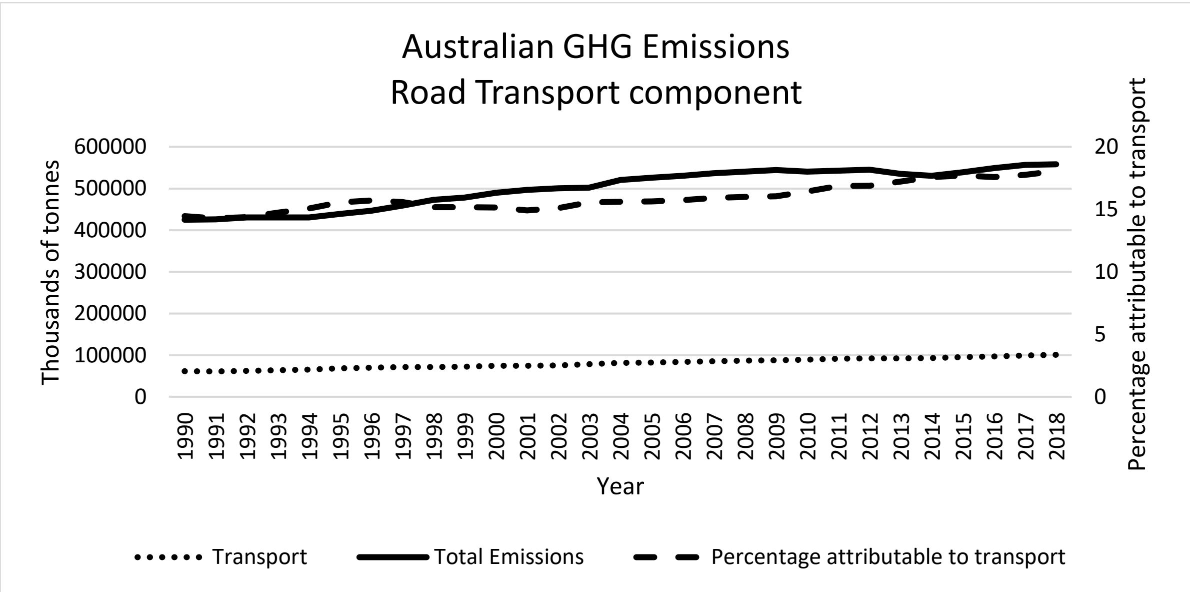

Figure 5: Australian Road Transport Emissions 1990–2018[18]

In 1990, the transport sector contributed just 14.5 per cent, but by 2018 the GHG emissions from the transport sector had risen to 18.1 per cent. Therefore, significant reductions in national GHG emissions might be achieved by a focus on reducing the GHG emissions from the transport sector of the Australian economy. That might be achieved primarily through the adoption of electric vehicles, which would reduce the dependence on fossil fuels for transport and lead to a general reduction in GHG emissions.

17 Organisation for Economic Co-operation and Development (n 5).

18 Organisation for Economic Co-Operation and Development, *Air Emissions by Source* (Web Page, 2021) <https://stats.oecd.org/viewhtml.aspx?datasetcode=AIR_EMISSIONS&lang=en#>.

In 2018 Fullarton's primary purpose was to refute a claim that the transition to electric vehicles would ultimately erode and endanger revenue set aside for the construction and maintenance of Australia's road network. He established that, while initially Australia's fuel excise had been hypothecated for the construction and maintenance of roadways, the practice had ceased in 1959 and therefore that this argument against transitioning away from internal combustion powered vehicles was no longer relevant.

However, despite this refutation, a key inhibitor of the transition to electrification in Australia's transport sector is the role of the taxes imposed on the nation's road users. This paper builds on the previous research, which was conducted in 2017, and further examines the impact of taxation on the transition of Australia's transport sector to electric vehicles, rather than the impact of the transition of electric vehicles on taxation revenue from Australia's transport sector.

It has been noted that electric vehicles sold in Australia often attract an added tax disincentive, in that most electric vehicles are sold at a price that exceeds Australia's luxury car tax threshold, and therefore an additional 33 per cent is added to the amount in excess of AUD 77,565 (2021).[19]

The luxury car tax appears to be an unfair addition to the total cost of purchasing a non-polluting vehicle compared to the cost of a vehicle of the same make and model powered by an internal combustion engine. Other taxes, such as state road maintenance taxes,[20] are imposed that target EV road users to compensate for lost fuel excises, despite Fullarton arguing in the previous paper that the loss of revenue had no impact on expenditure on Australian roadways.[21]

The following section looks at Fullarton's paper,[22] and compares the most recent data with the forecasts in that paper, to monitor the data presented then and to provide a more up to date and accurate forecast of the transition to electric vehicles in Australia. It will also examine research that has been published since the research was conducted in 2017[23] to provide confidence in Fullarton's findings.

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19 Australian Taxation Office, *Luxury Car Tax* (Web Page, 27 May 2016) <https://www.ato.gov.au/business/luxury-car-tax/>.

20 *Zero And Low Emission Vehicle Distance-Based Charge Act 2021* (Vic). The purpose of this is to require registered operators of zero and low emission vehicles to pay a charge for the use of their vehicles on certain roads. However, this state legislation is currently being challenged in the High Court of Australia <https://climate-laws.org/geographies/australia/litigation_cases/vanderstock-and-anor-vs-the-state-of-victoria>.

21 Fullarton (n 1).

22 Ibid.

23 For clarity it is iterated that the research of the case study was conducted in 2017 but published in this journal in 2018.

V THE IMPACT OF THE CHANGING TECHNOLOGY OF MOTOR VEHICLES ON ROAD TAX REVENUE

This section examines Fullarton's previously published paper (which was based on data current in 2016) to summarise its findings and conclusions. The aim of this examination is to establish what changes have been made in the five years since 2016 that affect the estimates about the transition to electric vehicles by Australians which were considered reasonable in 2017.

The data presented in the previous paper are compared to the statistics available in 2021 to investigate the forecasts made in 2017 and to provide updated forecasts, noting any significant changes. This paper makes updated predictions on the transition in Australia's transport sector towards the electrification of road transport and the corresponding reduction in GHG emissions from that sector.

This paper builds on the data and findings of the previous paper[24] and monitors the progress of the transition to EVs in Australia. It updates those data to attempt to judge the accuracy of the trends predicted in the previous paper.

The research approach continues to use a quantitative analysis of published statistics, and this paper provides further case study data on the use of a Mitsubishi Outlander PHEV in the northwest of Western Australia, as first presented in 2018. The case study data now cover the five-year period from 30 May 2016 to 30 May 2021 to provide a comparison for the fossil fuel consumption of a PHEV used in the northwest of Western Australia.

The research supporting this paper is conducted by way of a further statistical analysis of motor vehicle census data published by the Australian Bureau of Statistics (ABS) and raw ABS data supporting its publications since 2016, and a further examination of Australian Taxation Office (ATO) statistics since 2016 to establish the revenue received by the Commonwealth of Australia from the fuel excise tax levied on motorists in Australia. From that revenue, the annual expenditure on the diesel fuel rebate tax is deducted to establish the net value of the taxation of petroleum products to the Commonwealth government.

The ABS data are compared to the findings from the examination of the ATO statistics to estimate the contribution of passenger vehicles powered by fossil fuels to the net revenue. The updated findings of the case study based on the operation of the Mitsubishi Outlander PHEV used in the previous research are examined to update the economic costs of using that vehicle on roads in a remote region of Australia.

