e-brief

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Electric vehicles in NSW

by Tom Gotsis

1. Introduction

Electric vehicles (EVs) offer the promise of inexpensive and environmentally friendly driving. Despite the allure of this promise, sales of EVs in Australia fell by 23% in 2016 to 1,369 vehicles, or 0.1% of domestic market share.[1] In contrast, international sales of EVs grew by 40% in 2016 to 750,000 vehicles, reaching 1.1% of global market share.[2]

A major underlying cause of the disparity between Australian and overseas EV sales is public policy, rather than consumer sentiment. In the absence of policies in Australia and NSW that actively encourage the uptake of EVs, Australian consumers face higher purchase costs and limited charging infrastructure.[3] In contrast, the growth in EV sales in countries with robust EV policies demonstrates that such consumer concerns can be overcome. The United Kingdom, which announced it will ban the sale of petrol and diesel vehicles from 2040,[4] is notable in this regard. It has established an Office for Low Emission Vehicles and introduced incentives to facilitate EV uptake, such as tax exemptions and parking privileges.[5] Moreover, the *Automated and Electric Vehicles Bill 2017 (UK)* seeks to encourage EV use by regulating for a comprehensive network of EV charging points.[6]

It is in this context that this e-brief discusses the potential benefits of EVs; the main concerns relating to their manufacture and use; global EV policies and sales; the relationship between EV policy and energy policy; and recent developments in Queensland and Victoria.

2. What is an "electric vehicle"?

A conventional motor vehicles uses an internal combustion engine that burns fossil fuels to drive its wheels. In contrast, an EV uses electric motors to drive its wheels.[7] Those electric motors require a supply of electricity in order to operate. As set out in Table 1, that requirement has led to the development of three distinct EV technologies:

- Battery-Electric Vehicles (BEVs), which are charged exclusively from the electricity network.
- Plug-in Hybrid Vehicles (PHEVs), which are charged from the electricity network and/or an internal combustion engine.

- Fuel Cell Vehicles (FCEVs), which convert liquid hydrogen into electricity within their fuel cells.[8]

There is some debate as to whether Hybrid Electric Vehicles (HEVs), such as the Toyota Prius, should be categorised as EVs. In accordance with the approach of the Australian Electric Vehicle Council and the International Energy Agency,[9] this e-brief excludes HEVs from the definition of EV on the basis that HEVs cannot be plugged into the electricity network. The key differences between BEVs, PHEVs and FCEVs are set out in Table 1.

Table 1: Key differences between EV types[10]

	Battery EVs (BEVs)	Plug-in Hybrid EVs (PHEVs)	Fuel Cell EVs (FCEVs)
Powered by	Electricity	Electricity and/or fossil fuels	Electricity
Power source	Electricity network	Electricity network and/or internal combustion engine	Liquid hydrogen
Power storage	Batteries	Batteries and fuel tank	Batteries and fuel tank
Driving mode	Electric	Electric and/or internal combustion	Electric
Noise pollution	Low	Electric mode: Low Overall: Yes	Low
Tailpipe air pollution	None	Electric mode: None Overall: Less	None
Greenhouse gases	None	Electric mode: None Overall: Less	None

3. Potential benefits

The potential benefits of EVs include: reduced tailpipe air pollution; reduced greenhouse gas emissions; reduced road traffic noise; reduced driving costs; and increases in economic growth and national fuel security. Each of these benefits is discussed in turn below.

3.1 Reduced air pollution

Air pollution is associated with stroke, heart disease, lung cancer and respiratory diseases, including asthma.[11] Globally, outdoor air pollution causes an estimated 3.5 million premature deaths each year.[12] In OECD countries, an estimated 50% of the economic costs of air pollution-related death and ill-health is due to air pollution from motor vehicles.[13] Air pollution is a major concern underlying the development of EV policies in many nations; most notably the United Kingdom (where air pollution is regarded as being the “largest environmental risk to public health”[14]) and China.[15]

Australia’s major cities enjoy good air quality.[16] For instance, Sydney’s air quality was rated as being “very good” or “good” for 70–85% of days between 2012 and 2016.[17] Nevertheless, the scientific evidence “no longer supports the notion that there is a safe level for pollutant concentrations”.[18] Existing air pollution levels are also at risk of being increased by population growth and urbanisation, and increases in energy and transportation usage.[19] It has been estimated that 3,000 deaths (or 28,000 years of lost life) across Australia are attributable to the impact of urban air pollution each year.[20] The health costs of air pollution-related mortality in Australia are estimated to be between $11–24 billion per year.[21]

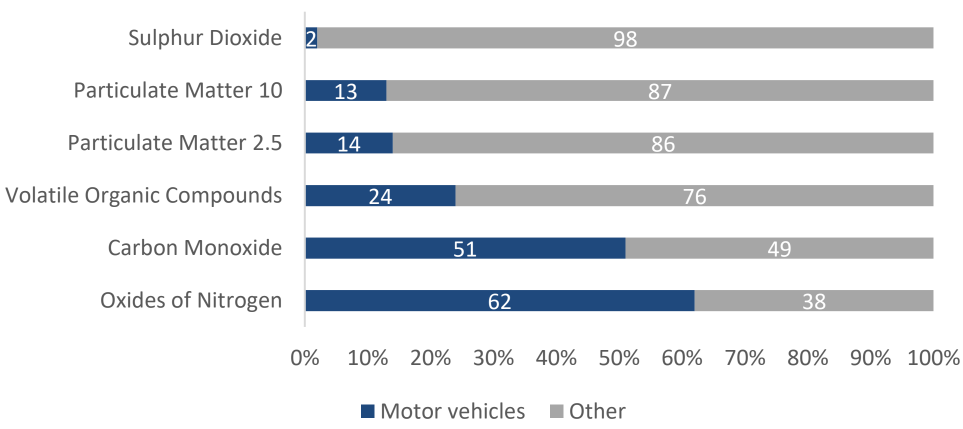
Table 2 provides an overview of the two types of air pollution produced by motor vehicles:

Table 2: Types of air pollution produced by motor vehicles

Pollution type	Definition
Tailpipe	Substances emitted from a vehicle’s tailpipe, including carbon monoxide, nitrogen oxides, sulphur dioxide, volatile organic compounds and particulate matter.[22]
Non-tailpipe	Particulate matter generated from the gradual wear of tyres, brakes and road surfaces.[23]

EVs can reduce or eliminate tailpipe air pollution.[24] As detailed in Table 1, BEVs and FCEVs produce no tailpipe air pollution. PHEVs also produce no tailpipe air pollution when driven in electric mode and comparatively less tailpipe air pollution overall. In contrast, as detailed in Figure 1, it is estimated that in 2008 Sydney’s conventional motor vehicles contributed 51% of all carbon monoxide air pollution, 62% of all nitrogen oxide air pollution, and 24% of all volatile organic compound air pollution.[25]

