Chapter 2

Electric vehicles—Definitions, background and projections

Introduction

2.1 This chapter provides a background to the electric vehicle (EV) industry and projections about the industry's future focusing on:

- Definition of an EV;
- EV statistics and projections;
- Hydrogen, hybrid and electric cars;
- Autonomous vehicles; and
- Public and active transport.

What is an EV?

2.2 There are a broad range of views on what constitutes an EV. Some submissions proposed a narrow approach, defining electric vehicles as vehicles propelled by one or more electric motors, and that can be plugged-in to charge.[1] A similar definition was adopted by the Victorian Parliament in its *Inquiry into electric vehicles*.[2]

2.3 Two categories of vehicles fit within this definition:

- **Battery-Electric Vehicles (BEVs)**—vehicles propelled by one or more electric motors, with batteries that require recharging from an external electricity source. Examples: Nissan Leaf, Tesla Model S, and Jaguar I-Pace; and
- **Plug-in Hybrid Electric Vehicles (PHEVs)**—vehicles powered by one or more electric motors with batteries that can be recharged using an external electric source, and a liquid fuel range extender/internal combustion engine (ICE). Examples: Mitsubishi Outlander PHEV, Mercedes-Benz C350e, BMW 330e, and Audi A3 e-tron.[3]

2.4 The Committee also received evidence that the following categories of vehicles should be included in the definition of EVs:

- **Hydrogen Fuel Cell Vehicles or Fuel Cell Electric Vehicles (FCEVs)**—vehicles propelled by one or more electric motors powered by electricity

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1 Dr Jake Whitehead, *Submission 49*, p. 5. See also: Royal Automobile Club of WA, *Submission 117*, p. [3].

2 Parliament of Victoria, *Inquiry into electric vehicles*, May 2018, p. 3.

3 Dr Jake Whitehead, *Submission 49*, p. 5.

generated on-board by a hydrogen fuel cell, and that require refuelling with hydrogen gas. Examples: Toyota Mirai, Hyundai Nexo;[4]

- **Hybrid Electric Vehicles (HEVs)**—combine an ICE with one or more electric motors and batteries, but cannot be plugged-in to an external electricity source to recharge. Example: Toyota Camry Hybrid.[5]

2.5 In its submission, the Department of the Environment and Energy stated that 'the term "Electric Vehicle" commonly includes PHEVs, BEVs and FCEVs'.[6]

2.6 Throughout this inquiry and for the purposes of this report, the Committee has been inclined to accept a definition of EVs that includes BEVs, PHEVs and FCEVs.

Background—current uptake, projections, and policy initiatives

Global uptake, projections and policies

2.7 Worldwide, in 2017, there has been a 57 per cent increase of new EV sales from the previous year to 3.1 million electric passenger cars sold. More than half of global sales of EVs were in China, where electric cars hold a market share of 2.2 per cent. Sales of EVs in China were more than double that of the United States, the next largest market.[7] In 2017, the highest proportion of new EV car sales were in the following jurisdictions:

- Norway with 39 per cent of new car sales (560 000 units);
- Iceland with 11.7 per cent; and
- Sweden with 6.3 per cent.[8]

2.8 The Department of the Environment and Energy stated in their submission that:

> Over one million new EVs have been added to the global fleet each year for the past three years. By 2030, the International Energy Agency expects between 125 million and 220 million EVs on the road globally and that EVs will comprise up to 12 per cent of light vehicle sales. Bloomberg New Energy Finance forecasts around 28 per cent of global new vehicle sales will be EVs in 2030, close to 30 million sales a year. Major vehicle manufacturers have committed to scaling up investments in EV technology in coming years. [9]

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4 Hyundai Australia, *Submission 103*, p. [3].

5 NSW Parliamentary Research Service, *Electric Vehicles in NSW*, May 2018, pp. 1–2, https://www.parliament.nsw.gov.au/researchpapers/Documents/electric%20vehicles%20in%20NSW.pdf (accessed 15 August 2018).

6 Department of the Environment and Energy, *Submission 72*, p. 2. See also: Department of Infrastructure, Regional Development and Cities, *Submission 111*, pp. 3–4.

7 International Energy Agency, 'Global EV Outlook 2018', May 2018, pp. 20–21, https://webstore.iea.org/global-ev-outlook-2018 (accessed 24 September 2018).

8 International Energy Agency, 'Global EV Outlook 2018', May 2018, p. 21.

9 Department of the Environment and Energy, *Submission 72*, p. 3.

2.9 The Electric Vehicle Council pointed towards the EV targets established by other nations. Some countries such as the UK and France have set a target of 100 per cent of new car purchases being EV by 2040, whilst others like the Netherlands and Norway aim to achieve the same target by 2025.[10]

Table 2.1: Electric Vehicle targets of selected markets[11]

Country	Target	Date
China	100%	'near future'
UK	100%	2040
France	100%	2040
Norway	100%	2025
Netherlands	100%	2025
Japan	20–30%	2030
India	30%	2030
New Zealand	64,000	2021
USA	3.3 million	2025
Germany	6 million	2030
Taiwan	100%	2040
Ireland	100%	2030

2.10 The Electric Vehicle Council emphasised the exponential rise in new global EV sales from 47 000 in 2011 to over 1.1 million in 2017 and the automotive sector's intentions to invest '$150 billion in electric vehicles by 2025'.[12] Many mainstream automotive manufacturers have established their own targets for EV sales ranging from 15–50 per cent of all sales by 2025 with the VW Group expected to offer 80 EV models. Whilst two Chinese automotive companies have set 100 per cent of sales as their benchmark within the same timeframe.[13]

2.11 In addition to targets, many jurisdictions are offering a range of other incentives to EV owners:

10 Electric Vehicle Council, *Submission 100*, p. 14.

11 Electric Vehicle Council, *Submission 100*, p. 14.

12 Electric Vehicle Council, *Submission 100*, p. 13.

13 Bloomberg New Energy Finance, *Submission 127*, pp. 8–9.

> • New Zealand's Electric Vehicle Programme; which includes a target of 64,000 EVs by 2021, tax exemptions until EVs reach 2% of fleet, government fleet purchasing, an annual $6m grant fund and $1m annual funding for a consumer awareness campaign.
>
> • The United Kingdom's Road to Zero Strategy; a target of 50-70% by 2030 and 100% by 2040, government fleet target of 25% by 2022 and 100% by 2030, financial incentives of up to £4,500 for cars, £7,500 for taxis and £8,000 for vans, and grant funding for R&D and charging infrastructure.[14]

2.12 One jurisdiction has seen a fall in EV uptake as a result of withdrawal of incentives. The Victorian Automobile Chamber of Commerce (VACC) observed:

> …the dramatic fall of EV sales in Denmark, dropping 60.5 percent in the first quarter of 2017 following the phasing out of its tax incentives on EVs in 2016. This dramatic reduction suggests clean-energy vehicles are not currently attractive enough to compete against ICEs, without some form of subsidy.[15]

Price parity

2.13 The point when an EV purchase price reaches parity with ICE equivalents is a critical economic precursor to cost competiveness and to higher levels of EV uptake. Bloomberg New Energy Finance submitted that price parity would be reached from the year 2024 up to 2040 in different segments of the market (for example, light passenger vehicle, commercial vehicles) in different countries.[16] Mr Steve Bletsos of VACC agreed that EV sales would increase once price parity was achieved.[17]