The previous paper explored Galvin's laboratory-based research for a Mitsubishi PHEV that was similar to, but not exactly the same as, the Mitsubishi Outlander PHEV used in this case study.[25] That examination provided a comparative analysis with the findings of the data of this field research. Fullarton found that Galvin's research findings were strongly supported by the field data of this case study. Those field data are extended in this paper, but Galvin's laboratory findings are not reviewed any further.

24 Ibid.

25 Ray Galvin, 'Energy Consumption Effects of Speed and Acceleration in Electric Vehicles: Laboratory Case Studies and Implications for Drivers and Policymakers' (2017) 53 *Transportation Research Part D* 234.

Previously, Fullarton found

> that unless fossil fuel-sourced electricity is displaced by renewable energy, there is no displacement of greenhouse gas emissions as a result of using electric vehicles. Due to losses in the generation and transmission of electricity, the use of electric vehicles may increase the volume of greenhouse gas emissions. Ultimately, the introduction of electric vehicles may have little or no significant impact on Australia's rate of greenhouse gas emissions. Rather, the source of the emissions moves from the exhaust pipes of motor vehicles to the chimney stacks of power stations.[26]

He also found

> that the transition from internal combustion engines to electric vehicles may have some impact on road tax revenues from fuel excises. Further, unless consumers can expect economic benefits, the transition to electric vehicles may not be significant in the transport sector.[27]

He suggested that, despite Australia's reliance on heavy road transport, it was likely that passenger vehicles would be dominant in the rise of electrically powered vehicles in the foreseeable future, as the technology for heavy transport vehicles was not yet fully developed in the commercial market at that time.[28] Save for the impact on net fuel excise revenue this paper also focuses on passenger vehicles.

The 2018 paper considered that

> The actual volume of electric vehicles on Australian roads is trivial, and certainly nowhere near the 20 per cent projected by the CSIRO, or 30 per cent according by Crowe's article. At a total rate of growth of 57 per cent, or 12 per cent per annum, the rate of growth is considerable, despite being established from a very low base of just 0.029 per cent of all vehicles. However, according to the ABS data, despite such a considerable growth rate in the number of electric vehicles on Australian roads, by 2035, electric vehicles will only make up less than 1 per cent of all passenger vehicles.[29]

The paper noted that in 2016, the number of electric vehicles was just 6546 vehicles of a total of 13 815 108[30] and figure 6 shows that at that time there were a number of possible projections. They ranged from a growth rate of just 12 per cent per annum to as high as 42.5 per cent per annum and indicated what the proportion of electric vehicles to total passenger vehicles might be by 2035 according to the various trends.[31]

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26 Fullarton (n 1) 38.

27 Ibid 39.

28 Ibid 41.

29 Fullarton (n1) 42. The article referred to is David Crowe, 'Electric Cars Blow Hole in Road-Building Petrol Tax Revenues' *The Australian* (Sydney), 16 August 2016. It is unclear which CSIRO report Crowe is referencing. However, the modelling in the 2016 CSIRO report considers 'a medium projection of 20 percent light duty road electric vehicle adoption by 2035, consistent with other studies which tend to focus on the next 15-20 years.' It is possible Crowe has used a 'high projection rate for journalistic impact'. Calculated at a growth rate of 19 per cent against a growth rate of 6.2 per cent for all passenger vehicles.

30 Fullarton (n1) 41.

31 Ibid 43.

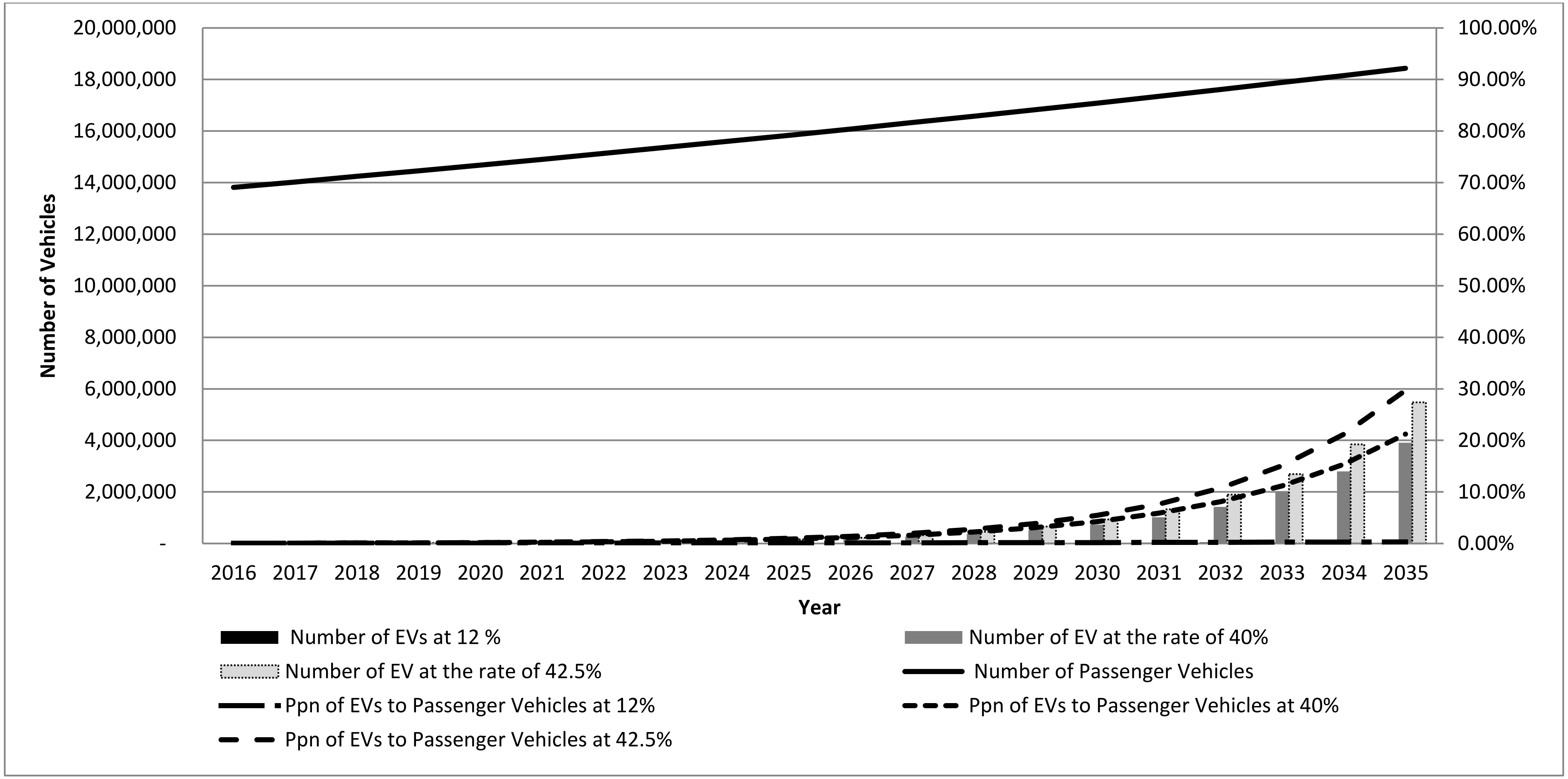

Figure 6: Possible Future Proportions of Electric Vehicles in Australia.
(Source: projected from ABS Motor Vehicle Census data 2013–16)[32]

32 This graph was compiled from ABS raw data and does not necessarily precisely match published Australian Bureau of Statistics, *Catalogue 9309.0 – Motor Vehicle Census, Australia, 31 Jan 2016*, which is a count of registered vehicles.