Figure 1: Estimated annual contribution of conventional motor vehicles to air pollution, Sydney, 2008[26]

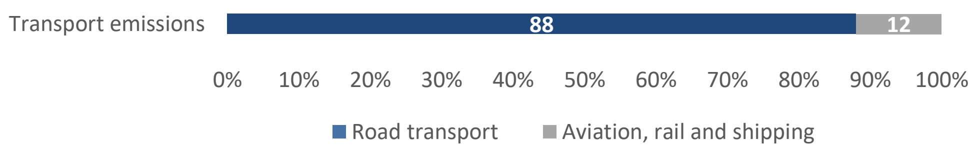


3.2 Reduced greenhouse gas emissions

Greenhouse gases include carbon dioxide, methane, nitrous oxide and synthetic greenhouse gases.[27] The principal greenhouse gas emitted by motor vehicles is carbon dioxide.[28] Increases in the atmospheric concentration of greenhouse gases over the past 250 years has "resulted in significant increases in positive radiative forcing, which has a warming effect on the climate".[29] In its *Climate Change Policy Framework* the NSW Government stated that it endorses the United Nations Paris Agreement on Climate Change and aspires to achieve net-zero greenhouse gas emissions by 2050.[30]

Transport accounted for 20% of NSW's total greenhouse gas emissions in 2013–14 (26 of 130.2 million tonnes CO_{2e}), making it the second largest source of greenhouse gas emissions.[31] As set out in Figure 2, in 2013–14 road transport accounted for 88% (23 million tonnes CO_{2e}) of NSW's transport greenhouse gas emissions.[32]

Figure 2: NSW transport greenhouse gas emissions, 2013–14[33]



As detailed in Table 1, BEVs and FCEVs produce zero greenhouse gas emissions and PHEVs produce less greenhouse gas emissions than conventional vehicles. Accordingly, as stated in Dr Alan Finkel's *Independent Review into the Future Security of the National Electricity Market*:

> … the right mix of incentives for the uptake of electric vehicles along with a decarbonised electricity grid could help to achieve significant emissions reductions.[34]

3.3 Reduced traffic noise

Traffic noise is a combination of noise emanating from engines, tyres, road surfaces and wind resistance.[35] A key determinant of traffic noise in NSW is the number of motor vehicles using the State's roads. Since the 1960s there has been an increase in the number of motor vehicles in NSW: from 246 vehicles per 1,000 people in 1960 to 634 vehicles per 1,000 people in 2007;[36] and from 5.3 million registered motor vehicles in June 2009[37] to 6.5 million registered motor vehicles in December 2017.[38]

The *NSW Road Noise Policy* states that road traffic noise has increased throughout NSW and is a "major issue affecting neighbourhood amenity".[39] Discussing the potential health effects of road traffic noise, the *NSW Road Noise Policy* states:

> … the shorter-term health effects of sleep disturbance due to excessive noise exposure can affect quality of life during the subsequent waking hours. Symptoms include fatigue, moodiness, irritability, headaches, stomach upsets, lack of concentration and reduced work ability. … Longer-term effects on health are more difficult to quantify, although tentative links have been drawn between noise exposure and heart rate, immune response, hypertension, blood pressure, occurrence of ischaemic heart disease,

> cardiovascular disease and myocardial infarction. The above links are often difficult to identify and quantify due to the presence of other environmental and lifestyle factors.
>
> There is also evidence that noise has an effect on child cognition … Children exposed to high levels of environmental noise may display sustained … attention deficits, difficulty concentrating, reduced auditory discrimination and speech perception, poorer memory, and reduced reading ability and school performance on national standardised tests.[40]

EVs at slower speeds are virtually silent, as they have no internal combustion engine and the only noise emitted from their electric motors is a barely perceptible high-pitched frequency.[41] EVs do produce noise from wind resistance and tyre–road contact, but this noise only becomes perceptible at higher speeds.[42]

3.4 Fuel savings

EVs offer potential fuel savings because, as set out in Table 3, it generally costs less to charge an EV from the electricity network than it does to refuel a conventional vehicle. However, the ability of EVs to provide fuel savings is dependent on the relative difference between the price of petrol and diesel and the price of electricity. This is illustrated in Table 3, which increases the price of electricity while holding constant the price of petrol and diesel (and other factors). The increase in electricity prices across the low, medium and high price scenarios shown in Table 3 more than halved the potential fuel savings offered by EVs.

Table 3: Potential fuel savings

Electricity price scenarios:	**Low**	**Medium**	**High**
Petrol/diesel cents per litre	129.5[43]	129.5	129.5
Litres per 100km	10.6[44]	10.6	10.6
Conventional vehicle $ per 100km	**13.72**	**13.72**	**13.72**
kWh price ($)[45]	0.15	0.35	0.5
kWhs per 100km	18[46]	18	18
EV $ per 100km	**2.7**	**6.3**	**9**
EV fuel savings $ per 100km	**11.02**	**7.42**	**4.72**
EV fuel savings $ per 10,000km	**1102**	**742**	**472**

FCEVs, which run on hydrogen, were not considered in this comparative analysis because there are currently no retail hydrogen refuelling stations in Australia.[47]

3.5 Economic growth and improved fuel security

The potential economic impacts of increased EV sales in Australia were considered by PricewaterhouseCoopers (PwC) in a March 2018 report entitled *Recharging the Economy: The economic impact of accelerating electric vehicle adoption.*[48] According to PwC, increased EV sales can stimulate economic growth via:

- investment in EV infrastructure;
- reduced greenhouse gas emissions;
- reduced vehicle ownership costs; and
- reduced fuel imports, which improves Australia's terms of trade.[49]

PwC's economic modelling was based on the assumption that Australia experiences a growth rate in EV sales similar to that experienced by Norway, which would result in EV sales comprising 57% of new car sales in Australia by 2030.[50] As to the attainability of this assumed growth rate in Australia, PwC stated that Norway "provides a real demonstration of EV growth potential with a high level of Government support".[51] According to PwC, if Australia were to achieve such growth in EV sales, it would:

- increase real GDP by $2.9 billion (0.2%), based on 2016–17 Australian GDP, and
- increase net employment by 13,400 jobs relative to 2016–17.[52]

Other sources of potential economic growth relate to the mining and recycling of the raw materials used to produce the lithium-ion batteries used in EVs.[53] For example, the potential economic gains for NSW from mining cobalt — one of the key ingredients of lithium-ion batteries — were discussed by the NSW Minster for Resources, Energy, Utilities and the Arts, Don Harwin MLC:

> Sourcing cobalt and other high-tech metals poses challenges and opportunities for the minerals industry and governments globally—a challenge New South Wales is now ready to meet. In fact, New South Wales is poised to be an important contributor as a cobalt supplier. Cobalt in New South Wales occurs in hard rock deposits, such as Cobalt Blue's Thackaringa project near Broken Hill, and Corazon's Cobalt Ridge prospect in New England. It is also found in shallow laterite soil deposits around Fifield, Port Macquarie and Thuddungra. …. This is yet another example of how New South Wales is well positioned to make the most of the next potential mining boom driven by the demand for high-tech metals and how we are ready to meet the challenges of a high-tech future. [54]

In addition to its economic benefits, a reduced reliance on fuel imports improves national fuel security. National fuel security is currently a pressing concern, with the Commonwealth Minister for the Environment and Energy, Josh Frydenberg MP, ordering a review of Australia's liquid fuel reserves after it was reported that, in contrast to International Energy Agency mandates that countries hold 90 days' supply of liquid fuel, Australia had 22 days of crude oil, 59 days of LPG, 20 days of petrol, 19 days of aviation fuel and 21 days of diesel remaining.[55]

4. Main concerns

The main concerns expressed about EVs relate to their capacity to reduce air pollution and greenhouse gas emissions; high purchase costs and depreciation levels; and "range anxiety" caused by limited charging infrastructure. Concerns relating to the manufacture and disposal of lithium-ion batteries have also been raised. Each of these concerns is considered in turn below.

4.1 Increased electricity demand

As stated by the Commonwealth Minister for the Environment and Energy, Josh Frydenberg MP:

> An extra one million electric cars is the equivalent of 5.2 terawatt hours of power demand. This is about a 2 per cent increase in overall grid demand.[56]

Any increase in electricity demand will exert pressure on already high electricity prices; particularly in the short term, following the closure of ten coal-fired power stations since 2012.[57] However, as the Australia Energy Market Operator (AEMO) has said:

> The 20-year impact of electric vehicles on electricity consumption and demand is projected to be small relative to the impact of other changes expected to take place, such as investment in renewable energy technologies, restructuring of the Australian economy, and energy efficiency improvements of major appliances.[58]

4.2 Increased air pollution and greenhouse gas emissions

Electricity generation in Australia is heavily reliant on coal and other fossil fuels.[59] As a result, electricity generation in Australia is a major source of air pollution and greenhouse gas emissions.[60] Given Australia's current reliance on coal and other fossil fuels for electricity generation, the positive externalities (environmental benefits) associated with EV driving may be offset by the negative externalities (environmental costs) associated with EV charging.

Figures 3 and 4 reveal that charging EVs from high fossil fuel electricity networks generates more greenhouse gas emissions than charging EVs from low fossil fuel electricity networks.[61] They also reveal that, in jurisdictions with high fossil fuel electricity generation, hybrid vehicles generate fewer greenhouse gas emissions than EVs. EVs produce the least amount of emissions of all vehicle types in Tasmania, where most electricity is generated from hydro and other renewable sources.[62]

Figure 3: Emissions by vehicle type in high carbon (Wyoming) and low carbon (California) US jurisdictions[63]

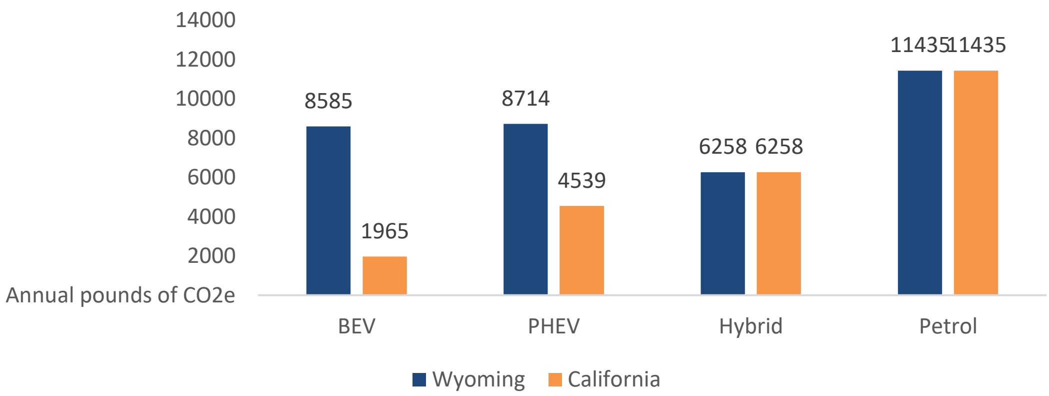
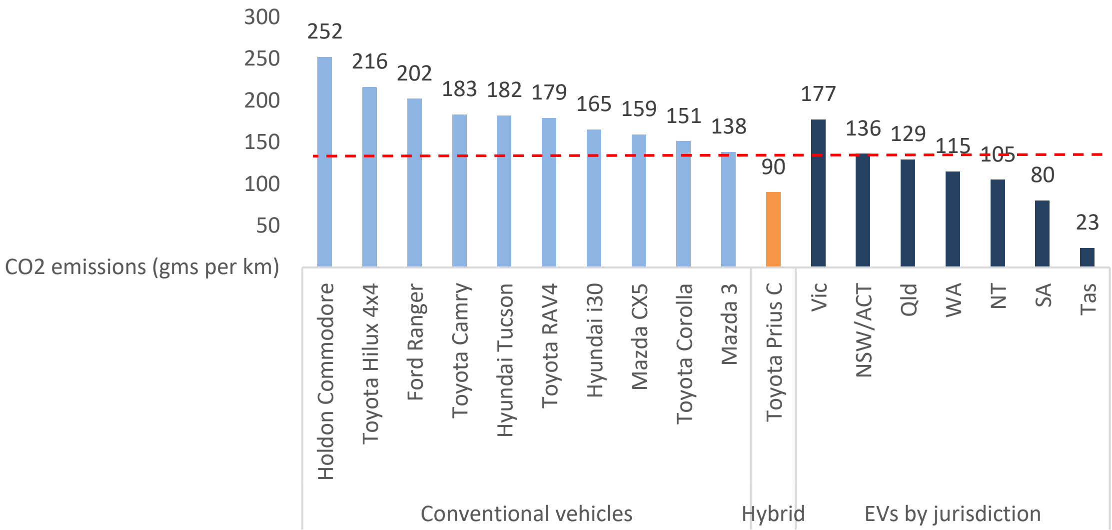


Figure 4: EV emissions across Australia compared with top selling conventional vehicles and a conventional hybrid (Prius)[64]



FCEVs can also be an indirect source of tailpipe air pollution and greenhouse gas emissions. Although FCEVs charge their batteries from liquid hydrogen and not from the electricity network, hydrogen gas and electricity are needed to produce the liquid hydrogen fuel that FCEVs require. Consequently, the benefits that FCEVs offer with respect to air pollution and greenhouse gas emissions are dependent on the manner in which the electricity and hydrogen gas used to produce liquid hydrogen fuel is sourced:

> The carbon emissions associated with hydrogen-fuel production depend on the source of hydrogen (typically, natural gas or water), the process used to extract it, and the source of the energy driving that process.
>
> Currently, most hydrogen is made by converting natural gas into hydrogen gas and carbon dioxide. The hydrogen can be made either at a central facility and trucked to a filling station or, if natural gas is available on-site, right at the station. However, hydrogen can also be produced from sources of energy that are lower in carbon than natural gas. Electricity from solar or wind power, for example, can be used to split water into hydrogen and oxygen through electrolysis. Another low-carbon source of hydrogen is methane gas from landfills and sewage treatment facilities.[65]

4.3 Higher purchase costs

EVs currently have higher purchase costs than comparable conventional vehicles.[66] The cost of lithium-ion batteries accounts for approximately 50% of the difference in price.[67] However, the cost of lithium-ion batteries has fallen since 2011 and is expected to decline further as increased production improves economies of scale and technological developments improve battery energy density.[68] In light of the expected reductions in battery costs, it is estimated that price parity between EVs and comparable conventional vehicles will be reached between 2023 and 2030.[69]

4.4 Higher rates of depreciation

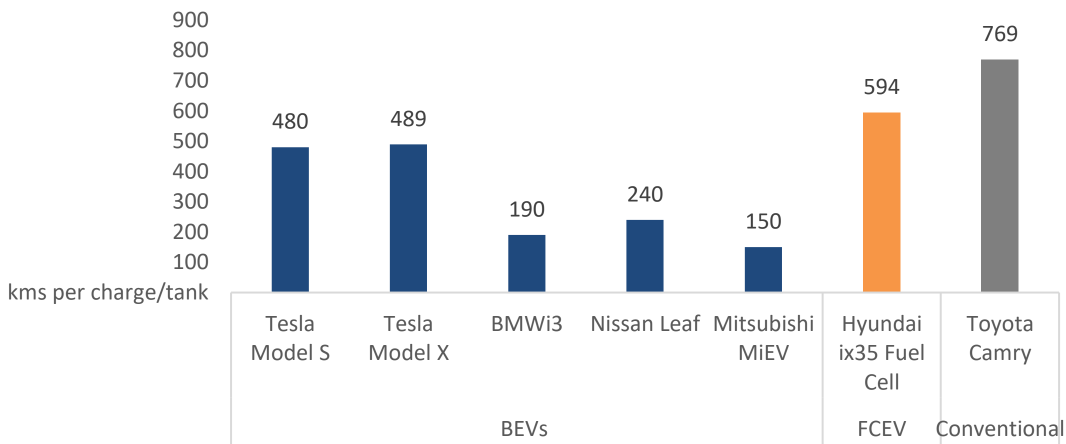
Recent data suggests that EVs depreciate at a faster rate than conventional vehicles.[70] For example, a petrol vehicle bought in 2012 retained 55% of its value over the first five years of ownership, while an EV bought in 2012 retained 43% of its value over the same period.[71] Two factors that may account for this faster rate of depreciation are: the ongoing and rapid technological development of EVs, which renders existing EVs increasingly obsolete; and concerns about the longevity of lithium-ion batteries, which eventually need replacing.[72]

Concerns about the longevity of lithium-ion batteries are especially likely to affect resale values. As the International Renewable Energy Agency states, "battery packs typically offer a lifetime of between eight and ten years".[73] However, the longevity of lithium-ion batteries cannot be predicted with any certainty, as it is determined by individual battery characteristics (capacity, structure and chemical composition) and operating conditions (including charging practices and ambient temperature).[74]

4.5 "Range anxiety" and limited charging infrastructure

Driving range is not a concern for most drivers of conventional vehicles. For instance, a Toyota Camry can be driven 769 kilometres on one tank of fuel and can be refuelled at approximately 6,400 petrol stations across Australia, with 1,920 petrol stations in NSW.[75] As PHEVs and hybrid vehicles can rely on their petrol engines, drivers of these types of vehicles are also not affected by concerns about driving range. In contrast, domestic and international surveys of consumers reveal a concern relating to the driving range of BEVs.[76] This concern, commonly referred to as "range anxiety", is the product of two factors. The first factor is the shorter driving range of current EV models, which is shown in Figure 5.

Figure 5: Driving range of BEVs and FCEVs, compared to a Toyota Camry[77]



The second factor is limited access to public EV charging and fuelling infrastructure. Discussing the significance of publicly accessible EV infrastructure, the National Roads and Motorists' Association (NRMA) said:

> While a significant portion of electric vehicle charging could occur at home or in the workplace, widespread public infrastructure is needed to mitigate range anxiety on the part of prospective purchasers. Accessible public infrastructure is also crucial for connecting rural and regional centres.[78]

As discussed above (at 3.4), there are no retail hydrogen fuelling stations in Australia.[79] Table 4 shows that, as at June 2017, there were 476 dedicated public charging stations across Australia, with 130 in NSW.[80] Most charging stations in Australia are slow charging AC stations, rather than fast charging

DC stations; with the Electric Vehicle Council reporting that, as at June 2017, there were only 11 fast charging DC stations in NSW.[81] As a general comparison (noting that there may be more than one charging unit at each charging station), in 2016 the United Kingdom had 1,523 publicly accessible fast charging units; the United States had 5,384; Japan had 5,990; and China had 88,476.[82]

Table 4: Charging stations across Australia, as at June 2017[83]

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	AUS
AC	11	119	1	70	41	16	127	51	436
DC	3	11	1	5	1	0	7	12	40
Total	**14**	**130**	**2**	**75**	**42**	**16**	**134**	**63**	**476**

Source: Electric Vehicle Council, *The state of electric vehicles in Australia*, 2017, p 9.