Table 2.2: Year of EV up-front price parity with ICE vehicles in selected markets[18]

Segment	US	EU	China	Japan
Small	2027	2028	2030	2040
Medium	2025	2024	2024	2029
Large	2026	2025	2029	2027
SUV	2024	2026	2040	2025

14 Electric Vehicle Council, *Submission 100*, p. 1.

15 VACC, *Submission 26*, p. 12.

16 Bloomberg New Energy Finance, *Submission 127*, p. 6.

17 Mr Steve Bletsos, Senior Research Analyst, VACC, *Committee Hansard*, 31 August 2018, p. 77.

18 Bloomberg New Energy Finance, *Submission 127*, p. 6.

Australian uptake, projections and policies

2.14 The most recent data shows that EVs are a relatively small segment of the total Australian new car market and total vehicle fleet. Of the approximately 17 million light passenger vehicles in Australia, around 7 300 of these are BEVs and PHEVs.[19] Recent annual sales figures show that of over a million cars purchased in 2017, around 2 300 were BEVs or PHEVs, about 0.2 per cent market share.[20]

2.15 In a joint report by ClimateWorks and the Electric Vehicle Council, it is stated that in 2017, business bought 63 per cent of EVs, private buyers purchased 34 per cent whilst government bought only 3 per cent.[21] This same report provided a state and territory breakdown of new EV purchases:

> Australia's states and territories differ in their rate of electric vehicle uptake…In the last seven years, Victorians have purchased the highest number of electric vehicles, with 1,324 vehicles purchased between 2011 and 2017 (excluding Tesla vehicle numbers). When taking into account market size however, the ACT continues to outperform other jurisdictions: in 2017, ACT residents purchased 21 electric vehicles for every 10,000 vehicles sold.[22]

2.16 Notwithstanding the recent increase in EV models, the Australian EV market is characterised by a relatively low number of models that are generally more expensive than overseas markets:

> The number of electric vehicle models available in Australia increased 44 per cent in the same period, from 16 models in 2016 to 24 in 2017. Twenty of the 24 electric vehicle models available are in the luxury vehicle category, priced at over $60 000. The cheapest electric vehicle currently available in Australia is the Renault Zoe priced at under $50 000.[23]

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19 ClimateWorks Australia and Electric Vehicle Council, *The state of electric vehicles in Australia, Second Report: Driving Momentum in Electric Mobility*, (ClimateWorks *Submission 46.1*), June 2018, p. 6, https://www.climateworksaustralia.org/story/media-release/australias-electric-vehicle-industry-gains-momentum-report (accessed 25 July 2018).

20 Federal Chamber of Automotive Industries (FCAI), *Submission 119*, p. 4 & ClimateWorks, *Submission 46.1*, p. 6. See also: Electric Vehicle Council, *Submission 100*, p. 13; Department of Infrastructure, Regional Development and Cities, *Submission 111*, p. 5.

21 ClimateWorks, *Submission 46.1*, p. 7.

22 ClimateWorks, *Submission 46.1*, p. 7. See also: Mr Sam McLean, Senior Manager, Tesla, *Committee Hansard*, 10 August 2018, p. 3. Tesla do not provide annual sales figures to the FCAI Vendor Field Analytical and Characterization Technologies System (VFACTS) database.

23 Department of Infrastructure, Regional Development and Cities, *Submission 111*, p. 5. See also, for example: Mr Ali Asghar, Senior Associate, Bloomberg New Energy Finance, *Committee Hansard*, 31 August 2018, p. 11. Ms Sarah Fumei, Project Manager, ClimateWorks Australia, *Committee Hansard*, 17 August 2018, p. 59; The Australia Institute, *Submission 1.1*, p. 6.

2.17 The Committee heard that there are a variety of reasons for this, including less stringent Australian vehicle emission standards,[24] a lack of direct incentives for consumers to choose EVs,[25] and the absence of clear Federal Government policy.[26]

2.18 In its submission, the Department of Infrastructure, Regional Development and Cities outlined some of the current Australian Government policies supporting the uptake of EVs:

> The Australian Government currently offers a discount on the Luxury Car Tax (LCT) threshold for fuel efficient vehicles, such as electric vehicles. The 2017-18 threshold for fuel efficient vehicles of $75,526 is $10,432 higher than for other vehicles. At an LCT rate of 33 per cent, this effectively translates to a tax saving of up to $3,442.
>
> The Department also administers two measures providing information to consumers; the mandatory fuel consumption label for new light vehicles and the Green Vehicle Guide (GVG) website. Both the label and the GVG help consumers choose more efficient vehicles. All of the top 20 performing vehicle models currently listed on the GVG are electric or plug-in hybrid vehicles.[27]

2.19 The Department of the Environment and Energy noted other Australian Government initiatives supporting EV uptake:

> The Australian Renewable Energy Agency [ARENA] is funding research into consumer preferences for EVs. The Clean Energy Finance Corporation [CEFC] has made up to $950 million in capital (debt and equity) available to assist business with investment in low emissions vehicles. The CEFC and ARENA recently commissioned Energeia to complete an Australian market study on electric vehicles, helping new businesses understand Australia's unique market needs.[28]

2.20 The Department of the Environment and Energy also highlighted the work of the Ministerial Forum on Vehicle Emissions:

> The Forum was established to provide a coordinated, whole-of-government approach to addressing vehicle emissions. It is consulting on ways to reduce vehicle emissions, including by supporting uptake of low emissions vehicles.
>
> The Ministerial Forum brings together the Commonwealth Ministerial members of the [Council of Australian Governments' (COAG)] Energy Council and COAG Transport and Infrastructure Council. The COAG

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24 Mr Ali Asghar, Senior Associate, Bloomberg New Energy Finance, *Committee Hansard*, 31 August 2018, p. 11.

25 Mr David Magill, Director, Government Relations and Public Policy, GM Holden, *Committee Hansard*, 31 August 2018, p. 65.

26 Australian Electric Vehicle Association, *Submission 8*, p. 2.

27 Department of Infrastructure, Regional Development and Cities, *Submission 111*, p. 6.

28 Department of the Environment and Energy, *Submission, 72*, p. 7.

> Energy Council can coordinate and pursue the regulatory and governance reforms needed to prepare the electricity system for widespread EV uptake.[29]

2.21 In addition to Australian Government initiatives, ClimateWorks and the Electric Vehicle Council observed there had been notable policy developments in Australia over the past 12 months, occurring mainly at a state, territory and local government levels:

> The majority of state and territory governments across Australia have either announced or are developing an overarching electric vehicle policy framework or strategy, the ACT Government recently released their Transition to Zero Emissions Vehicles Action Plan 2018-21; the Queensland Government has released their electric vehicle strategy The Future is Electric; the Tasmanian Government outlines a range of electric vehicle action items in Climate Action 21: Tasmania's Climate Change Action Plan 2017-2021; and the New South Wales Government's Future Transport Strategy has been released for public consultation. The South Australian Government is also developing an electric vehicle strategy and the Northern Territory Government is considering a climate change framework.[30]

2.22 The ACT Minister for Climate Change and Sustainability, Mr Shane Rattenbury, explained the key elements of the ACT Government's plan:

> Our action plan is very short term—it's only a three-year plan—partly because we wanted to make sure we'd put something in place that we just got on with…
>
> The key focus in the three-year action plan is a number of specific measures. The leading one, we believe, is that the ACT government have committed to transform our government fleet to 100 per cent electric vehicles over a three-year cycle…
>
> Our action plan also includes the requirement for the installation of vehicle-charging infrastructure in new mixed-use and multiunit developments…it's very expensive to retrofit electric charging points into the basement of a large multiunit building because if you build it in at construction point the marginal cost is almost zero. So we've decided to mandate that into our planning laws so that we essentially future-proof these buildings that are going up at the moment in Canberra; we are seeing a significant number of new buildings.[31]

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29 Department of the Environment and Energy, *Submission, 72*, p. 6.