However further statistical data provided by the ABS in 2021 permits table 1 (which is an update of table 1 in Fullarton's 2018 paper) to be created and those projections examined further.

Year	Electric Vehicles	Passenger Vehicles	Percentage of EVs	Total Vehicles	Percentage of EVs
2013	4,167	13,000,023	0.032	20,757,657	0.020
2014	4,705	13,297,170	0.035	21,313,721	0.022
2015	5,215	13,549,450	0.038	21,785,979	0.024
2016	6,546	13,815,108	0.047	22,249,088	0.029
2017	7,774	14,078,569	0.055	22,733,051	0.034
2018	9,728	14,330,429	0.068	23,215,235	0.042
2019	8,935	14,504,151	0.061	23,625,540	0.038
2020	15,688	14,679,246	0.107	24,002,745	0.065
2021	23,128	14,850,675	0.156	24,475,128	0.094

Table 1: Growth of Electric Vehicles in Australia 2013–21. [33]

The data from table 1 are used to update the graph shown in figure 6 and create the graph in figure 7. Figure 7 provides an updated projection of the expected proportions of electric vehicles on the Australian roads to 2035.

The earlier estimates, based on data from 2016 which showed uptakes of just 12 per cent and 40 and 42.5 per cent, have been omitted from this later graph. Rather, ABS data for 2021 indicate that the uptake growth rate exceeded the rate of 42.5 per cent and instead rose to 47.4 per cent from 2020 to 2021. Therefore, the earlier possible growth rates have been omitted from this paper and only the rate of 47.4 per cent has been adopted in figure 7.

33 ABS Motor Vehicle Census data 2013–20. This table is compiled from raw ABS data and there is not necessarily a precise match with the data published by the Australian Bureau of Statistics, *Catalogue 9309.0.55.003 – Microdata: Census of Motor Vehicles, Australia, 24 July 2020* <https://www.abs.gov.au/AUSSTATS/abs@.nsf/ProductsbyCatalogue/51BEF79A03CAE65DCA257C4400190474?OpenDocument>.

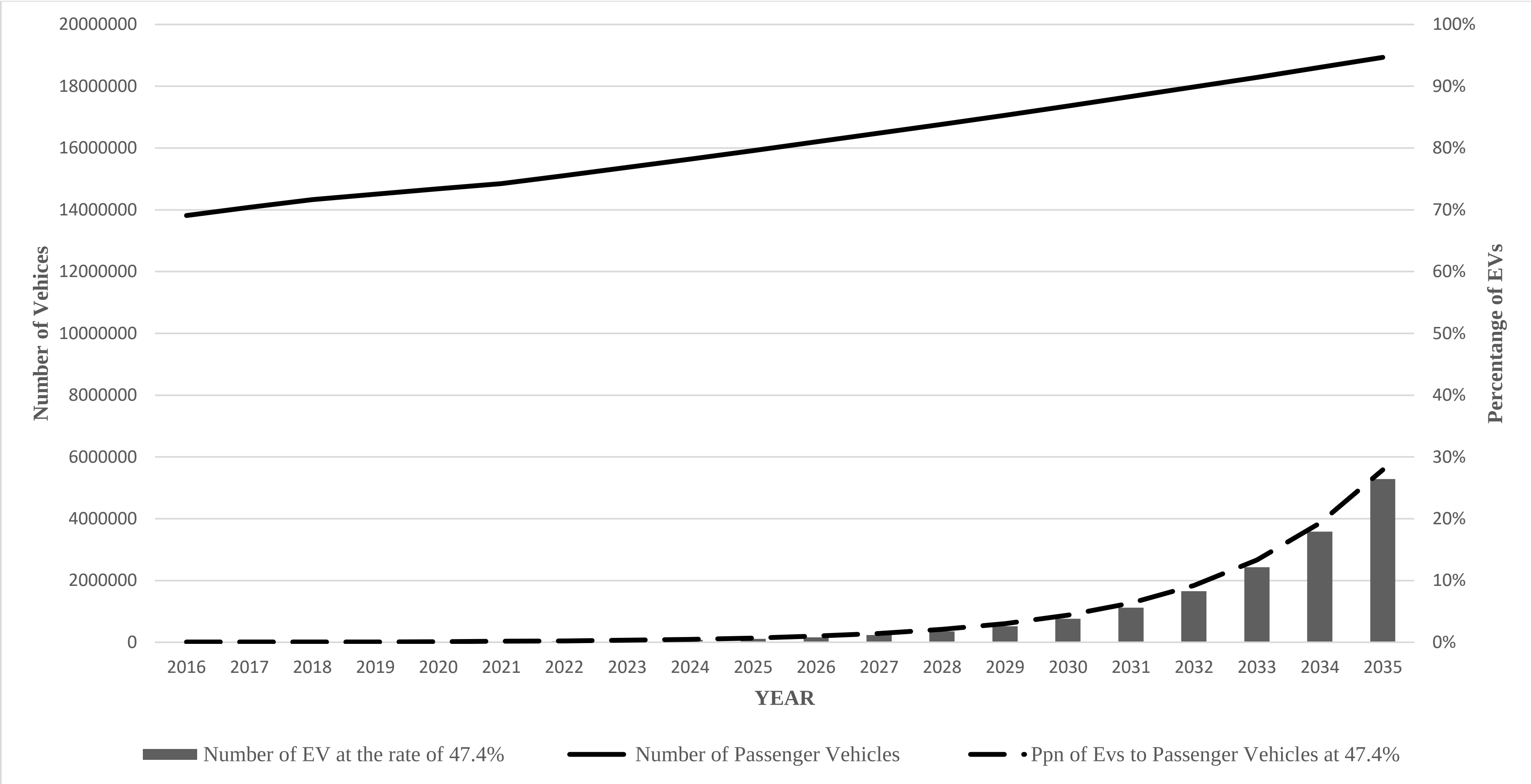

Figure 7: Possible Future Proportions of Electric Vehicles in Australia (2021 projections).
(Source: projected from ABS Motor Vehicle Census data 2013–21)[34]

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34 Ibid.

In 2018 Fullarton noted that the uptake of roof-mounted solar pv installations in the late 2000s exceeded the expectations of governments and electricity utility companies, and suggested that '[g]iven similar social and economic influences, the uptake of electric vehicles could replicate the rate of uptake of solar pv installations.'[35]

Figure 6 reproduced from the previous paper, shows the rate at which the Australian public had embraced renewable energy through the installation of solar pv systems from 2001-15. In particular, in the period 2007-11 the uptake had been a rate of 6341 per cent.[36]

