# Perception and Capacity Factors affecting the Uptake of Electric Vehicles in Australia

## Synthesis Report - Module 1

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# EXECUTIVE SUMMARY

This report provides a synthesis of findings from a desktop investigation of a selection of factors that have the potential to affect the uptake of electric vehicles (EVs) in Australia. The report draws on findings presented in a number of reports, papers and case studies from both Australia and around the World to inform consideration of measures to affect the uptake of EVs. The initial findings suggest that:

1) It is difficult, if not impossible, to totally predict the uptake of EVs over time to a level of assurance suitable to inform public policy and decision making, the question is not whether the transition will happen, but rather how quickly will nations, states, companies, and communities position themselves to take advantage.

2) The transition to EV saturation is now well underway globally, is unstoppable, and is likely to follow a standard innovation diffusion curve, with a slow rise followed by a period of rapid uptake reaching saturation sometime before 2050.

3) The widespread adoption of EVs will present both risks and opportunities (with risks experienced by those who are slow to move, and opportunities able to be captured by those who prepare carefully and take early and strategic action) with the level of 'government ambition' influencing how much of each is experienced, with higher ambition leading to lower risk and greater opportunity.

4) As with other waves of innovation, even in the early stages, electro-mobility is already causing disruption to existing systems, due in part to the contribution to the increased rate of uptake of distributed energy resources affecting existing grid conditions, and in part to the fact that electro-mobility will see the need for an unprecedented nexus of transport, energy and development sector interests.

One of the reasons it is difficult to effectively predict the uptake of EVs is due to the fact that there are a range of interconnected factors that may influence uptake and it is not clear what the relative influence will be, which has resulted in varying predictions. For instance it is not clear what level of public charging facilities will be needed to facilitate greater uptake, with some calling it a major constraint and others saying it will have negligible impact. Based on the research for this report it is likely that the early majority of electric vehicles will be charged overnight at home using equipment provided with the vehicle. Typically this will involve the use of charging cords that can be plugged into a standard electrical outlet, with some 70 percent of Australians able to park in a private space with access to an electrical outlet. It is also likely that such charging will initially take advantage of off-peak tariffs that will provide the lowest cost and highest convenience option.

However this is the least advantageous outcome for the energy sector with the batteries in vehicles not available to the grid during the day, but rather increasing the base load requirement overnight – recognised by the WA Government 'Distributed Energy Resources Roadmap' considering "*incentives to promote daytime charging to help make best use of the midday solar generation peak.*"[1] Hence it is likely that if left to ad hoc efforts the early majority of EVs will not be available for storing excess renewable energy during the day, balancing loads across the grid to compensate for the rapid rise of small scale distributed energy generation (such as rooftop solar), or to contribute to the grid supply during times of peak demand. This means that because such services are not available at times that make sense to the grid, EV owners and operators will largely miss out on the opportunity to be compensated. In this scenario – effectively a 'Home-Range Scenario' – in the short term there are few implications for Transport Agencies other than to forgo possible compensation from fleets and to potentially provide long haul rapid charging along intra-city routes (as outlined in the WA Electric Vehicle Strategy[2]).

[1] Government of WA (2019) Distributed Energy Resources Roadmap, Energy Transformation Taskforce, Government of Western Australia.
[2] Government of WA (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.

It is clear however that Australia will soon move beyond early adopters of EVs and see an increasing rate of uptake due to shifts in three key factors, namely:

1) The running costs of EVs are now some 60 percent lower than internal combustion vehicles (ICV) and the purchase price is decreasing rapidly and will soon reach parity - for instance the purchase price of the Toyota Camry Hybrid EV being just $3,000 more than the internal combustion version (See Summary of Factor 1).
2) The median range of EVs is now over 400 km and maximum range over 600 km, which will dispel concerns around range for the majority of users (See Summary of Factor 2).
3) The majority of EV owners will be able to charge their vehicles cheaply and easily overnight in their home, dispelling the majority of concerns about the lack of road-side charging options (See Summary of Factor 3).

Hence as the uptake of EVs increases the opportunity costs associated with overnight charging will increase and this will very likely lead to a focus on shifting charging (and discharging) to periods where it can be of most utility to the electricity grid (also beneficial to the EV owner) – namely during the day, and especially during times of peak renewable generation and peak grid demand. In the longer term there will be a number of implications for Transport Agencies including:

- The *opportunity to provide day-time charging facilities*, mainly for slow-medium charging in car parking areas throughout the day for commuters (such as public transport parking areas), and for rapid charging at shorter stay destinations such as shopping centres and other hubs for those that cannot access home or work charging options.
- The *opportunity to provide grid services* using out-of-service vehicles such as buses, trains, and government agency fleets that can be connected to the grid to provide storage and balancing services at appropriate times to create value.
- The need to *develop effective road user pricing mechanisms* to allow EV users to contribute to costs associated with the road network that is currently supported through taxes on fossil fuel sales – which will decline over time as EV uptake increases.