30 ClimateWorks, *Submission 46.1*, p. 25. The NSW Government's released its Electric and Hybrid Vehicle Plan on 21 January 2019, see: NSW Government, *Future Transport 2056: Electric and Hybrid Vehicle Plan*, January 2019, available at: https://www.future.transport.nsw.gov.au/sites/default/files/media/documents/2019/Future_Transport_NSW_Electric_and_Hybrid_vehicle_plan.pdf (accessed 21 January 2019).

31 Mr Shane Rattenbury, MLA, ACT Minister for Climate Change and Sustainability, *Committee Hansard*, 17 August 2018, pp. 1–2.

2.23 Mr Rattenbury also referred to financial incentives provided by the ACT Government to consumers:

> We have what I believe are currently the most generous concessions in Australia for electric vehicles. We have zero stamp duty at the time of purchase and then an ongoing 20 per cent discount for registration. We have been very conscious of how we provide subsidies.[32]

2.24 Ms Sally Noonan, Chief Economist, Queensland Department of Transport and Main Roads (DTMR), explained the approach the Queensland Government is taking to support EV uptake and noted 'The Future is Electric: Queensland Electric Vehicle Strategy':

> To accelerate the adoption of EVs, effort is needed from across multiple and diverse stakeholders, from the energy sector to tourism, fleet operators and industry development leaders. To raise awareness, [DTMR] has participated in multiple community events across Queensland, including showcasing the benefits of EVs and the electric superhighway at the recent Royal Queensland Show in Brisbane…
>
> The Queensland government has committed a further $2.5 million to build additional charging stations at new sites along the Queensland electric superhighway. Queensland now has the highest number of fast chargers in any state of Australia. The number of slower charging sites has also increased.[33]

2.25 Ms Noonan also noted registration concessions that the Queensland Government offers for EVs.[34]

2.26 Table 2.3 is a summary provided by ClimateWorks and the Electric Vehicle Council of the current policy approaches of Australian federal, state and territory governments that support EV uptake.

32 Mr Shane Rattenbury, MLA, ACT Minister for Climate Change and Sustainability, *Committee Hansard*, 17 August 2018, p. 3.

33 Ms Sally Noonan, Chief Economist, Queensland Department of Transport and Main Roads, *Committee Hansard*, 27 September 2018, p. 31.

34 Ms Sally Noonan, Chief Economist, Queensland Department of Transport and Main Roads, *Committee Hansard*, 27 September 2018, p. 31.

Table 2.3: Overview of federal, state and territory government policy[35]

		ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Cwth
Uptake	EV purchases 2011 - 2017	165	1238	13	688	957	61	1324	375	4821
	EV sales per 10,000 vehicles (2017)	21	10	1	6	22	3	10	8	7
Regulation	Vehicle CO_2 emissions standards									•
Financial incentives	Stamp duty, registration and tax discounts	✓	✓	✓	✓	•		✓		✓
	Direct vehicle subsidy									•
	Fleet incentive									✓
	Charging infrastructure incentive	✓		•	✓		✓			•
	Toll and parking discounts				✓					
Non financial incentives	Vehicle lane and parking privileges	✓								
	Electric vehicle public transport trials	✓		✓		✓				
	Government fleet policy	✓	✓			✓	✓			
	Information and education programs	✓	✓		✓	✓	✓	✓		✓

Table notes: Policies that are in place are marked ✓, and policies under consideration are marked •. This table was compiled through a survey of Australia's state, territory and federal governments on their electric vehicle policies. The Australian Capital Territory, New South Wales, the Northern Territory, Queensland, South Australia, Tasmania, Victoria and Western Australia provided a response to our survey. For the Commonwealth Government we used the response provided for the previous report and we undertook additional desktop research study. Vehicle purchase numbers do not include Teslas.

35 Climateworks, *Submission 46.1*, p. 26.

2.27 Some submitters were optimistic about the future of EVs in Australia. The Australia Institute noted the Australian Energy Market Operator's forecasts that there will be between 526 000 and 3.9 million EVs on Australian roads by 2030.[36] Bloomberg New Energy Finance projected by 2025 that 6 per cent of new passenger vehicles will be EVs rising to 28 per cent by 2030, and 60 per cent by 2040.[37] The Department of the Environment and Energy observed:

> EV uptake has been slower in Australia but is expected to increase as technology becomes more affordable and evolves to suit consumer requirements.[38]

2.28 In a 2018 report commissioned by the ARENA, Energeia modelled three EV uptake scenarios for the Australian market—no intervention, moderate intervention and accelerated intervention. Energeia forecast by 2030 that yearly EV sales could range from 22 per cent of new passenger vehicles under a no intervention scenario to 49 per cent (moderate intervention), and up to 64 per cent (accelerated intervention).

2.29 Energeia stated its assumptions for the moderate and accelerated scenarios:

> Moderate Intervention Scenario: assumes an unco-ordinated mix of policy support, across several layers of government, including potential federal policy changes to luxury car tax, fringe benefits tax and vehicle emissions standards, and a mix of the most likely state and local government [plug-in electric vehicle (PEV)][39] support from the list below. This scenario assumes no long-term decarbonisation target.
>
> - Australian states with net-zero targets and a history of policy action to support this in power generation introduce policies to support PEV uptake in their states. Policies include stamp duty and registration exemptions.
> - Local and state government fleets are pushed to increase fleet purchases of PEVs where there is a comparable PEV in the class.
> - Removal of restrictions on import of second-hand PEVs drives a larger second-hand market.
> - Preferential parking and use of transit lanes.
> - Assumes that a range of actors (governments, motoring associations, private companies) accelerate the roll-out of charging infrastructure which removes range anxiety, e.g. [Queensland] Superhighway and the NRMA network.

36 The Australia Institute, *Submission 1.1*, p. 1.

37 Bloomberg New Energy Finance, *Submission 127*, p. 17.

38 Department of the Environment and Energy, *Submission 72*, p. 3.

39 Energeia defines a PEV or plug-in electric vehicle as either a plug-in hybrid electric vehicle (PHEV) or battery electric vehicle (BEV).

- Assumes [Original Equipment Manufacturers] react to this policy support by increasing PEV model availability.[40]

Accelerated Intervention Scenario: assumes the unco-ordinated policy and OEM actions in the Moderate Intervention scenario occur earlier and to a higher level of support, representing a more aggressive push to support PEVs. In addition, it is assumed that as foreign-produced ICEs model availability decreases that a total ban in ICE sales is implemented towards the end of the projection period.