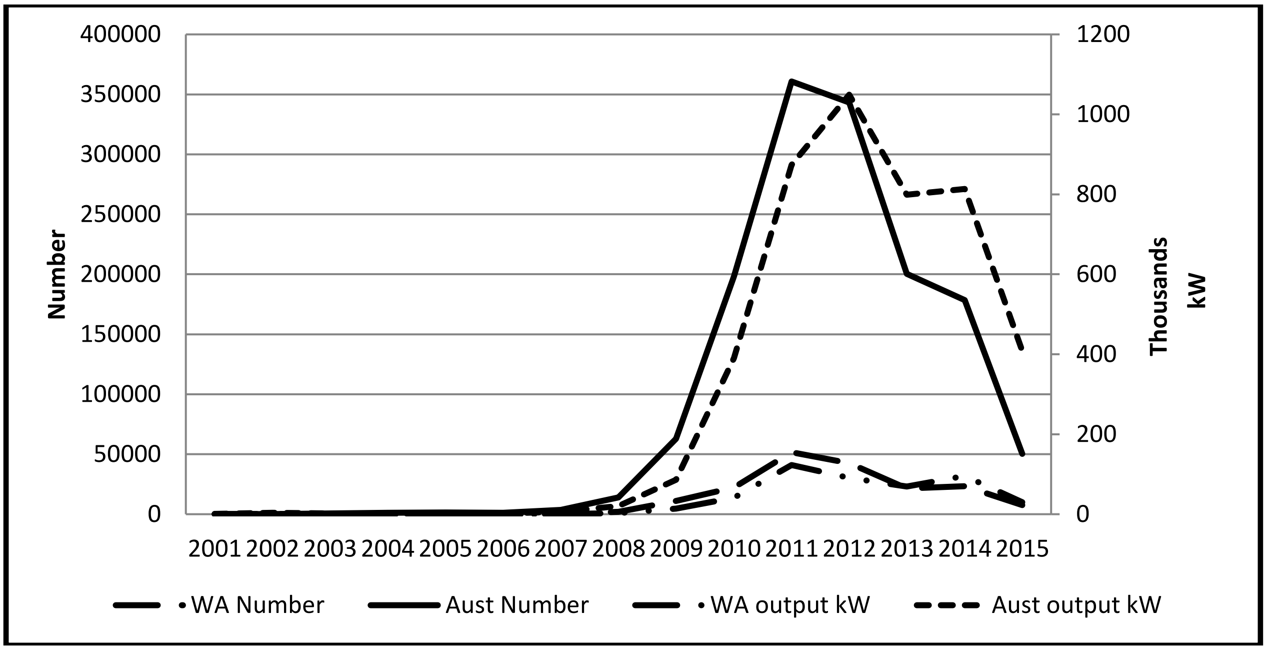

Figure 6: The number of small-scale solar photovoltaic installations by year for Western Australia and Australia: 2001–2015.
(Sources: Solex data, Australian Clean Energy Regulator, and Australian PV Institute[37])

Fullarton suggested that owners of solar photovoltaic electricity generation systems might already be aware of the benefits of self-generated renewable energy, and that charging electric vehicles from solar pv sources might be an extension of the use of renewable energy.[38]

His anticipated correlation between residential solar pv energy systems and the adoption of electric vehicles to take advantage of 'free' electricity sources does not appear to have occurred at this point in time. It is possible that the significant difference between the heavily subsidised capital cost of solar pv installations and the highly taxed cost of electric vehicles could be a factor in reducing the rate of transition to electric vehicles. That correlation is beyond the scope

35 Fullarton (n 1) 44.

36 Ibid.

37 Sources: Solex data held by Alexander Fullarton, Australian Clean Energy Regulator, and Australian PV Institute, as quoted in Alexander Robert Fullarton, *Watts in the Desert: Pioneering Solar Farming in Australia's Outback* (Ibidem Verlag, 2016) 4.

38 Fullarton (n1) 44.

of this research. However, it may influence consumer demand for electric vehicles in the future.

Detailed analysis of the correlation between the sales data provided by Mitsubishi Motors Australia Limited and the ABS statistics is beyond the scope of this research. However, it is noted that the company provided information that the total number of PHEVs sold (which was 1,660 in 2016) had risen to over 7,200 in 2021.[39] However, this is significantly different from the ABS statistics for June 2021, which reveal that only 422 Mitsubishi Outlander PHEVs are registered on the Australian roads.

There are a range of possible explanations for this. One possible explanation was illustrated in the previous paper:

> The 'plug-in hybrid electric vehicle' has been recorded as a petrol-powered vehicle. The error arises from the use of the term 'petrol/hybrid' by the motor vehicle dealer, instead of 'plug-in'. One incorrect registration in 6546 is insignificant, but it does indicate a lack of awareness of the difference between internal combustion engine-powered and electric vehicles, even by motor vehicle distributors. However, as examined later in the case study section of this paper, the clerical misunderstanding of the terminology may not give rise to significant statistical errors at this point in time.[40]

In 2016 the difference between the purchase cost of the Mitsubishi Outlander PHEV and the purchase cost of its 'standard' internal combustion engine powered variant was AUD 11,000[41] or 30 per cent. In 2021 the difference was the same, at AUD 11,000, or 29.7 per cent (as the base price had risen).[42]

In terms of total ownership cost, the additional AUD 11,000 in capital cost will be returned through savings in the avoided cost of petrol. Because of the range of ULP prices and the cost and fuel consumption differentials, the following algebraic formulae have been developed to evaluate the duration of time and the distance that are required to recover the additional capital cost between the PHEV and the equivalent ICE make and model.

km = (Capital cost difference/ULP price)/(ULP consumption difference (L/100km)*100)

and

Months = km/average monthly distance travelled

By substituting data into the formulae for the given variables, the distance required to be travelled and the duration can be estimated.

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39 Email from Tom Pitman (General Manager – Network Strategy and Operations, Mitsubishi Motors Australia Ltd) to Alexander Robert Fullarton, 2 November 2021. Note the figure does not include the 2017 statistics and that in 2018 the number was fused with the number of pure electric vehicles sold.

40 Fullarton (n 1) 41.

41 2016 Mitsubishi Outlander PHEV $47,490 and Outlander 4WD XLS $36,490. Email from Tom Pitman (General Manager – Network Strategy and Operations, Mitsubishi Motors Australia Ltd) to Alexander Robert Fullarton, 2 November 2021.

42 Ibid.

The time taken for the recovery of the additional capital cost is influenced by the difference between the purchase cost of the electric (or plug-in variant) vehicle and the purchase cost of the internal combustion engine powered make and model, the cost of ULP and the other ongoing operational costs of the vehicle. This paper recognises that there are other capital costs associated with charging the PHEV, and notes that there are reductions in other operational costs such as the cost of servicing the vehicle and tyre use compared to the ICE powered variant of the vehicle, but these are beyond the scope of this paper.

On current trends, it is almost certain that one in three passenger vehicles will be an electric vehicle by 2035. The reduction in the volume of traffic producing toxic exhaust fumes on Australian roads should be reflected in a significant reduction in GHG emissions from the transport sector.

A commensurate 30 per cent reduction in GHG emissions might not be achievable, as most electric passenger vehicles are currently at the lower end of vehicle size; heavier, less fuel efficient, vehicles will remain on Australian roadways. It is also worth noting that while expenditure on Australian roadways is unrelated,[43] net road tax revenue is therefore not expected to fall by the same 30 per cent.

43 Fullarton (n 1) 54.

Fuel Excises and Fuel Tax Credits

Table 2 shows Australia's fuel excise rates and the total annual fuel excise revenue for the period 2003–04 to 2020–21.

Year ended 30 June	Fuel Excise Rate Cents/Litre	Excise Revenue $m
2004	38.143	13,186
2005	38.143	14,245
2006	38.143	13,926
2007	38.143	14,840
2008	38.143	15,115
2009	38.143	15,544
2010	38.143	15,667
2011	38.143	16,359
2012	38.143	17,282
2013	38.143	17,736
2014	38.143	17,806
2015	38.600	17,760
2016	39.200 - 39.500	17,804
2017	40.100 - 40.300	18,371
2018	40.300 - 41.200	19,472
2019	41.200 - 41.800	19,530
2020	41.800 - 42.300	tba
2021	42.300 - 42.700	tba

Table 2: Australia's Fuel Excise Rates 2004–21.
(Sources: *Excise Tariff Amendment (Fuel Indexation) Act 2015* (Cth); [44] Australian Government *data.gov.au*[45])

There is a detailed discussion comparing fuel excises and road construction and maintenance expenditure in the previous paper,[46] and this will not be repeated in this paper. Table 2 updates the fuel excise rates to 2021.