4.6 Cobalt production

Cobalt is used to produce the lithium-ion batteries used by EVs. While EVs currently use only about 10% of global cobalt supply, Bloomberg New Energy Finance have said that the expected increase in global EV sales could more than quadruple global demand for cobalt, from approximately 100,000 tonnes in 2017 to 450,000 tonnes by 2030.[84]

The Australian Council of Learned Academies notes that there are pronounced "supply chain criticality"[85] issues relating to cobalt because half of the global production of cobalt comes from the Democratic Republic of Congo (DRC) and the vast majority of global cobalt resources are in the DRC and Zambia.[86] Moreover, cobalt production in the DRC is environmentally harmful,[87] unsafe for workers and involves child exploitation:

> Smaller independent mines using low-tech means to extract the metal, called artisanal mines, have grown to meet the demand for cobalt. These types of mines have been implicated in child labour, dangerous work conditions and even several deaths from accidents such as collapses. Amnesty International … released a report in 2016 detailing the danger and unethical behaviours behind these types of mines. The United Nations Children's Fund estimated that as many as 40,000 children could be working in the mines.[88]

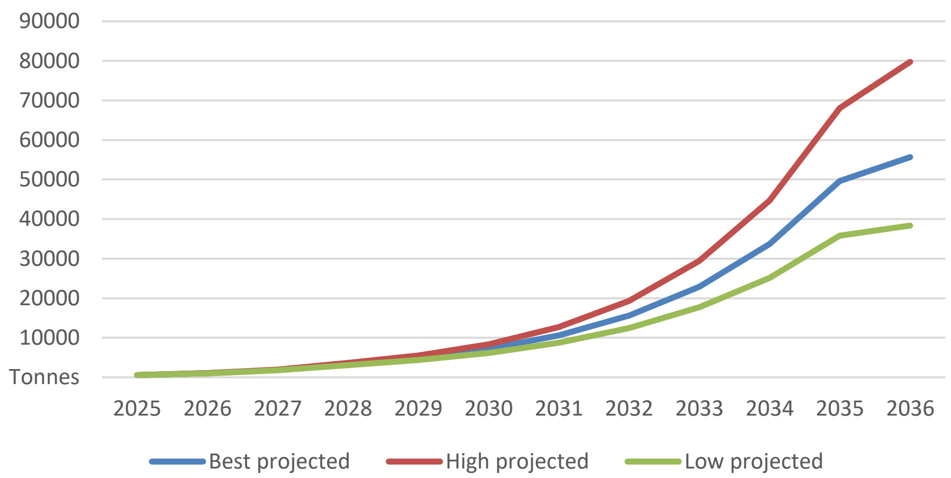
For these reasons, some EV manufacturers are attempting to source cobalt from outside the DRC.[89]

4.7 Recycling

While lithium-ion batteries are recyclable, "there is neither the economic driver nor a policy incentive for recycling in Australia."[90] Consequently, Australia does not currently possess the capacity to recycle EV lithium-ion batteries.[91] Some automotive manufacturers have standard operating procedures for retrieving and recycling waste lithium-ion EV batteries, but these efforts ultimately rely on sending waste batteries to overseas recycling plants.[92] Some stakeholders argue that, in light of the expected increases in EV waste lithium-ion batteries depicted in Figure 6, it is necessary to build domestic capacity for recycling waste EV lithium-ion batteries.[93]

The average projected annual growth rates in EV lithium-ion waste batteries shown in Figure 6 ranges from 47% (low projection) to 57% (high projection); with the best (most likely) projection representing an average annual growth rate of 52%.[94]

Figure 6: Projections for waste EV Lithium-ion batteries in Australia (excluding batteries from hybrid vehicles)[95]



4.8 Pedestrian safety

Pedestrian safety is a major road safety concern in NSW. There were 74 pedestrian fatalities in 2016 (19% of all NSW road fatalities for that year) and 1,095 pedestrian serious injuries in 2015–2016.[96] It has been recognised overseas that EVs pose an additional risk to pedestrian safety, due to the low level of noise they emit at low speeds.[97] For instance, on 14 November 2016, the United States Department of Transportation's National Highway Traffic Safety Administration announced:

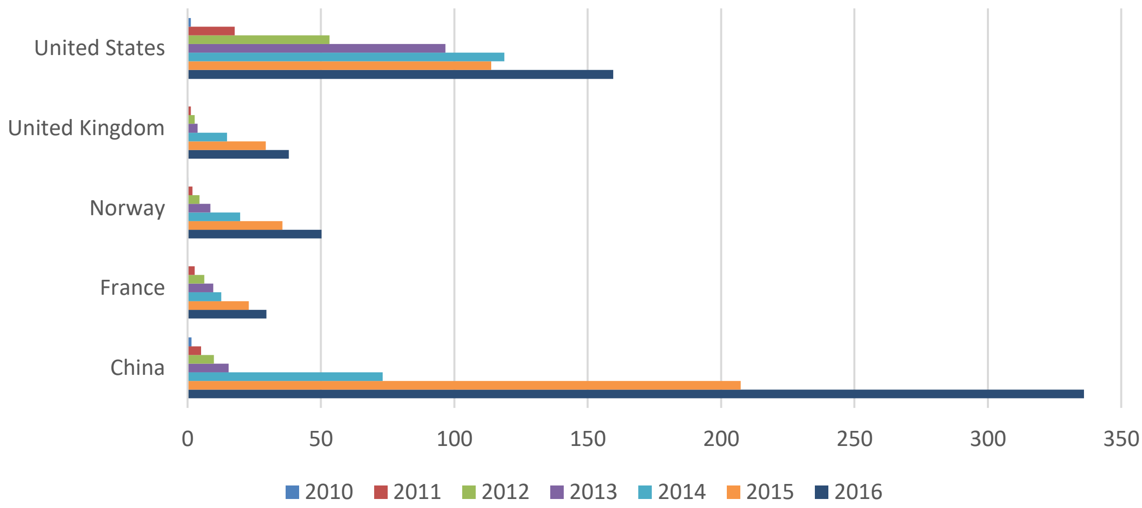
> … that it is adding a sound requirement for all newly manufactured hybrid and electric light-duty vehicles to help protect pedestrians. The new federal safety standard will help pedestrians who are blind, have low vision, and other pedestrians detect the presence, direction and location of these vehicles when they are traveling at low speeds … Under the new rule, all hybrid and electric light vehicles with four wheels and a gross vehicle weight rating of 10,000 pounds or less will be required to make audible noise when traveling in reverse or forward at speeds up to 30 kilometers per hour (about 19 miles per hour). At higher speeds, the sound alert is not required because other factors, such as tire and wind noise, provide adequate audible warning to pedestrians.[98]

5. Global EV sales and policy

5.1 BEVs and PHEVs

The International Energy Agency (IEA) has reported that 95% of EV sales take place in just ten countries with robust EV policies: China, the United States, Japan, Canada, Norway, the United Kingdom, France, Germany, the Netherlands and Sweden.[99] The IEA stated that this global experience "broadly confirms that electric car market mechanisms are still largely driven by policy support".[100] Figure 7 details the impact of EV policies on EV sales in five nations that represent distinct socio-economic conditions: China, France, Norway, the United Kingdom and the United States.