However, realising the opportunity cost of having the majority of EVs charging overnight in private homes and facilities by shifting charging to times to suit and optimise the grid will require careful consideration of a number of additional factors, namely:

- The built environment will need to be upgraded to provide bidirectional charging facilities, mainly in private dwellings, commercial facilities, public short stay destinations, and public and private car parking areas (See Summary of Factor 4).
- The electricity grid will need to be upgraded to accommodate such bidirectional charging facilities, which will include a mix of slow and fast charging options depending on the location, which will have direct implications for the stability of the grid (See Summary of Factor 5).

It is clear that the level of government ambition directly affects the rate of uptake of EVs and such ambition can be communicated through a range of mechanisms, including policy, standards, financial incentives, infrastructure investments and awareness campaigns. Various developed nations have initiated incentives, such as Norway reducing taxes and parking fees on EVs[3] and each of the G7 countries offering purchase incentives, which have

[3] Fridstrøm, L. (2021) The Norwegian Vehicle Electrification Policy and Its Implicit Price of Carbon. *Sustainability* 2021, 13, 1346.

contributed to increasing uptake of EVs.[4] The Australia Electric Vehicle Council states that no successful electric vehicle market exists globally without financial incentives lowering the price barrier to entry for consumers.[5]

Understanding that both monetary and fiscal policy can affect uptake of EVs – rather than seeking to predict the level of uptake to inform decision making around electro-mobility readiness and response – it is recommended that careful consideration is given to the relative risks and opportunities associated with different levels of government ambition, namely:

1. *A Passive EV Approach*: As part of a passive approach the uptake of EVs is not actively encouraged or supported, with efforts to respond being held until risks manifest, resulting in limited opportunities to capture benefits.
2. *A Pre-Emptive EV Approach*: As part of a pre-emptive approach little is done to actively encourage or support the uptake of EVs, but efforts are initiated early to respond to both perceived short-term risks and opportunities.
3. *A Pro-Active EV Approach*: As part of a pro-active approach the uptake of EVs is actively encouraged and supported, and swift action is taken to respond to short and longer-term risks and opportunities.

As in the current under-supplied Australian car market, a lack of government ambition sends a clear signal to EV manufacturers that a nation or state is a weak market for EVs, discouraging manufacturers' efforts to export EVs as compared to other markets.[6] For instance, car manufacturers such as Kia have shown that lack of legislation to reduce carbon emissions is a direct deterrent to introduce EVs into the Australian market as it is their policy to only send their EVs to "*countries that have $CO_2$ regulations and have legislation in place*", according to the COO of Kia Australia.[7] While the level of federal government ambition remains low Australian consumers will not have access to the most advanced or affordable vehicles, further compounding the low ambition and ability of the market to uptake EVs.[8] The ACT Government however has a 'Transition to Zero Emissions Vehicles Action Plan - 2018-2021' that involves transitioning the government fleet to 100 percent EV, mandating planning laws to include vehicle charging infrastructure for all new mixed-use and multi-unit developments, eliminating EV stamp duty on EV sales and reducing EV registration fees by 20 percent.[9]

The Western Australian government released its 'State Electric Vehicle Strategy' in 2020 followed by its 'Electric Vehicle Action Plan' in 2021, with the goal to achieve *'a minimum 25 per cent electric vehicle target for all new light and small passenger, and small and medium SUV government fleet vehicles by 2025/26*'.[10] The strategy includes measures such as: investment in charging facilities in government buildings, trials of electric buses, and encouraging the Federal Government to introduce vehicle $CO_2$ emissions standards that are in line with other OECD countries, and providing *"reliable and easily accessible information on electric vehicles".* The priority areas of action as part of the strategy released in 2021 include:

- Electric vehicle uptake: which involves "*stimulating the electric vehicle market through fleet uptake, increasing awareness and promoting the importance of emission standards*", with a commitment to "*achieve a minimum 25 per cent electric vehicle target for all new light and small passenger, and small and*

[4] IEA (2020) Global EV Outlook 2020: Entering the decade of electric drive? International Energy Agency.
[5] EVC (2020) Submission to the House of Representatives Standing Committee on the Environment and Energy Inquiry, Electric Vehicle Council.
[6] Electric Vehicle Council (2020) 'State of Electric Vehicles August 2020', wwwelectricvehiclecouncil.com.au.
[7] Schmidt, B. (2019) Kia e-Niro delayed due to Australia's failure to introduce $CO_2$ regulations, The Driven, 13 November 2019.
[8] Electric Vehicle Council (2020) 'State of Electric Vehicles August 2020', wwwelectricvehiclecouncil.com.au.
[9] ACT Government (2018) The ACT's Transition to Zero Emissions Vehicles, Action Plan 2018-21, ACT Government.
[10] Government of WA (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.

*medium SUV government fleet vehicles by 2025/26*" along with developing information materials for the public;

- Infrastructure: which involves "*investing in, and facilitating, the provision of electric vehicle charging and refuelling infrastructure*", with a key focus on requirements for EV charging in new public buildings to be 'EV Ready', and consideration of ways to encourage day-time connection of EVs to the grid;
- Standards, guidelines and planning approvals: which involves "*developing and updating guidelines, standards and requirements for planning approvals to assist the safe and efficient adoption of electric vehicles and associated infrastructure*", with a focus on standardising charging equipment, supporting calls for 'EV Ready' buildings to be required in the National Construction Code; and
- Industry development: which involves "*developing areas of industry relevant to our state*".