Table 3 shows the net revenue after fuel tax credits have been refunded to certain taxpayers in the heavy transport, mining and other industries, such as agriculture, forestry and fishing, which are not considered to be road users.[47]

44 *Excise Tariff Amendment (Fuel Indexation) Act 2015* (Cth) No. 101, 2015.

45 Australian Government, *data.gov.au*, (Web Page, 25 November 2021) Australian Tax Office Taxation Statistics 2014-15 <http://data.gov.au/dataset/taxation-statistics-2014-15/resource/37b0b252-7c5a-4895-a708-db071c54d5fd?inner_span=True>.

46 Fullarton (n 1).

47 Australian Taxation Office, *Fuel Schemes/Eligible Activities (2017)* (Web Page, 25 November 2021) <https://www.ato.gov.au/business/fuel-schemes/fuel-tax-credits---business/eligibility/eligible-activities/>.

Year	Fuel Excise $m	Fuel Tax Credits $m	Net Revenue $m
2005	14,245	3,747	10,498
2006	13,926	3,814	10,112
2007	14,840	4,516	10,324
2008	15,115	4,703	10,412
2009	15,544	5,065	10,479
2010	15,667	4,994	10,673
2011	16,359	5,109	11,250
2012	17,282	5,527	11,755
2013	17,736	5,374	12,362
2014	17,806	5,706	12,100
2015	17,760	6,010	11,750
2016	17,804	6,095	11,709
2017	18,371	6,256	12,115
2018	19,472	6,796	12,676
2019	19,530	7,137	12,393
2020	19,308	7,382	11,926
2021	tba	tba	tba

Table 3: Tax Credits paid in Respect of Eligible Off-Road and Heavy Transport Activities
(data.gov.au Taxation Statistics 2017-20 Excise[48])

Table 3 reveals that fuel excises rose by 37.1 per cent during the period 2005–19, but fell slightly by 3.8 per cent in 2020. The previous paper revealed that during 2005–16 the increase was 28.44 per cent. The increased revenue is due to the removal of the cap on fuel excise in 2016, as shown in table 2.

Further, the fuel tax credits given in 2019 were 90.47 per cent higher than the credits in 2005, which should be compared to the 62.32 per cent increase in the period 2005–16. After the fuel tax credits had been given to the eligible businesses, the increase in net road revenue from this source was 18.05 per cent from 2005 to 2019; during 2005 to 2016 the increase was only 11.5 per cent. (Table 3 of the previous paper gave that figure as 15.56 per cent[49]). Given the rise in fuel tax credits to eligible off-road users and the heavy transport sector, most taxed road users continue to be drivers of passenger vehicles.

It can be noted that the gross excise collections fell from 2019 to 2020, and yet the fuel tax credits rose in the same period. It is suggested that this may be due to the travel restrictions imposed on Australian citizens during the Covid-19 pandemic, at a time when heavy transport

48 Australian Taxation Office, *Research and Statistics; Taxation Statistics (2017-18)* (Web Page 23 October 2021) < https://data.gov.au/data/dataset/taxation-statistics-2017-18>. Table 3 in this paper varies a little from table 3 in the 2018 paper as the ATO has reviewed the previous figures. Further, it appears that condensate and heavy fuels have been added to the gross excise collection figures. Those fuels are chiefly consumed in shipping and very heavy industry. This paper focuses on roadway transport, and therefore the reviews and the addition of certain types of fuels may alter the figures for the collections and credits slightly but do not influence the principal argument.

49 Fullarton (n1) 48.

continued with its freighting activities and other industries continued to function. However, the impact of the Covid-19 counter measures is beyond the scope of this paper. It is also beyond the scope of this paper to suggest whether the electrification of passenger vehicles from renewable resources will have a significant impact on reducing the GHG emissions from Australia's transport sector, as the bulk of fossil fuel consumers are not being taxed.

ATO statistics for the fiscal year 2018–19 show that the volume of petrol sold was 14,476 megalitres compared to diesel sales of nearly twice that, at 27,771 megalitres.[50] Diesel is the preferred fuel for off-road users, such as those in the mining and the fishing industries, as well as the heavy transport sector. Therefore, increasing fuel excises may reduce fossil fuel consumption in passenger vehicles, but the major polluters will have no such disincentive to seek alternative, renewable, non-polluting fuel sources.

ABS data show that the total number of motor vehicles registered in Australia rose 12.33 per cent from 16,368,383 in 2011[51] to 18,387,136 in 2016.[52] That number continued to rise, to 18,824,136 in 2020.[53] It can be seen that the rate of growth slowed from 12.33 per cent over the five years 2011–16, to just 2.38 per cent over the four years 2016–20. The impact of a reduction in the rate of growth of motor vehicles generally on Australian roadways is beyond the scope of this paper, but it is fair to observe that fewer vehicles must lead to fewer problems associated with road construction and maintenance, and fewer GHG emissions.

The following section focuses on the Mitsubishi Outlander PHEV travel and fuel consumption data derived from log books kept during the period 30 May 2016 – 31 October 2021 to establish actual fossil fuel reduction compared to its ICE variant in a rural setting in Australia.

VI MITSUBISHI OUTLANDER PHEV CASE STUDY

This section examines a case study conducted on a Mitsubishi Outlander PHEV that is owned and operated by the Solex Solar Project in Carnarvon, Western Australia. In the previous paper, the vehicle was used in a rural/urban setting for a period of 17 months from May 2016 to October 2017. This paper extends that trial to October 2021.

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50 Australian Taxation Office, *Research and Statistics; Taxation Statistics (2018-19)* (Web Page 23 October 2021) < https://data.gov.au/data/dataset/taxation-statistics-2018-19>.

51 Australian Bureau of Statistics, *9309.0 - Motor Vehicle Census, Australia, 31 Jan 2011* (Web Page 1 November 2021) <https://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/DB874793F9B4083FCA257A61001705EB?opendocument#:~:text=There%20were%2016.4%20million%20motor,million%20vehicles%20registered%20in%20Australia>.

52 Australian Bureau of Statistics, *9309.0 - Motor Vehicle Census, Australia, 31 Jan 2016* (Web Page, 21 July 2016) <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/9309.031%20Jan%202016?OpenDocument>.

53 Australian Bureau of Statistics, *9309.0 - Motor Vehicle Census, Australia, 31 Jan 2020* (Web Page, 2020) <https://www.abs.gov.au/statistics/industry/tourism-and-transport/motor-vehicle-census-australia/latest-release#data-download>. Note that the 2020 census figures for non-freight carrying vehicles was unavailable in April 2021. The figure of 25,000 was extrapolated from previous data for 2015 and 2019 and projected forward to 2020.

As before, the main focus of this paper is the negative impact of fuel excise on the transition to electric vehicles, and therefore examination of other taxes such as goods and services tax and licence fees those taxes are outside the scope of this paper and will not be examined further in this paper.

For clarity the focus of the study is repeated from the previous paper.

> The Outlander is garaged in Carnarvon Western Australia. It is primarily used for travel within the small town for round trips of less than 20km. Its fuel source, while in Carnarvon, is exclusively electricity sourced from renewable energy generated by the Solex Solar Farm. It is energised by way of a 15-amp general purpose outlet to a 240-volt AC supply. The vehicle is charged during daylight hours when not in use. The supply is metered. However, no data of charging times has been kept.[54]

As in the previous case study, long-range trips of around 1000km were conducted in roughly three-month periods, but fewer trips took place in 2020–21 because of the Covid-19 measures implemented in the Perth metropolitan area

The previous research data is updated to extend the period under review from 30 May 2016 to 1 November 2017 to 31 October 2021. Appendix A shows that during the period 30 May 2016 to 31 October 2021 the vehicle travelled 78,462 km (48,754 miles) and consumed 3880.84L (853.67Imp gal) of unleaded petrol. Those data show an average fuel consumption of just 4.95L/100km (57.07mpg Imp) (previously 5.56L/100km or 50.81mpg Imp).