Figure 7: EV new registrations (000s) in nations with EV policies[101]*



* Excludes sales of FCEVs

Table 5 and 6 show the EV policies introduced by each of these nations. Some of those EV policies focus on increasing the demand for EVs through various tax discounts. Norway, where one in every three new vehicles sold is an EV,[102] has taken this approach furthest, as its tax discounts effectively lower an EV's purchase price to that of a conventional vehicle.[103] A contrasting approach is represented by California's Zero Emission Vehicle (ZEV) mandates, which were first introduced in that State in 1990 and which are expected to be introduced in China in 2019.[104] A ZEV mandate focuses on increasing EV supply by:

> … requir[ing] automakers to develop and sell EVs … Automakers that do not sell enough EVs relative to their other vehicle sales can either buy credits from those that over-comply … or pay a stiff financial penalty.[105]

Table 5: Overview of EV Policies in leading EV nations[106]

	China	France	Norway	UK	US
Economy/emission standards	✓	✓	✓	✓	✓
Tax exemptions and subsidies	✓	✓	✓	✓	✓
Bonus-malus scheme	×	✓	×	×	×
ZEV mandates	✓	×	×	×	✓*
Driving/parking privileges	✓	×	✓	✓	✓*
EV infrastructure support	✓	✓	✓	✓	✓*
EV targets/bans on non-EVs	✓	✓	✓	✓	×**

* Some states, most notably California. ** Proposed in California by the Clean Cars 2040 Bill 2018 (CA)

Table 6: Details of EV policies in leading EV nations[107]	
China	Fuel consumption standard • Tax exemptions • Local Subsidies • Exemptions from licence plate access restrictions • Access to bus lanes • Free charging • Free parking • ZEV mandate from 2019 • Future ban on the sale of conventional vehicles announced.
France	European Union tailpipe emission standard (Euro 6) • European Union fuel economy regulation • CO_2/km based "bonus-malus" scheme that pays a rebate on low emitting vehicles and imposes a tax on high emitting vehicles • Company car tax credits • Electricity and hydrogen tax exemptions • Government fleet commitments from 2017 • Ban on sale of conventional vehicles from 2040.
Norway	European Union tailpipe emission standard (Euro 6) • European Union fuel economy regulation • Purchase tax exemption • Value Added Tax (VAT) exemption for BEVs (25% of vehicle price before tax) • Additional purchase rebates and tax waivers for PHEVs • VAT exemption for leased BEVs • Circulation tax exemption • Waiver on road tolls • Free parking measures • All passenger vehicles to be zero emission by 2025.
United Kingdom	European Union tailpipe emission standard (Euro 6) • European Union fuel economy regulation • CO_2/km based and zero emission range based purchase subsidy scheme • Tax incentives: fuel duty exemption, excise duty exemptions (BEVs) and discounts (PHEVs) • Planned Government spending (US$770 million) to support ultra-low emission vehicle manufacturing and uptake • Go Ultra-Low City scheme • exemption from congestion charging • EV infrastructure development • free parking and bus lane access • *Automated and Electric Vehicles Bill 2017 (UK)* currently before Parliament • Ban on the sale of conventional vehicles from 2040.
United States	Corporate Average Fuel Economy standard • Tax credit of US$2,500–7,500 to be phased out after 200,000 units per manufacturer sold for domestic use • ZEV production mandates in 9 States • In some States, purchase rebates, registration tax exemptions and driving privileges • EV infrastructure support in California • Proposal to ban sale of petrol and diesel cars in 2040 in California: Clean Cars 2040 Bill (CA)

5.2 FCEVs

Due to their reliance on hydrogen fuelling infrastructure, FCEVs have experienced a slower and more geographically restricted uptake than BEVs and PHEVs. A total of 6,475 FCEVs were sold globally between 2013 and 2017, with over 50% sold in California.[108] As detailed by the Californian Air Resources Board (ARB), California actively invests in hydrogen fuelling infrastructure:

> Through its [Assembly Bill 8] AB 8 program, the State of California has co-funded 62 hydrogen fuelling station projects. Many of these stations are currently open … AB 8 dedicates up to $20 million per year to support continued construction of at least 100 hydrogen fuel stations. This focus will enable hydrogen FCEVs, along with other zero emission vehicle (ZEV)

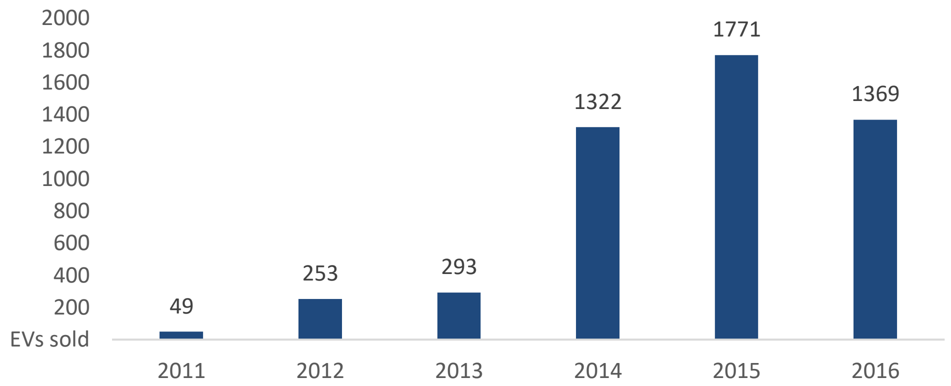
> technologies, to play a significant role in meeting multiple policy objectives established by Governor Brown and the Legislature …
>
> The State of California is co-funding the initial network of hydrogen fuelling stations, in advance of vehicle launches, through the Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program.[109]

The low number and geographically concentrated distribution of FCEV sales suggests that, in order to increase the uptake of FCEVs, policy intervention is both necessary and sufficient.

6. National sales and policy

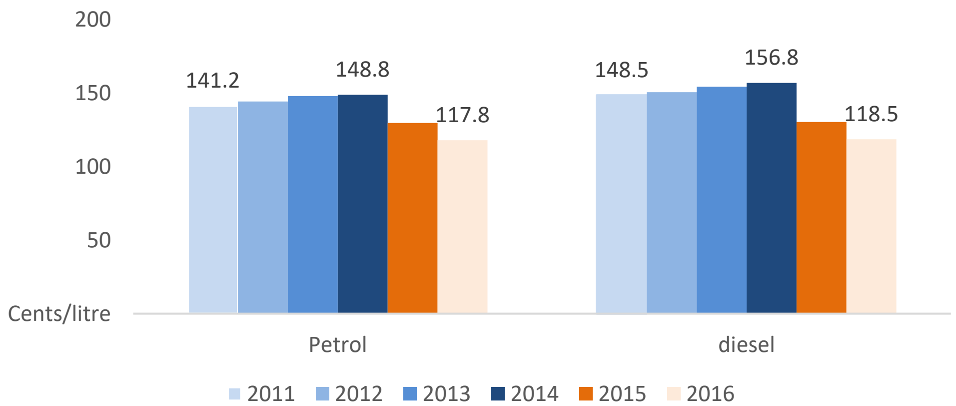
In 2016, 1,369 EVs (701 PHEVs and 688 BEVs) were sold, which represents 0.1% of the Australian new car market.[110]As Figure 8 illustrates, Australia's EV sales increased from 2011 to 2015, before falling by 23% between 2015 and 2016. One factor that may account for the pronounced increase in EV sales between 2013 and 2014 is that, as depicted in Figure 9, petrol and diesel retail prices had increased by approximately 6 cents per litre between 2011 and 2014, before decreasing by over 30 cents per litre between 2014 and 2016.[111] As discussed above (at 3.4), such a decrease in petrol and diesel prices could erode the potential fuel cost savings offered by EVs.