2.30 Energeia described the likely trajectory of EV uptake under a moderate and no intervention scenario:

> In the No Intervention scenario, PEV sales increase slower over time due to a reduced decline in PEV price premiums and model availability. Under the No Intervention scenario, the first PEVs to reach the two-year pay-back do so in 2027, three years later than the Moderate Intervention scenario. As a result, forecast PEV stock in the No Intervention scenario reaches almost 832,000 vehicles by 2030, 3.6 times smaller than the Moderate Intervention scenario. Looking further ahead, the PEV stock under the No Intervention scenario reaches 6.78 million vehicles by 2040, 48% smaller than the Moderate Intervention scenario.[41]

2.31 Table 2.4 provides a summary of the forecast model.

Table 2.4: EV uptake by scenario[42]

Scenario	2018			2020			2030			2040		
	Yrly Sales (%)	Yrly Sales (000s)	Stock (000s)	Yrly Sales (%)	Yrly Sales (000s)	Stock (000s)	Yrly Sales (%)	Yrly Sales (000s)	Stock (000s)	Yrly Sales (%)	Yrly Sales (000s)	Stock (000s)
No Intervention	0%	3	10	1%	12	30	22%	257	832	73%	1,045	6,775
Moderate Intervention	0%	3	10	1%	12	31	49%	612	3,010	100%	1,895	13,078
Accelerated Intervention	0%	3	10	4%	44	79	64%	857	4,927	100%	2,247	17,315

2.32 Notwithstanding the projected increasing uptake of EVs, the Federal Chamber of Automotive Industries (FCAI) remained more circumspect, submitting its research findings that ICEs will 'remain the predominate [drivetrain] for Australia light vehicles out to 2030':

> The internal combustion engine (ICE) will be the dominant source of power in passenger cars through to 2030. Hybrids will expand significantly (but they still have ICEs in them). Pure EVs will be niche.[43]

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40 Energeia, *Australian Electric Vehicle Market Study*, May 2018, p. 6.

41 Energeia, *Australian Electric Vehicle Market Study*, May 2018, p. 70, prepared for Australian Renewable Energy Agency and Clean Energy Finance Corporation.

42 Energeia, *Australian Electric Vehicle Market Study*, May 2018, p. 70.

43 FCAI, *Submission 119*, p. 8.

2.33 FCAI also noted that the 'incremental transition to low-emission power trains' would be a function of the relatively low replacement rate of the large Australian light passenger car fleet and that as annual new vehicle sales currently only represent 6.75 per cent of this fleet (and that new EV sales represent 0.2 per cent of this) that this would be a gradual process.[44]

Charging infrastructure

2.34 There is a variety of charging infrastructure or electric vehicle supply equipment (EVSE). Typically, these fall into three categories that are determined by the amount of charge that can be delivered in a set period of time which in turn determines how quickly an EV battery can be charged. First, is the standard household plug (less than 3.7 kilowatts (kW)). Second, is a slow charger (3.7kW to 22kW). Lastly, there are the fast chargers which can range from 22kW to 43kW. All of these chargers use alternating current (AC).[45]

2.35 There is now a range of DC chargers with up to 350kW, with higher levels currently under development.[46] The benefit of these chargers with a faster charging capacity is that an EV with a 60kW battery can be recharged in about 15 minutes, with new higher capacity chargers (up to 475kW) likely to reduce this time further.[47] Public charging infrastructure generally falls into two categories—fast/ultra-fast chargers for long-haul applications and slower chargers for destination or convenience charging, such as at supermarkets or parking stations.

2.36 ClimateWorks and the Electric Vehicle Council observed that in 2018 there were 783 public charging sites in Australia—an increase of 64 per cent from 476 in 2017—equating to 'one charging station for every six EVs'. The vast majority of these—714 chargers—are AC chargers.[48] These public chargers are in addition to chargers found in homes (which in most countries is estimated to be about one private charger—home or work—per electric car). [49]

2.37 Figure 2.1 shows the total number of chargers found worldwide with China being the dominant in terms of EV units sold and publicly accessible chargers. China has nearly three-quarters of the publicly accessible fast chargers despite holding 40 per cent of EV stock.

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44 FCAI, *Submission 119*, pp. 4 & 6.

45 International Energy Agency, 'Global EV Outlook 2018', May 2018, p. 42.

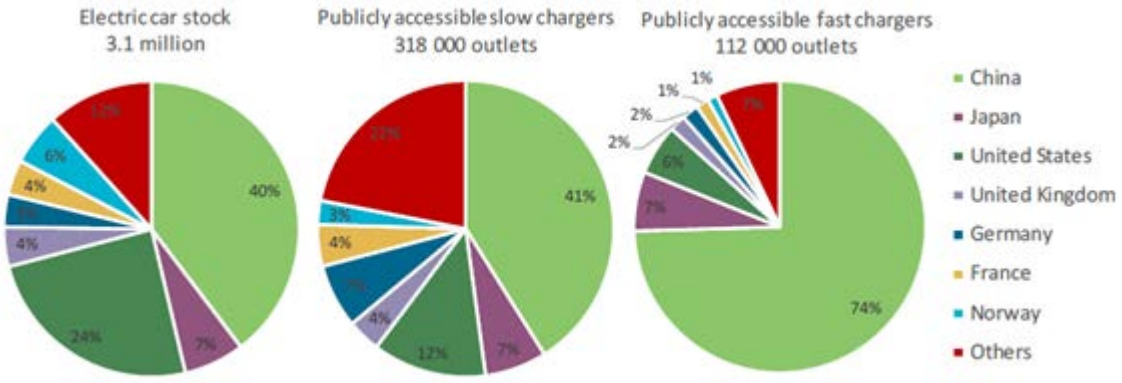
46 International Energy Agency, 'Global EV Outlook 2018', May 2018, p. 42. See also: Mark Kane, 'Chargefox launches first ABB Ultra-Fast Chargers in Australia', *InsideEVs*, 25 October 2018, https://insideevs.com/chargefox-abb-ultra-fast-chargers-australia/ (accessed 26 November 2018).

47 See, for example: Dr Paul Sernia, Chief Product Officer, Tritium, *Committee Hansard*, 27 September 2018, p. 8; Tritium, https://www.tritium.com.au/veefillpk (accessed 26 November 2018).

48 ClimateWorks, *Submission 46.1*, p. 13.

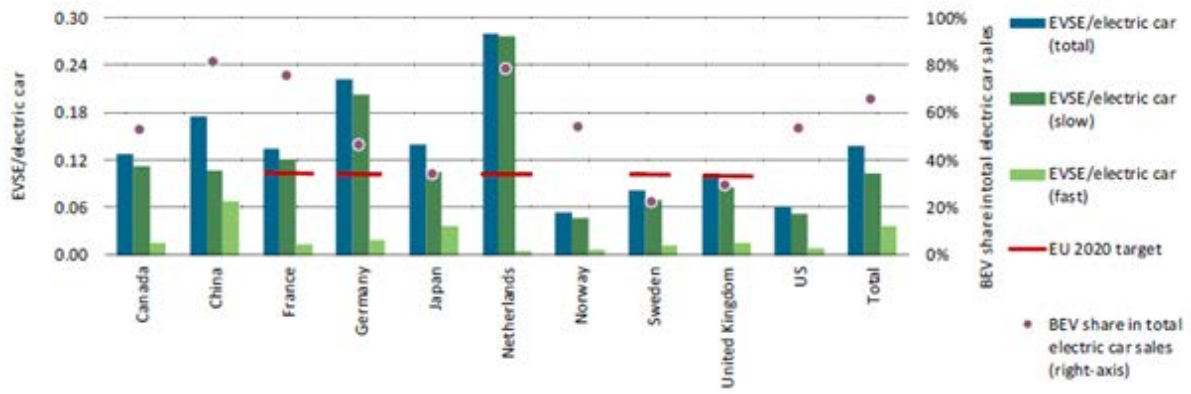
49 ClimateWorks, *Submission 46.1*, p. 13.