In addition to the unleaded petrol consumed, the vehicle also consumed 4476kWh of electricity. By applying an estimate of 330ml of petroleum to produce 1kWh of dispatchable electricity,[55] as applied in the previous paper, an additional 1477.08L (324.91 Imp gal) of unleaded petrol has been displaced. The total fuel consumption, including the electric charge in equivalent unleaded petrol, is now 5357.92L (1178.58 Imp gal) which produces an average fuel consumption, including the electric charge, of 6.83L/100km (41.36 mpg Imp). For comparison, the previous data from 30 May 2016 to 1 November calculated that the fuel consumption including the electric charge was 7.52L/100km (37.56 mpg Imp).

A detailed log of trips is shown in Appendix A. The log shows that ULP consumption varies considerably. It is as low as from 0.76L/100km (371.68 mpg Imp) on 31 August 2021 for local running in Carnarvon when constantly within battery capacity range and regularly charged with electricity, to 13.76L/100km (20.53mpg Imp) for a trip from Carnarvon to Perth against strong to moderate winds in July 2020.[56]

As in the previous paper

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54 Fullarton (n1) 50.

55 Santiago Arnalich, *Epanet and Development: How to Calculate Water Networks by Computer* (Arnalich, Water and Habitat, Spain 2011) 153. Arnalich uses diesel to establish a calculation of 300ml/kWh. This calculation has been made on the basis that motor petroleum is 88 per cent of the energy contained in diesel. This paper uses the schedule in Part 3 of the National Greenhouse and Energy Reporting (Measurement) Determination 2008 made under subsection 10(3) of the *National Greenhouse and Energy Reporting Act 2007* to support the calculation used here.

56 It is noted that the log reveals considerable higher ULP consumptions but these are anomalies caused by not filling the ULP fuel tank to capacity. When the fuel tank is eventually filled completely the consumption figures become distorted.

> It was noted that wind resistance has considerable influence on the fuel consumption rates of the Mitsubishi Outlander PHEV. When located in Carnarvon, the vehicle is charged regularly with electricity, and therefore uses very little unleaded petrol. All of the electricity is sourced from solar pv renewable sources generated from the Solex solar farm. The manufacturer has advertised fuel consumption rates of as low as 1.7L/100km (166mpg Imp).[57]

Galvin's research findings and comparative ICE vehicle fuel consumptions were examined in detail in the previous paper and are not examined further in this paper.[58] It was concluded that Galvin's 'findings are consistent with the principles of physics of work, power and energy.[59] It is simple physics that the energy required to carry out the movement of a certain mass, over a certain distance, within a certain time, will always be the same no matter what the energy source is.'[60]

The manufacturer's publications, which disclose a fuel consumption rate of around 2L/100km, do not appear to take the fossil fuel equivalent for the generation of the electrical charge of around 24kWh/100km into consideration. Therefore, for the purpose of this analysis the fossil fuel equivalent of the consumption will also be ignored and the focus is solely on ULP consumption.

The data in this case study research can be applied to the formulae given in the previous section: the additional capital cost is AUD 10,524; the ULP difference is 2.25L/100km; the ULP price is AUD 1.759; and the average monthly distance travelled is 1,200km.

The distance required to recover the additional capital cost by way of ULP displaced by electricity is:[61]

km = ((AUD 10,524/AUD 1.759)/(2.25L/100km))*100

= (5,982.945/2.25)*100

= 2,659.086*100

= 265,908km

Months = 265,908km/1,200km

= 221 months or 18 years and 5 months

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57 Fullarton (n1) 50.

58 Ibid 51-3.

59 Stanley Leonard Martin and Andrew Kenneth Connor, *Basic Physics 1* (Whitcombe and Tombs Pty Ltd, 1968) 64-76.

60 Fullarton (n1) 53.

61 Note: in this case the electricity used for on board generation is sourced from the Solex Solar Farm and is deemed to be a free renewable resource, ignoring the capital cost of the solar farm and the opportunity cost of 'internal consumption' rather than the sale of electricity to the state utility.

Therefore, using data from this case study, it is estimated that the additional capital cost might be recovered through the avoided fuel costs over as much as 265,908km or just short of 20 years.[62]

On the other hand, if the PHEV were to be entirely used as an EV and no ULP were consumed then the entire 6.83L/100km would be avoided and the capital cost recovered in just over 70 months (assuming that the electricity was 'free' electricity sourced entirely from a solar pv installation and ignoring the capital cost of the installation).

km = ((AUD 10,524/AUD 1.759)/(6.83L/100km))*100

= (5,982.945/6.83)*100

= 875.980*100

= 87,598km

Months = 87,598km/1,200km

= 73 months or 6 years and 1 month

Case Study Conclusion

The previous paper focussed on road tax revenue and the opportunity cost of lost tax revenue caused by the transition to electric vehicles in Australia. This extension of the case study research has focused on the unleaded petrol savings and therefore reduction in GHG emissions caused from a transition to electric vehicles in Australia.

It finds that by using the Mitsubishi PHEV in the role of an EV, by constant charging from solar pv electricity sources considerable fiscal savings in avoided unleaded petrol costs can be achieved. The less the vehicle is used for long distance journeys the greater the fiscal savings. It notes there is a greater capital cost of the PHEV version over the comparable ICE version but that cost could be recovered in as short as six years or up to nearly 19 years if used in a remote location such as Carnarvon Western Australia. That cost recovery period remains within the expected effective lifespan of the vehicle.

Therefore, while the PHEV may cost more in capital cost operational savings will eventually cover that higher capital cost. There is an overall fiscal benefit in transitioning to a PHEV in remote Australia.

The capacity to generate electricity from an 'on board generation system' permits the vehicle to operate and have the same range as its comparative ICE version. The higher unleaded fuel costs rise in remote Australia and the more often the vehicle is used in an urban environment, compared to highway travel the shorter the cost recovery period.

62 The estimate is based on a ULP fuel saving of 2.25L/100km being the manufacturers estimate shown in table 5 and average consumption shown by the data in Appendix A. (7.2L/100km and 4.95L/100km). The price used in the median price for Carnarvon Western Australia on 30 October 2021 (175.9c/L). Petrol Spy Australia, https://petrolspy.com.au/map/latlng/-24.872274736615623/113.68456647526159.

VII CONCLUSION

The previous conclusion that '[i]n the modern world, where the reduction of greenhouse gas emissions from burning fossil fuel is viewed as a pressing environmental concern, the subsidisation of fossil fuels appears incongruous with society's goals'[63] remains the focus of this paper. However, this paper further contributes to the previous paper in that it finds that the transport sector contributes nearly one fifth of Australia's total atmospheric pollution emissions, and that transitioning to EVs and PHEVs could have a significant effect on reducing the nation's GHG emissions and its contribution to global climate change. This further examination of recent data from the ABS and ATO provides a clearer indication that the proportion of electric vehicles on Australian roadways will escalate to a level that may have a significant impact on reducing GHG emissions by 2035.