Figure 8: EV sales in Australia, 2011 to 2016[112]*



*These figures rely on estimates of Tesla sales, as Tesla does not publicly release its sales figures.

Figure 9: National average petrol and diesel retail prices[113]



Australia's EV sales have occurred in the absence of an overarching policy framework designed to provide price parity between EVs and conventional vehicles, and easy access to charging infrastructure.[114] Whether Australia should have an overarching EV policy, and what form that policy should take, is a topic of debate within the Commonwealth Government.[115]

In general terms, Australia's policy options for promoting EV sales can be categorised as either demand-side or supply-side. Demand-side policies include: reducing or removing taxes on EVs; increasing taxes on conventional vehicles and fossil fuels; and providing EV drivers with privileges, such as road toll exemptions and access to bus lanes and designated parking spaces. Supply-side policies include tightening emissions standards (which in Australia are currently based on Euro 5 standards);[116] subsidies for manufactures of EVs and EV charging stations; and ZEV mandates that require vehicle manufacturers to sell a set number of zero emission vehicles in Australia.[117]

The international experience detailed above (at 5) indicates that different policy combinations can be effective in increasing EV sales. However, tax reductions and subsidies entail costs in the form of forgone revenue or expenditure of public funds; costs which must be considered against the potential economic and environmental benefits accruing from any increase in EV sales. A variety of policy combinations are available. For instance, the Australia Institute has recommended the introduction of the following four policies: a Luxury Car Tax exemption for EVs; charging station rebates; use of bus lanes; and a finely calibrated (revenue neutral) bonus-malus scheme that places an extra tax on high emitting vehicles and pays an equivalent rebate on low emitting vehicles.[118] Academic Jonn Axsen points out that, ultimately, there is:

> … no easy answer for which strategy is best for a given region. Norway and California provide excellent examples of leadership — though each has its own unique cultural and political contexts. Any region, national or subnational, that is serious about supporting EVs will need to consider the trade-offs for themselves.[119]

The effectiveness of any national EV policy is also dependent on the decarbonisation of its electricity network.[120] The dependence of EV policy on energy policy could be viewed as an impediment to the deployment of EVs. For instance, Commonwealth MP Craig Kelly has opposed subsidies for EVs on the ground that:

> The risk here is you'll have the rich person in Balmain buying a Tesla, subsidised by a bloke in Penrith who's driving a Corolla and the Tesla will have more carbon emissions than the Corolla.[121]

Alternatively, the dependence of EV policy on energy policy could be viewed as an opportunity to align transport and energy policies in order to maximise the benefits of technological innovation for the entire economy. An alignment of EV and energy policies would accentuate the global trend discussed by academic Stephen Pinker; namely, the inexorable shift away from coal towards natural gas and renewable energy that has occurred over the last 50 years.[122] That trend has resulted in a decline in carbon intensity (CO_2 emissions per dollar of GDP) for the world as a whole and, for the first time in human history, decoupled the link between economic growth and carbon emissions.[123] In short, the development of a national EV policy could be viewed as a catalyst for transitioning Australia's economy from high to low carbon intensity in line with global developments.

7. NSW policy

Approximately 850 EVs were sold in NSW between 2011 and 2016.[124] This excludes EVs manufactured by Tesla, as Tesla does not publicly release its sales data.[125] (As at the end of 2017, 972 Tesla EVs were registered in NSW).[126]

Although EV sales in NSW have occurred in the absence of a State EV policy, NSW has taken some steps towards promoting EV sales. In particular, EVs with CO_2 emissions no higher than 150 grams per kilometre in the combined (urban and extra urban) driving cycle attract discounted registration rates.[127] A pilot program aimed at increasing the use of EVs in NSW Government fleets was also announced in 2017.[128]

In terms of future developments, the NSW Government's *Future Transport Strategy 2056* states that the Government "supports an industry-led response to the development and take up of electric vehicles" and will deliver an Electric and Hybrid Vehicle Plan to facilitate EV sales.[129] The NSW Government's *Climate Change Fund: Draft Strategic Plan 2017 to 2022* also states that it will:

> … develop a New South Wales electric vehicles strategy to increase the uptake of low emission and electric vehicles by individual and business consumers. Potential actions include:
>
> - advocate for higher national fuel efficiency standards.
> - investigate appropriate incentives to encourage the purchase of fuel efficient light vehicles and to retire inefficient vehicles, including through stamp duty and registration charges.
> - provide the right 'real-world' information so that businesses and individuals can choose fuel efficient light and heavy vehicles.
> - work with vehicle suppliers and clean energy providers to make zero emission and flexible fuel vehicles available to the New South Wales vehicle market.
> - investigate and consider how the government could best invest in a fleet of electric vehicles, including for public transport, and charging infrastructure at government sites.
> - investigate the case for public investment in EV charging infrastructure and the requirements for renewable energy power supply…[130]

8. Queensland

In July 2017 the Queensland Government launched an EV strategy, entitled *The Future is Electric*. The Queensland Government is also facilitating the development of a Queensland Electric Super Highway, a series of fast charging stations along the Queensland coast (Figure 10).[131]

Figure 10: Queensland Electric Superhighway[132]

In its EV Strategy the Queensland Government states that it "recognises the enormous potential of this innovative technology" and:

> Given the full emissions reduction benefits of EVs can only be realised if these vehicles are charged using renewable energy … is also actively pursuing credible pathways to decarbonise our electricity sector.[133]

Queensland's EV strategy includes:

- Establishing a new Queensland Electric Vehicle Council to inform the long-term direction of Queensland's EV strategy.
- Raising EV awareness by engaging with the community and developing online resources.
- Encouraging renewable energy and battery storage technologies.
- Developing the Queensland Electric Super Highway and regional infrastructure.
- Piloting EV workplace charging infrastructure projects.
- Encouraging discussions on EVs with other State Governments and the Commonwealth Government.
- Transitioning the Queensland Government fleet towards EVs.
- Supporting EV tourism across Queensland.
- Investigating ways of integrating EVs with transport hubs.