Figure 2.1: Electric car stock and publicly accessible charging outlets by type and country, 2017[50]



2.38 The Australian ratio of about one charger to every six EVs compares favourably with other countries, but also reflects the relatively low numbers of EVs in Australia. A comparison of the ratio of EV chargers to EVs in other countries with a higher proportion of EVs can be found below in Figure 2.2.

Figure 2.2: Ratio of publicly available charging outlets per electric car for selected countries[51]



2.39 Charging infrastructure and its interaction with the electricity grid will be discussed later in the report.

Diverse range of EVs—light passenger, commercial and public transport

2.40 The Committee notes that there is a wide diversity of EV transport types, from light passenger vehicles, to commercial vehicles, buses, boats, planes, bikes, and trackless trams. While the Committee received evidence in relation to a range of EVs,

50 International Energy Agency, 'Global EV Outlook 2018', May 2018, p. 46.

51 International Energy Agency, 'Global EV Outlook 2018', May 2018, p. 47.

the discussion focussed primarily on light passenger vehicles, followed by commercial vehicles and buses.

Hydrogen, hybrids or electric only

2.41 Earlier in the chapter, the different types of EVs including BEVs, PHEVs, and FCEVs (or hydrogen powered vehicles) were described. There were a range of views put forward as to what the transport fleet of the future would and should look like, and how this will influence the choices of consumers.

Hydrogen fuel cell vehicles

2.42 Ms Claire Johnson, Chief Executive Officer of Hydrogen Mobility Australia (HMA) made the following observation about hydrogen as a fuel source:

> The use of hydrogen in the mobility sector is being recognised globally as a solution to reducing greenhouse gas emissions and the world's reliance upon fossil fuels…
>
> With Australia's competitive advantages in renewable energies, combined with our automotive expertise from the ongoing R&D post local manufacturing in the country, we are really well placed to optimise the electric revolution taking place in the transport sector from both the hydrogen electric and battery electric perspective. However, in relation to hydrogen transport, the opportunity is even more significant. Australia is increasingly being recognised as a potential large-scale exporter of hydrogen to the world, and the CSIRO technology launched just this week in Brisbane represents a stepping stone towards fulfilling this exciting objective.[52]

2.43 Ms Johnson explained how hydrogen can be produced on-site at a service station with an energy source and water. Hydrogen can also be transported and stored using existing infrastructure:

> You can make your own hydrogen on site with an electrolyser—so generating hydrogen from water—or, alternatively, that hydrogen can be delivered via a pipeline or via a tube trailer. They are really the three methods by which the hydrogen is getting to the stations.[53]

2.44 Associate Professor Nerimi Ertugrul, from the School of Electrical and Electronic Engineering at the University of Adelaide, observed that 'based on the technical aspects, hydrogen has a future in big trucks, in long distance travel'.[54]

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52 Ms Claire Johnson, Chief Executive Officer, Hydrogen Mobility Australia, *Committee Hansard*, 10 August 2018, p. 26.

53 Ms Claire Johnson, Chief Executive Officer, Hydrogen Mobility Australia, *Committee Hansard*, 10 August 2018, p. 26.

54 Associate Professor Nerimi Ertugrul, School of Electrical and Electronic Engineering, University of Adelaide, *Committee Hansard*, 10 August 2018, p. 44.

2.45 Dr Jake Whitehead of the University of Queensland affirmed that hydrogen FCEVs could play a role in this space, whilst also acknowledging that there are other non-electric solutions available:

> The big challenge, I'll openly admit, is longer-haul travel. When we're talking about semitrailers that do 2,500 kilometres at the moment, current battery technology is just not feasible for reaching that distance in terms of the energy density. So, that's where we've got to try to understand what other technology's out there. Hydrogen's one option that may make sense, recognising that it's going to have a pretty high cost for fuel but also for infrastructure.[55]

2.46 In an answer to a question taken on notice, HMA noted that 'the tank to wheel efficiency of a hydrogen fuel cell vehicle is less efficient' than a lithium battery powered EV.[56] However, Ms Johnson noted that refuelling a FCEV is comparable with a diesel or petrol vehicle.[57] Dr Whitehead quantified the difference in efficiency between FCEVs and other types of EVs such as BEVS and PHEVs:

> Every time you change the molecules, you require energy, so in that process of extracting water, applying electricity to split it and compress it, transport it and run it through a hydrogen fuel cell vehicle, there are many more steps, and so, across those steps, there's a far greater loss. We talk about well-to-wheel efficiencies, and, with hydrogen fuel cell vehicles, they're a little bit better than petrol and diesel vehicles, but only by a magnitude of a couple of per cent, whereas electric vehicles are much higher. That's because you can use that electricity to directly charge a battery.

2.47 Dr Whitehead also commented on the likely cost differential between the two technologies:

> Based on the current projections of improvements in both technologies, we expect that EVs are going to stay around $3 per 100 kilometres, whereas hydrogen fuel cell vehicles will be $14 to $16 per 100 kilometres, so that is a significant price differential for consumers as well.[58]

2.48 Dr Whitehead extrapolated on the impact a fully hydrogen powered fleet versus a fully electric fleet would have on electricity demand:

> Let's just play out a hypothetical here where we're talking about 100 per cent of the passenger vehicle fleet in Australia being based on hydrogen. That's 14 million cars. That would result in about a 60 to 70 per cent increase in the national consumption of electricity. That's a major, major

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55 Dr Jake Whitehead, Research Fellow, School of Civil Engineering, University of Queensland, *Committee Hansard*, 27 September 2018, p. 53.

56 Hydrogen Mobility Australia - answers to questions on notice from public hearing in Adelaide on 10 August 2018 (received 11 September 2018).

57 Ms Claire Johnson, Chief Executive Officer, Hydrogen Mobility Australia, *Committee Hansard*, 10 August 2018, p. 28.

58 Dr Jake Whitehead, Research Fellow, School of Civil Engineering, University of Queensland, *Committee Hansard*, 27 September 2018, p. 51.