Previously ABS data indicated that the proportion electric vehicles to all passenger vehicles was less than one half of one per cent at the end of the 2016 calendar year. However, that figure rose to nearly one per cent by 2021. This indicates that electric vehicles might constitute nearly 30 per cent of Australia's entire national fleet of passenger vehicles by 2035 if the same rate of uptake experienced in 2020 and 2021 is continued in future years.

Examination of the ATO data in the previous paper, as updated in this paper, reveals that the reduction in fuel excise revenue caused by the transition to electric vehicles will be irrelevant to national road revenue collections. This paper re-iterates that the federal government removed the hypothecation of fuel excises to roadway construction and maintenance in 1959, and those assertions that the transition to non-petroleum-based passenger vehicles will have a severely negative impact on expenditure on Australian roads are not true. This paper has found no further evidence to refute that finding.

This updated study continues to illustrate that

> The case study has proved that the 'hybridisation', of an internal combustion engine powered by an on-board generation system with an external electrical charging capability, works effectively and efficiently. The vehicle performs a dual role – it is an electric vehicle in an urban setting and an internal combustion engine powered vehicle for the purposes of long-distance travel.[64]

VIII RESEARCH LIMITATIONS

This research is limited to Australian legislation applicable to fuel excises levied on petroleum products used in the road transport industry. There are many other jurisdictions and enterprises that have not been examined, and the findings of this research should not be applied directly to other jurisdictions or economies.

Government-sponsored incentives and other influencing factors that may encourage the uptake of electric vehicles by Australian motor vehicle owners have not been considered in this research. While the cost of displaced unleaded petrol has been examined, the range of other costs of operating a motor vehicle, such as insurance, registration, servicing, tyres and the replacement of the PHEV's main drive battery, have not been considered, and nor have the

63 Fullarton (n1) 54.

64 Ibid.

social and environmental benefits been evaluated or reduced to monetary values. Therefore, the overall impact of those social, economic and environmental drivers on the uptake of electric vehicles is not investigated or estimated in this paper.

The case study is limited to a rural/urban environment in a remote hamlet some 900 km distant from Western Australia's capital city. Several long-distance journeys have been included in the fuel consumption data collated over 65 months and 78,462km. While the data portray a blend of urban and long-distance travel reasonably well, the use of the vehicle is far from being typical of average urban use, either in Western Australia or in any other urban environment.

In its current use pattern, the Mitsubishi Outlander PHEV can be readily recharged from renewable energy sources, and the short trips it makes are less than 25km. An urban commuter is likely to make far longer journeys. When the vehicle makes long-distance journeys, the distances are greater than 500km. A vehicle located in a city is unlikely to make such journeys on a regular basis.

A comparative cost of maintenance between a PHEV and a comparative ICE-powered vehicle has not been attempted. It is noted that the costs will vary widely from state to state, from manufacturer to manufacturer and from nation to nation. The costs of unleaded petrol, licensing and insurance and the source and supply costs of electricity will also vary considerably.

This case study has only indicated how costings could be carried out, not what the actual costs could be. That area could form the focus of future research. Suggestions for further research, which has been noted as beyond the scope of this research, are made in the following section.

IX SUGGESTIONS FOR FURTHER RESEARCH

This section considers some of the areas of research that have been identified as being beyond the scope of this paper. These could be investigated to develop a broader understanding of the impact of changing technology on the manner in which passenger vehicles are used and powered.

- The social and environmental impacts or benefits of transitioning away from internal combustion engines to vehicles powered by electric motors are beyond the scope of this paper. A study could include a detailed scrutiny of Australia's GHG emission reduction policies in the transport sector, to identify Australia's role and conduct in reducing global GHG emissions.

- An investigation could be conducted into the contribution of GHG emissions from the transport sector towards air pollution, and therefore the influence of this sector on the causes of the respiratory disease known as Covid-19 pandemic. It is possible that GHG emissions could contribute to a progressively polluted atmosphere.

- A detailed study of Australia's road networks could be conducted to provide an understanding of the vast distances between population centres and the unique challenges faced by the Australia population in reducing GHG emissions from transport.

- An analysis could be conducted of the impact of the disparity between the capital cost of an electric vehicle and that of the alternative internal combustion engine powered version of that vehicle make and model, to assess the economic impact of the capital cost on the total ownership cost of the vehicle. That analysis could attempt to predict the time it would take to recover that difference in the capital cost in terms of the reduced total operating costs over the effective lifespan of the vehicle.

- An investigation could be conducted as to a possible correlation between residential solar pv energy systems and the adoption of electric vehicles to take advantage of the ‘free’ electricity generated by solar pv installations.

- Other capital costs associated with charging a PHEV and the reductions in other operational costs such as the cost of servicing the vehicle and tyre use compared to the ICE powered variant of the vehicle could be considered, to contribute to a better understanding of the total ownership cost of EVs and PHEVs over the lifespan of the vehicles.

- This paper focuses on the impact of the rise in the proportion of electric vehicles on Australian roads. A study of the impact of a reduction in the overall rate of growth of motor vehicles generally on Australian roadways could support or refute the observation that fewer vehicles must lead to fewer problems associated with road construction and maintenance and fewer GHG emissions from the transport sector, in Australia and the other nations of the world.

- It is suggested that the terminology and definitions used by different organisations and manufacturers may be leading to inaccurate statistical conclusions. In turn, these inaccuracies could lead to faulty decision-making processes.

  In this research it has been noted that a PHEV can be used to mean a ‘petrol hybrid electric vehicle’, which derives its energy solely from fossil fuels (ULP or diesel), or a ‘plug-in hybrid electric vehicle’. In this case study the energy for roughly half of the PHEV’s travel came from electricity sourced from a solar pv installation, and the balance from an ICE (an on-board ULP-fuelled generation system).

  The case study found that the Mitsubishi Outlander PHEV has been classified by the licensing authority as a petrol-fuelled vehicle or ICE. In fact, it is not.[65] This may only apply to one vehicle, but the ABS data for the state of Western Australia for 2017 stated that there were no Mitsubishi Outlander PHEVs registered in that state. A misunderstanding of initials and terminology has resulted in an erroneous statistical analysis, on which governments and other decision-makers rely.

  An investigation into the correlation between the sales data provided by motor manufacturing agencies and dealerships, the data of licensing and registration authorities and the data provided by the ABS could be conducted to reconcile the statistics produced by each organisation.

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65 It should be noted that the Mitsubishi Outlander PHEV used in this case study is clearly marked with the badge **Plug-in Hybrid EV**. All the documentation and service booklets are also titled **Plug-in Hybrid EV**.

- A suggestion for further research made in the previous paper, but not covered in this research update, is an investigation into the introduction of electric vehicles in the workplace for the purpose of employees commuting from their residences to places of work.

  It was suggested that employers could provide electric vehicle charging facilities powered from renewable energy sources. Employers could install roof mounted solar pv systems and provide employees with free, or heavily subsidised, electricity. Employees would benefit from a reduction in the costs of commuting to and from the workplace, and there would be environmental benefits from reduced greenhouse gas emissions. The economic savings of the reduced fuel costs could be shared between the employer and the employees.

Finally, the introduction of electric vehicles enables a transition to renewable energy sources for the road transport sector to develop readily. This transition is strongly recommended by this paper.