- Investigating the feasibility of using EVs as buses, commercial vehicles and heavy vehicles.
- Investigating the economic opportunities of recycling EV batteries or reusing EV batteries as home batteries.[134]

9. Victoria

The Parliament of Victoria's Economy and Infrastructure Committee has conducted an Inquiry into EVs.[135] The Inquiry's Terms of Reference required the Committee to report on:

> 1. The potential benefits of widespread uptake of electric vehicles in Victoria to the environment, including greenhouse gas emissions, air quality, noise and amenity…
>
> 2. The regulatory, infrastructure, economic, employment and incentive options for supporting the uptake of privately owned electric vehicles.
>
> 3. The applicability of electric vehicles in public transport bus fleets and public sector fleets.
>
> 4. Options for supporting the manufacture and assembly of electric vehicles in Victoria, including transition of workers and suppliers affected by the closure of vehicle manufacturing in Victoria.
>
> 5. The applicability of electric vehicles to the car share providers market.[136]

The Committee tabled its report on 8 May 2018. Table 7 sets out select findings made by the Committee relating to the key issues discussed in this e-brief.

Table 7: Select findings of the Victorian Parliament's EV Inquiry[137]	
Finding 1	Currently the high upfront cost of EVs compared to other vehicles in the same class makes them prohibitively expensive for many persons.
Finding 4	The electricity grid will need to adapt for the increased uptake of EVs.
Finding 5	While increasing the number of EVs in Victoria is unlikely to lead to significant reductions in carbon dioxide without a shift to renewable energy sources, more EVs in the road will lead to an improvement in air quality in Metropolitan Melbourne.
Finding 6	Some governments in other jurisdictions have established targets for EV uptake to increase the number of EVs in their jurisdictions. A State EV target that aligns with the current Victorian Government's Renewable Energy Targets may support Victoria to achieve net zero emissions by 2050.
Finding 26	Regulations for the safe recycling and disposal of EV batteries will need to be developed if the uptake of EVs increases.

The Committee also made a number of findings relating to:

- the need for EV infrastructure to be nationally consistent, so that EVs can be easily driven across Australia (Finding 11);
- the capacity of regional EV infrastructure to enable long-distance driving and promote regional tourism (Finding 10); and
- the transition of existing domestic automotive industry workers to an EV-based automotive industry (Finding 3).[138]

10. Conclusion

EVs are a disruptive technology with potential to provide a range of environmental and economic benefits. Many international jurisdictions have introduced EV policies designed to transition away from conventional vehicles towards EVs. This policy intervention was both necessary and sufficient for increasing EV sales. In contrast, Australia and NSW have not developed overarching EV policies and, as a result, have experienced relatively slow EV sales growth.

Some overseas jurisdictions have addressed EV-related concerns, such as pedestrian safety. Other concerns, such as those relating to the manufacture and recycling of lithium-ion batteries, remain. These concerns will likely assume greater significance as more EVs are produced and reach the end of their lifespan.

Queensland has developed an EV strategy that seeks to promote the use of EVs in that State and the Victorian Parliament has just concluded an Inquiry into EVs. At the national level, there is debate about the advantages and disadvantages of promoting the uptake of EVs. That debate has highlighted the reliance of EVs on energy generated from the electricity network. That issue can be viewed as grounds for opposing the uptake of EVs; alternatively, it can be viewed as an opportunity to align EV and energy policies, in order to harness the benefits of technological innovation across the entire economy.

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[2] International Energy Agency, *Global EV Outlook 2017: Two million and counting*, 2017, p 12 and 51.

[3] Climate Works Australia, *The State of electric vehicles in Australia*, 2017, p 12. See also: Diss K, The big problem with electric vehicle resale prices compared to petrol, diesel and hybrid cars, *ABC News*, 6 February 2018.

[4] See: *ABC News*, UK to ban sales of petrol and diesel cars from 2040 in pollution crackdown, reports say, 26 July 2017; *BBC News*, New diesel and petrol vehicles to be banned from 2040 in UK, 26 July 2017. Other countries that have made similar announcements include France, China, India, Norway and the Netherlands: Roberts D, The world's largest car market just announced an imminent end to gas and diesel cars, *Vox*, 13 September 2017; *ABC News*, France moves to ban petrol and diesel cars in a bid to meet Paris agreement targets, 7 July 2017; Roberts G, China's indication to ban sale of non-electric cars a 'tipping point' for global industry, *ABC News*, 14 September 2017; Diss K, The big problem with electric vehicle resale prices compared to petrol, diesel and hybrid cars, *ABC News*, 6 February 2018; Petroff A, These countries want to ditch petrol and diesel cars, *CNN Money*, 26 July 2017.

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7 Union of Concerned Scientists, *How Do Battery Electric Cars Work?*, no date, [website—accessed 6 February 2018]. Wiseman E, What's the difference between a hybrid, a plug-in hybrid, and an electric 'EV' car?, *The Telegraph (UK)*, 9 August 2017; Union of Concerned Scientists, *How Do Plug-in Hybrid Electric Cars Work?*, no date [website—accessed 7 February 2018]. Although the term "EV" typically refers to passenger vehicles, it may also include motorcycles, light commercial vehicles, buses and trucks.

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9 See: Electric Vehicle Council, *The state of electric vehicles in Australia*, 2017, p 5 and International Energy Agency, *Global EV Outlook 2017: Two million and counting*, 2017, p 5.

10 Information in Table 1 sourced from: Union of Concerned Scientists, *How Do Battery Electric Cars Work?*, no date [website—accessed 6 February 2018]; Wiseman E, What's the difference between a hybrid, a plug-in hybrid, and an electric 'EV' car?, *The Telegraph (UK)*, 9 August 2017; Plummer L, Hydrogen fuel cell cars: How do they work?, *alphr*, 10 August 2017; Union of Concerned Scientists, *How Do Hybrid Cars and Trucks Work?*, no date [website—accessed 7 February 2018].

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17 NSW Government, *Air Quality in NSW*, 2017, p 1–2. The NSW Government operates accredited air quality monitoring stations: NSW Government, *Monitoring Air Quality in NSW*, 2017, p 1.

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21 Keywood MD, Hibberd MF and Emmerson KM, *Australia, State of the Environment 2016: Atmosphere*, Department of the Environment and Energy, 2017, p 67.

22 See, for instance, NSW Government, Clean Air for NSW, *Vehicle Emissions*, 2017, p 2

23 See, for instance, NSW Government, Clean Air for NSW, *Vehicle Emissions*, 2017, p 2. It is unclear whether EVs produce relatively less non-tailpipe pollution due to their use of regenerative braking, or relatively more non-tailpipe pollution due to their comparatively greater weight: see, for instance: Loeb J, Particle pollution from electric cars could be worse than from diesel ones, *Engineering and Technology*, 10 March 2017.

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[45] Retail off-peak and peak electricity prices vary considerably over time and across Australia. The kWh prices used in this table are assumed values that broadly reflect this variation.

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