> energy increase required for the country to be able to go through. If we compare that to EVs, we're talking about something around 15 per cent.[59]

2.49 In response to a question on the risks and dangers of using and storing hydrogen, Ms Johnson said:

> Hydrogen fuel cell cars are on sale around the world, and the regulations, codes and standards have been developed for the handling of hydrogen gas from a transport perspective. The tanks themselves have been tested. They are tested in a fire bath, they are dropped from significant heights and they even do a gunshot test. They're actually made of carbon fibre that is inches thick.
>
> There have been no issues to date with the number of fuel cell cars on the roads. As I mentioned, there are regulations in place overseas, and we see the handling of hydrogen gas as no less safe than petrol or diesel. Because hydrogen is actually lighter than air, if there is to be a hydrogen leak, what will occur is that the hydrogen will actually dissipate into the air itself, unlike LPG, for instance, which is heavier than air, so that can pool in particular areas. Hydrogen does have some risks, of course, but they're all manageable, and they've been addressed overseas.[60]

2.50 Energeia acknowledged that FCEVs are seen as a potential challenger to plug-in electric vehicles, however noted the following downsides with FCEVs:

> FCEVs might require an entirely new hydrogen infrastructure to be developed, compared to PEV's which can rely on the existing electricity network for energy delivery.[61]

2.51 Energeia continued:

> It is worth noting that FCEV development has progressed at a slower pace than PEVs, and model availability is limited.
>
> The key question for FCEVs then is when FCEV costs, model availability and refuelling time will come down to benchmark levels, keeping in mind the rate of PEV improvement in driving range and refuelling time. In Energeia's view, recent PEV announcements by FCEV stalwarts including Toyota and Honda signals that even they are finally accepting that PEVs may become the dominant technology longer-term.[62]

2.52 Table 2.5 sets out plug-in electric vehicle and FCEV performance relative to ICE.

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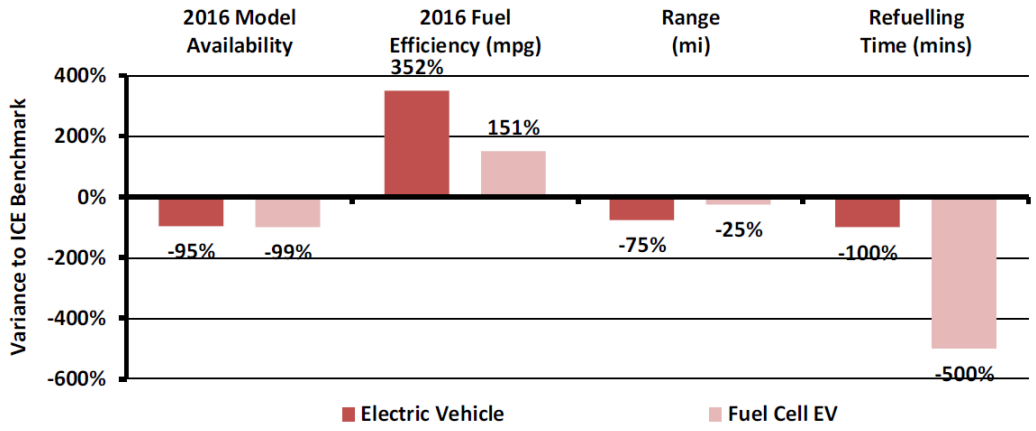
59 Dr Jake Whitehead, Research Fellow, School of Civil Engineering, University of Queensland, *Committee Hansard*, 27 September 2018, p. 51.

60 Ms Claire Johnson, Chief Executive Officer, Hydrogen Mobility Australia, *Committee Hansard*, 10 August 2018, p. 29.

61 Energeia, *Australian Electric Vehicle Market Study*, May 2018, p. 47, https://arena.gov.au/assets/2018/06/australian-ev-market-study-report.pdf (accessed 29 November 2018).

62 Energeia, *Australian Electric Vehicle Market Study*, May 2018, p. 48.

Table 2.5: Plug-in Electric Vehicle and FCEV performance relative to ICE[63]



2.53 HMA argued in its submission that 'any discussion pitching one clean technology against another limits the world's ability to achieve meaningful emission reductions'.[64]

2.54 Woodside Energy provided the following summary of the global uptake of hydrogen FCEVs (HFCEVs):

> Hydrogen is being used successfully as a fuel in California where half of the world's private HFCEVs have been adopted. California has 30 refuelling stations that service 3,430 cars, and plans to build 200 stations by 2025.
>
> In Japan, there are currently 100 hydrogen refuelling stations. By May 2021, Japan aims to have 160 hydrogen refuelling stations and 40,000 HFCEVs on the country's roads. By 2030, it aims to have 900 stations to service some 800,000 HFCEVs including buses and forklifts.
>
> …Korea currently has 12 hydrogen refuelling stations with 310 planned for operation by 2022. The Korean government has ordered 5000 Hyundai Nexo HFCEVs.
>
> Hydrogen vehicle uptake has increased in European countries such as Germany, Italy, France, and the UK. Hydrogen buses are a core part of their clean air strategy.[65]

Plug-in hybrid electric vehicles

2.55 Range anxiety was highlighted as a barrier to EV uptake, particularly in a large country such as Australia. A number of witnesses flagged the role that PHEVs could play in providing greater certainty for long distance or more remote trips

63 Energeia, *Australian Electric Vehicle Market Study*, May 2018, p. 48.

64 Hydrogen Mobility Australia, *Submission 73*, p. [5].

65 Woodside Energy, *Submission 42*, p. [2].

through maintaining a traditional ICE as a back-up propulsion system.[66] Mr David Magill, Director of Government Relations and Policy at General Motors (GM) Holden told the Committee about a recent plug-in hybrid model and the benefits it provided in relation to alleviating range anxiety:

> In 2012 we had the Holden Volt, which was an electric vehicle with a [petrol] range extender. You could drive that vehicle permanently on battery, if you charged it up within the range of about 110 kilometres of driving on the battery. If you wanted to go further, the vehicle annulled range anxiety because it had a little generator that you could put some petrol in and extend the range to 650-odd kilometres.[67]

2.56 Mr Bernard Nadal, Senior Manager, Product Planning and Pricing at Toyota Australia expressed a similar view, supporting plug-in hybrids as an interim measure bridging the gap between conventional ICEs and fully electric vehicles:

> …ultimately, the push to an electrified environment won't happen overnight, and the purpose of plug-in [hybrids] is to allow people to experience the technology, become familiar with it and render the benefits of not just a hybrid system but also the extension of an increased battery range within the vehicle.[68]

Autonomous vehicles

2.57 The Committee has also heard that the development of autonomous vehicle technology will occur in parallel with the increased uptake of EVs. The recent Victorian Parliamentary report on EVs stated that the four pillars underpinning the future of transport are electric, connected, automated and shared.[69] Mr Daniel Hilson, Founder and Managing Director at Evenergi put the future of the transport and energy sectors into context:

> In a world where mobility and energy markets are being completely disrupted, we need to ask ourselves now if we want to be part of a backwater where old technology and old mobility solutions come to die or we want to be leading the world in which autonomous, connected, electric shared vehicles are implemented alongside and integrated with a renewable-powered and smart grid.[70]

66 See, for example: Mr Craig Norris, National PHEV Sales Manager, Fleet, Mitsubishi Motors Australia Ltd, *Committee Hansard*, 10 August 2018, p. 2.

67 Mr David Magill, Director of Government Relations and Policy at GM Holden, *Committee Hansard*, 31 August 2018, p. 62.

68 Mr Bernard Nadal, Senior Manager, Product Planning and Pricing, Toyota Australia, *Committee Hansard*, 31 August 2018, p. 66.