Appendix A

ULP Consumption					
Date	Distance	Odometer	ULP	ULP Consumption - L/100km	Highway Use (km)
30/05/2016	0				
2/06/2016	1088	1088	77.68	7.14	890
4/09/2016	1449	2537	23.32	1.61	
23/09/2016	725	3262	7.00	0.97	
23/09/2016	57	3319	32.65	57.28	
14/10/2016	1459	4778	145.38	9.96	1780
14/10/2016	1088	5866	35.61	3.27	
16/10/2016	225	6091	50.81	22.58	
28/10/2016	494	6585	13.34	2.70	
16/11/2016	1012	7597	27.01	2.67	
17/11/2016	476	8073	32.08	6.74	
17/11/2016	429	8502	45.21	10.54	1780
19/11/2016	168	8670	13.80	8.21	
19/11/2016	492	9162	33.27	6.76	
19/12/2016	939	10101	34.00	3.62	950
19/12/2016	377	10478	34.43	9.13	
23/01/2017	1096	11574	44.35	4.05	
25/01/2017	536	12110	44.15	8.24	950
20/03/2017	1018	13128	44.35	4.36	
20/03/2017	463	13591	44.57	9.63	1780
21/03/2017	480	14071	38.77	8.08	
23/03/2017	697	14768	44.58	6.40	
26/03/2017	549	15317	41.38	7.54	
29/04/2017	921	16238	38.06	4.13	
30/04/2017	542	16780	37.23	6.87	950
24/06/2017	1296	18076	36.55	2.82	
1/07/2017	380	18456	10.48	2.76	950
12/07/2017	230	18686	44.16	19.20	
25/07/2017	973	19659	47.04	4.83	
25/07/2017	524	20183	10.00	1.91	
26/07/2017	195	20378	46.41	23.80	1280
27/07/2017	502	20880	10.01	1.99	
14/09/2017	837	21717	41.23	4.93	
15/09/2017	479	22196	35.36	7.38	950
4/10/2017	905	23101	30.00	3.31	
1/11/2017	875	23976	21.43	2.45	950
12/11/2017	484	24460	27.01	5.58	
13/11/2017	255	24715	23.01	9.02	950

10/01/2018	1303	26018	34.51	2.65	
15/01/2018	305	26323	17.61	5.77	
15/01/2018	240	26563	20.01	8.34	
20/01/2018	430	26993	34.27	7.97	1780
	409	27402	31.00	7.58	
	217	27619	14.10	6.50	
7/03/2018	983	28602	25.52	2.60	
	247	28849	7.00	2.83	
8/03/2018	249	29098	33.37	13.40	950
	238	29336	10.00	4.20	
25/03/2018	678	30014	15.01	2.21	
29/04/2018	770	30784	26.86	3.49	
30/04/2018	283	31067	18.80	6.64	
	270	31337	24.02	8.90	
4/05/2018	633	31970	15.17	2.40	
5/05/2018	460	32430	34.27	7.45	1780
	233	32663	6.85	2.94	
9/06/2018	748	33411	36.33	4.86	
10/06/2018	207	33618	9.48	4.58	
	275	33893	27.29	9.92	
	411	34304	35.02	8.52	
12/06/2018	124	34428	3.00	2.42	
	442	34870	35.90	8.12	
13/06/2018	281	35151	7.99	2.84	
28/07/2018	1122	36273	12.00	1.07	
25/10/2018	1500	37773	28.00	1.87	
	249	38022	20.01	8.04	
26/10/2018	250	38272	22.40	8.96	950
	232	38504	17.18	7.41	
23/11/2018	725	39229	21.54	2.97	
6/01/2019	915	40144	27.03	2.95	
7/01/2019	264	40408	20.88	7.91	
	235	40643	19.35	8.23	
	439	41082	35.22	8.02	
19/01/2019	321	41403	25.05	7.80	1780
20/01/2019	432	41835	35.74	8.27	
	262	42097	23.04	8.79	
12/02/2019	789	42886	15.00	1.90	
	129	43015	29.49	22.86	
	231	43246	19.73	8.54	
	246	43492	17.93	7.29	
5/05/2019	1484	44976	28.00	1.89	
	134	45110	7.80	5.82	
	227	45337	5.00	2.20	

	163	45500	6.00	3.68	
	109	45609	33.61	30.83	
6/05/2019	244	45853	21.29	8.73	
7/05/2019	401	46254	25.72	6.41	
	389	46643	10.00	2.57	1734
16/05/2019	247	46890	13.17	5.33	
26/07/2019	1285	48175	28.00	2.18	
	242	48417	19.23	7.95	
27/07/2019	259	48676	21.79	8.41	950
	218	48894	15.81	7.25	
3/11/2019	1806	50700	15.59	0.86	
5/11/2019	276	50976	19.26	6.98	
6/11/2019	255	51231	21.16	8.30	
	423	51654	34.04	8.05	
9/11/2019	229	51883	15.90	6.94	
	416	52299	33.00	7.93	1780
10/11/2019	235	52534	19.00	8.09	
7/01/2020	933	53467	24.65	2.64	
8/01/2020	259	53726	20.27	7.83	
9/01/2020	251	53977	24.00	9.56	950
	233	54210	15.01	6.44	
5/03/2020	1137	55347	22.00	1.93	
	241	55588	18.83	7.81	
6/03/2020	252	55840	22.00	8.73	950
	479	56319	11.00	2.30	
20/05/2020	1321	57640	16.42	1.24	
16/07/2020	1021	58661	16.40	1.61	
	242	58903	23.06	9.53	
	297	59200	8.07	2.72	
18/07/2020	218	59418	30.00	13.76	1340
	384	59802	28.01	7.29	
10/09/2020	1250	61052	38.01	3.04	
11/09/2020	303	61355	22.00	7.26	950
	180	61535	13.02	7.23	
13/11/2020	1127	62662	26.11	2.32	
14/11/2020	157	62819	18.00	11.46	
15/11/2020	505	63324	31.00	6.14	
21/11/2020	491	63815	26.00	5.30	
22/11/2020	409	64224	30.00	7.33	1780
	242	64466	20.00	8.26	
3/12/2020	435	64901	20.00	4.60	
29/01/2021	1141	66042	32.24	2.83	
30/01/2021	247	66289	18.00	7.29	
31/01/2021	617	66906	31.00	5.02	

1/02/2021	424	67330	31.00	7.31	950
3/02/2021	278	67608	22.00	7.91	
21/02/2021	556	68164	19.00	3.42	
22/02/2021	249	68413	21.00	8.43	
23/02/2021	265	68678	21.00	7.92	
23/02/2021	231	68909	20.00	8.66	950
12/03/2021	436	69345	24.00	5.50	
13/03/2021	372	69717	31.00	8.33	
14/03/2021	314	70031	28.00	8.92	
17/03/2021	394	70425	21.00	5.33	
18/03/2021	260	70685	32.00	12.31	700
18/03/2021	216	70901	18.00	8.33	
29/04/2021	755	71656	23.75	3.15	
29/04/2021	246	71902	19.00	7.72	
30/04/2021	311	72213	23.59	7.59	950
2/05/2021	427	72640	34.27	8.03	
30/05/2021	414	73054	0.00	0.00	0
3/06/2021	288	73342	23.05	8.00	
4/06/2021	249	73591	19.10	7.67	
4/06/2021	357	73948	10.00	2.80	950
29/06/2021	407	74355	10.00	2.46	
6/08/2021	810	75165	34.00	4.20	
8/08/2021	253	75418	12.00	4.74	
9/08/2021	242	75660	23.00	9.50	
9/08/2021	256	75916	20.00	7.81	
14/08/2021	537	76453	17.00	3.17	
14/08/2021	27	76480	21.00	77.78	
15/08/2021	272	76752	20.00	7.35	1780
31/08/2021	777	77529	5.92	0.76	
31/10/2021	918	78462	0.00	0.00	
Total	**78462**		**3880.84**	**4.95**	38114

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