69 La Trobe University, *Submission 18*, p. 1.

70 Mr Daniel Hilson, Founder and Managing Director, Evenergi, *Committee Hansard*, 31 August 2018, p. 57.

2.58 Mr Tony Wood, Director of the Energy Program at the Grattan Institute warned that the future of transportation would be characterised by automation and that must be considered as part of any policy development with respect to EVs:

> the potential for autonomous vehicles is a very different dimension that adds significantly to the social consequences of transport. The way in which electric vehicles would then be operated, charged, managed and owned may very well be different. Again, we need to be careful that we don't commit our policy to a specific assumption about what the future might hold.[71]

2.59 Mr Wood elaborated:

> The consequences of autonomous vehicles which may be owned not by individuals but rather by companies, from whom we would use the vehicle, is a completely different paradigm. We'd have fewer vehicles on the road, but they'd be doing many more kilometres, and their usage and the way they would be charged and recharged would be completely different to if we had personal vehicles.[72]

2.60 In Adelaide, the Committee heard from a panel of private companies that are currently developing and rolling out autonomous vehicle technology both here in Australia and internationally. Mr Simon Pearce, Head of EasyMile Asia Pacific told the Committee about the work that his company have been involved in:

> EasyMile, as an organisation, is around 4½ years old. We have introduced over 260 autonomous electric vehicles around the world. Of those, we currently have nine in Australia, two from last year and seven this year. We are continuing to see an expansion in the autonomous electric vehicle market, which is shared autonomous public transport. To complement that we have recently partnered with the Transit Australia Group for automation of their larger electric vehicle, the XDi bus, within Adelaide, for production here. We'll continue to support not only the EZ10 shuttle but also other electric vehicles with other original equipment manufacturers, from an automation perspective, and 95 per cent of our vehicles are electric vehicles which do not have combustion engines.[73]

2.61 The Committee were told that there are a number of regulatory challenges with autonomous vehicles, specifically relating to operating driverless vehicles in public spaces such as roads, and that these vehicles are legally required to have a driver's seat and dashboard despite their being no operational requirement for either.[74]

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71 Mr Tony Wood, Director, Energy Program, Grattan Institute, *Committee Hansard*, 31 August 2018, p. 13.

72 Mr Tony Wood, Director, Energy Program, Grattan Institute, *Committee Hansard*, 31 August 2018, p. 15.

73 Mr Simon Pearce, Head, EasyMile Asia-Pacific, *Committee Hansard*, 10 August 2018, p. 12.

74 Mr Simon Pearce, Head, EasyMile Asia-Pacific, *Committee Hansard*, 10 August 2018, p. 13.

The Committee also heard about a number of other constraints that would impede the uptake of autonomous vehicles including issues around legal liability and insurance.[75]

2.62 Mr Christian Reynolds, Director of bus manufacturer, Precision Buses pointed out that automation offers an opportunity to prevent accidents rather than simply mitigating the consequences of one:

> I think, over the term, product design and architecture has been led towards management of crash or management of an event. Technology within autonomous has moved us more towards prevention, which then leaves the gap in how you engineer a product between and the classifications of product between. I think that's going to be the interesting place, because autonomous pods don't have the ANCAP five-star rating that passenger cars would have, but it prevents more than a historic vehicle would prevent.[76]

2.63 Although automation is starting to become more visible in controlled environments such as airports, witnesses acknowledged that full automation is still a number of years away:

> A level 5 vehicle, which is fully autonomous—eyes-off, hands-off—that's at least seven to 10 years away at this stage.[77]

First mile and last mile transport solutions

2.64 A number of submitters commented on the role that autonomous EVs would play in delivering first mile and last mile transportation solutions in concert with a broader public transport network. Sage Automation described the benefits of this type of transport solution:

> Providing enhanced mobility for those with disabilities and the aged by extending public transport to include the first mile / last mile of a journey. For example, providing transport from a car park to a hospital entrance or from a train station to a university.[78]

2.65 In its submission, La Trobe University described how first mile and last mile transportation augments public transport:

> Automated and electric vehicles, particularly when providing connectivity to public transport for what is referred to as 'first and last mile connectivity solutions', have the potential to substantially shift attitudes to mass transit. If an automated vehicle can bridge the gap between the source (e.g. one's home), the destination (e.g. La Trobe University) and the closest mass transit transportation hubs already (e.g. train stations or bus interchanges),

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75 Mr Adrian Fahey, Chief Executive Officer, SAGE Automation & Mr Roger Van der Lee, Director, Autonomous Programs, Aurrigo Ltd, *Committee Hansard*, 10 August 2018, p. 14.

76 Mr Christian Reynolds, Director, Fusion Capital and Director, Precision Buses, *Committee Hansard*, 10 August 2018, p. 25. See also: Associate Professor Jeremy Wooley, Director, Centre for Automotive Safety Research, University of Adelaide, *Committee Hansard*, 10 August 2018, p. 41.

77 Mr Simon Pearce, Head, EasyMile Asia-Pacific, *Committee Hansard*, 10 August 2018, p. 15.

78 Sage Automation, *Submission 84*, p. [6].

> then people would be more likely to use the public transport already on offer.[79]

2.66 The issue of familiarising and educating people on the use of EVs and AVs is examined further in Chapter 5.

Public and active transport

2.67 Internationally, there is an increased demand for electric buses. The Bus Industry Federation explained:

> Shenzhen, with its fleet of more than 16 300 buses, is the world's largest and only all-electric bus fleet. Electric bus technologies featured prominently in Shenzhen Bus Group's Bukit Merah bus contract bid in Singapore. Volvo has announced that it will only launch electric and hybrid models starting from 2019. France and the UK have announced plans to ban sales of diesel and petrol cars by 2040, with local air quality again a key driver of this change but [greenhouse gas] emission reduction is also important. The Netherlands and Norway plan earlier phase out dates.[80]

2.68 In its submission, Doctors for the Environment cited projections from Bloomberg New Energy Finance which suggested that sales of new electric buses could be as high as 84 per cent of all new buses by 2030. This trend would be driven by 'the total cost of electric buses being lower than conventional buses as early as next year'.[81]

2.69 A number of witnesses highlighted the need to promote an increased use of public transport and active transport.[82] Whilst acknowledging the benefits of increased uptake of EVs, the Public Transport Users Association (PTUA) has advocated for a focus on a 'greater role for public EVs and active transport' in order to reduce some of the negative impacts of vehicle use such as traffic congestion.[83] Public transport and active transport requires significantly less land for travel and parking than private

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79 La Trobe University, *Submission 18*, p. 3.

80 Bus Industry Confederation, *Submission 68*, pp. 3–5. See also: Queensland Conservation Council, *Submission 83*, p. 1.

81 Doctors for the Environment, *Submission 50*, p. 5. See also: Bloomberg New Energy Finance, *E-buses to surge even faster than EVs as conventional vehicles fade*, 12 July 2018, https://www.bloomberg.com/professional/blog/e-buses-surge-even-faster-evs-conventional-vehicles-fade/ (accessed 10 October 2018).

82 See, for example: Dr Ingrid Johnston, Senior Policy Officer, Public Health Association of Australia, *Committee Hansard*, 17 August 2018, p. 40. Mr Shane Rattenbury, Minister for Climate Change and Sustainability, Australian Capital Territory Parliament, *Committee Hansard*, 17 August 2018, p. 2; Ms Michelle English, Associate Director, Sustainability, City of Adelaide, *Committee Hansard*, 10 August 2018, p. 48.

83 Public Transport User Association, *Submission 45*, p. 1.

vehicles.[84] The PTUA expressed the opinion that 'the benefits of EVs don't come from EV use *per se*, but from the non-use of private ICEVs'.[85]

2.70 Notwithstanding these views on public transport, Mr Shane Rattenbury MLA, the ACT Minister for Climate Change and Sustainability advised the Committee of the overwhelming Australian trend to use private vehicles as the primary means of transport:

> Certainly, in this city, we have the lowest public transport usage of the large cities in Australia, in terms of people getting to work, and a very dominant use of the private motor vehicle for transport around town. Ninety-five per cent of those transport emissions come from private motor vehicle use.[86]

2.71 Ms Sally Noonan, Chief Economist at the Queensland Department of Transport and Main Roads reported that the Queensland Government was currently trialling the rollout of eleven electric buses in the Brisbane airport precinct as part of a collaboration with local government.[87] The South Australian Government is trialling electric buses[88] as too is the ACT Government which has recently purchased two fully electric buses and one hybrid bus.[89] As a result of a recent hybrid bus trial, which concluded that hybrid buses use 30 per cent less fuel than a standard diesel bus, the Victorian Government has committed to procuring 50 hybrid electric buses to be delivered by 2022.[90]

2.72 Ms Noonan also described the Queensland government's partnership with organisations such as James Cook University, Queensland Rail and local governments to co-locate public charging infrastructure with public transport.[91]

Electric buses

2.73 In its submission, the Sassafras Group was quite supportive of electrifying buses and heavy vehicles:

> The time tables and daily driving distances are well understood, and the vehicles and charging infrastructure can be readily configured to meet operational requirements. These vehicles will also provide the greatest public good as their have high annual driving distances therefore abating

84 Public Transport User Association, *Submission 45*, pp. 4 & 5.

85 Public Transport User Association, *Submission 45*, p. 13. Emphasis in original.

86 Mr Shane Rattenbury, Minister for Climate Change and Sustainability, Australian Capital Territory Parliament, *Committee Hansard*, 17 August 2018, p. 2.

87 Ms Sally Noonan, Chief Economist, Queensland Department of Transport and Main Roads, *Committee Hansard*, 27 September 2018, pp. 34–35.

88 Mr Christian Reynolds, Director, Precision Buses, *Committee Hansard*, 10 August 2018, p. 20.

89 Mr Shane Rattenbury, Minister for Climate Change and Sustainability, Australian Capital Territory Parliament, *Committee Hansard*, 17 August 2018, p. 3.

90 Bus Industry Confederation, *Submission 68*, p. 4. See also: Volvo, *Submission 70*, p. 1.

91 Ms Sally Noonan, Chief Economist, Queensland Department of Transport and Main Roads, *Committee Hansard*, 27 September 2018, p. 35.

> more CO_2 and harmful exhaust emissions and their low operating cost will either reduce the cost of public transport subsidisation or lower the cost for commuters.[92]

2.74 Mr Reynolds also noted that buses can, if needed, be charged very quickly. Notwithstanding some safety and engineering issues to be worked through, it is technically possible to charge an electric bus in about 10 minutes.[93] NHP reasoned that the usage pattern of buses is suited to night charging:

> Buses form an integral part of the public transport networks in our cities, with thousands of them on the road every day. Fuel for these buses is typically diesel. The average bus in Melbourne does around 200km of stop-start driving in a 24 hour period, with a long period parked at a depot every night. This usage profile makes buses, especially the ones on shorter routes, a perfect candidate for transitioning to electric immediately.[94]

2.75 The PTUA also noted that an increased use of public transport would result in significantly fewer road fatalities, indicating that use of private EVs would not change the number of fatalities associated with private internal combustion engine vehicle use.[95]

2.76 The Bus Industry Confederation remarked on some of the challenges for electric buses including 'road infrastructure impacts of increased bus gross vehicle mass as a result of batteries'.[96] Volvo also noted that longevity remains an ongoing issue that manufacturers are working to resolve:

> Our experience shows us that some electric buses last for 3 years—some last for 7 years, but none last for 15 to 20 years yet. Volvo's philosophy is that the bus we offer must achieve the same levels of reliability, longevity and service delivery as the diesel bus we replace. In the electromobility segment, the same principles apply as diesel in relation to reliability of the driveline, body life, parts support, dealer support and technical expertise.[97]

2.77 Volvo also highlighted the role that hybrid electric buses could play as an interim measure on the journey to fully electric buses:

> In operation, the Volvo diesel hybrid has proven over many years to be as reliable, or better than standard diesel buses. The design of the Volvo hybrid driveline enables the diesel engine to power the bus independently of the hybrid system if required. In addition, the fact the Volvo diesel hybrid does not rely on external electricity supply also ensures transport

92 Sassafras Group, *Submission 106*, p. 6.

93 Mr Christian Reynolds, Director, Precision Buses, *Committee Hansard*, 10 August 2018, p. 25.

94 NHP, *Submission 95*, p. [5].

95 Public Transport User Association, *Submission 45*, pp. 4–6.

96 Bus Industry Confederation, *Submission 68*, p. 5.

97 Volvo, *Submission 70*, p. 1.

> security in case of power outage, which becomes a critical issue to consider in the move to full electric buses.[98]

Trackless electric trams

2.78 An emerging type of electrified transport are trackless trams. Professor Peter Newman AO, Professor of Sustainability at Curtin University described trackless trams technology in a recent media article:

> Trackless trams are neither a tram nor a bus, though they have rubber wheels and run on streets. The high-speed rail innovations have transformed a bus into something with all the best features of light rail and none of its worst features.
>
> It replaces the noise and emissions of buses with electric traction from batteries recharged at stations in 30 seconds or at the end of the line in 10 minutes. That could just be an electric bus, but the [autonomous rail transit] is much more than that. It has all the speed (70kph), capacity and ride quality of light rail with its autonomous optical guidance system, train-like bogies with double axles and special hydraulics and tyres.
>
> It can slide into the station with millimetre accuracy and enable smooth disability access. It passed the ride quality test when I saw kids running up and down while it was going at 70kph – you never see this on a bus due to the sway.[99]

2.79 Professor Newman added that:

> The autonomous features mean it is programmed, optically guided with GPS and LIDAR [Light detection and ranging remote sensing technology], into moving very precisely along an invisible track. If an accident happens in the right of way a "driver" can override the steering and go around. It can also be driven to a normal bus depot for overnight storage and deep battery recharge.
>
> The standard [autonomous rail transit (ART)] system is three carriages that can carry 300 people, but it can take five carriages and 500 people if needed. In three years of trials no impact on road surfaces has been found.[100]

2.80 Trackless trams can be delivered at a fraction of the cost of conventional light rail or tram systems—$6–8 million per kilometre as opposed to $80–120 million for recent projects undertaken in Sydney, Canberra and the Gold Coast.[101]

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98 Volvo, *Submission 70*, p. 1.

99 Professor Peter Newman, 'Forget light rail, Perth: it's time to look at trackless trams', *WA Today*, 29 September 2018, https://www.watoday.com.au/national/western-australia/forget-light-rail-perth-it-s-time-to-look-at-trackless-trams-20180928-p506qj.html (accessed 15 October 2018).

100 Professor Peter Newman, 'Forget light rail, Perth: it's time to look at trackless trams', *WA Today*, 29 September 2018.

101 Professor Peter Newman, 'Forget light rail, Perth: it's time to look at trackless trams', *WA Today*, 29 September 2018.