According to the Strategy, "*The McGowan Government is committed to delivering a cleaner, more sustainable environment and supporting the industries of the future that will drive economic strength and create long-term jobs. The electrification of transport through the increasing adoption of battery electric and plug-in hybrid vehicles … will advance these priorities in our state…. The adoption of electric vehicles powered by increasing levels of renewable energy will be fundamental to reducing greenhouse gas emissions in the transport sector… The electric vehicle transition holds the promise of cleaner, more efficient transportation with a significant role for Western Australian industry*."[11]

[11] Government of WA (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.

# INTRODUCTION

## The Growth of Electro-Mobility

It is well established that the uptake of electric vehicles will rise dramatically in the coming decades and that this calls for a rethinking of the interaction between transport, energy, and urban systems. According to the State Electric Vehicle Strategy for Western Australia, "*The electrification of transport is emerging rapidly. Improvements in battery technology and reduction in costs, together with stricter vehicle emission standards and targets in many jurisdictions around the world, have led to increasing adoption of electric vehicles. Forecasts show a steep rise in global electric vehicle uptake as price parity with conventional vehicles becomes closer… The State Government is preparing for the increased domestic and international adoption of electric vehicles to ensure that we take advantage of economic, social and environmental benefits*".[12]

The swift development of sophistication and availability of EVs in recent years is a direct result of private investment and as a result, major obstacles to EV uptake globally have either been overcome or are expected to be overcome in the near future. For instance in January 2021 the US Government announced its intention to replace the entire federal vehicle fleet of some 645,000 vehicles with EVs, with a strong preference for EVs manufactured in the United States.[13] Shortly after this announcement General Motors announced they are phasing out diesel and internal combustion cars completely, with only electric to be sold after 2035.[14] However even such efforts are relatively late given that 99 percent of the worldwide electric bus fleet is in China, providing a significant head start on what is an inevitable transition to full electro-mobility in this century.[15] The growth in EVs globally is accelerating, with the Australian Parliament citing the following in a January 2019 Select Committee on Electric Vehicles report:

> "*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*."[16]

The Senate report also suggests that EVs will create a number of growth sectors in the Australian economy (namely infrastructure development, manufacturing sectors, installation activities, battery manufacturing, recycling, associated mining and EV research and development) that will provide significant opportunities for both Government and the private sector. Globally, the level of private investment in EV manufacturing - as well as research and development for improving performance and battery technology - has increased exponentially. This has been motivated by both altruistic and economic incentives. Australia however is poorly placed to benefit from such progress due to comparatively low sales growth, with car manufacturers uninterested in the Australian market due to a lack of government ambition to reduce greenhouse gas emissions and support electro-mobility.

This is despite findings such as those highlighted in the Electric Vehicle Strategy for Western Australia, that according to ClimateWorks, even in 2018, "*An average BEV charged using electricity from Western Australia's main grid – the South West Interconnected System – generates almost 30 per cent less greenhouse gas emissions*

[12] Government of WA (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.
[13] Hyatt, K. (2021) Biden administration will replace the entire federal vehicle fleet with EVs, CNET, 25 January 2021.
[14] Domonoske, C. (2021) General Motors Sets All-Electric Target for Vehicles by 2035, NPR, 01 February 2021.
[15] BloombergNEF (2020) Electric Vehicle Outlook 2020, BloombergNEF.
[16] Commonwealth of Australia (2019) Select Committee on Electric Vehicles Report, Senate Select Committee on Electric Vehicles, Parliament of Australia.

*than an average internal combustion engine vehicle in Australia*".[17] The Strategy also points out that "*Accelerating the uptake of electric vehicles in Western Australia will provide public health benefits of over $20 million each year by reducing air pollution*."

With the recent growth in uptake in EVs globally many authorities and businesses are now asking what the uptake rate will look like over the coming ten to twenty years in order to inform decision making.[18] In response, a number of modelling approaches have been used.[19] Beyond the fundamental aspects of the modelling approach used, EV forecasting efforts are heavily data-driven even by econometric standards, with data quality and availability often the primary restrictions in model choice. The key obstacles include limited transport sector datasets, sensitivity to unpredictable fuel prices, differing consumer values and preferences, and expensive datasets that are restricted to commercial users.[20] There is some scope to address data limitations using machine learning; however these forecasting methods are in their infancy and their development may be outpaced by actual EV uptake. Nevertheless, even with improvements in data acquisition and treatment, the problem is innately complex. EV uptake depends on dynamic economically and geographically disparate variables, and the present forecasting efforts vary heavily in boilerplate assumptions and disclaimers. However one thing is clear: nearly all forecasts agree that policy support is the key driver for EV uptake.[21]

A number of agencies and organisations have released predictions on the level of uptake of EVs in the coming decades however there is yet to be consensus, given the complexity of such predictions. For instance, Deloitte Insights suggest that by 2030 the global market share of EVs will be 32 percent based on compounding growth over the next 10 years of 29 percent, as shown in Figure 1.

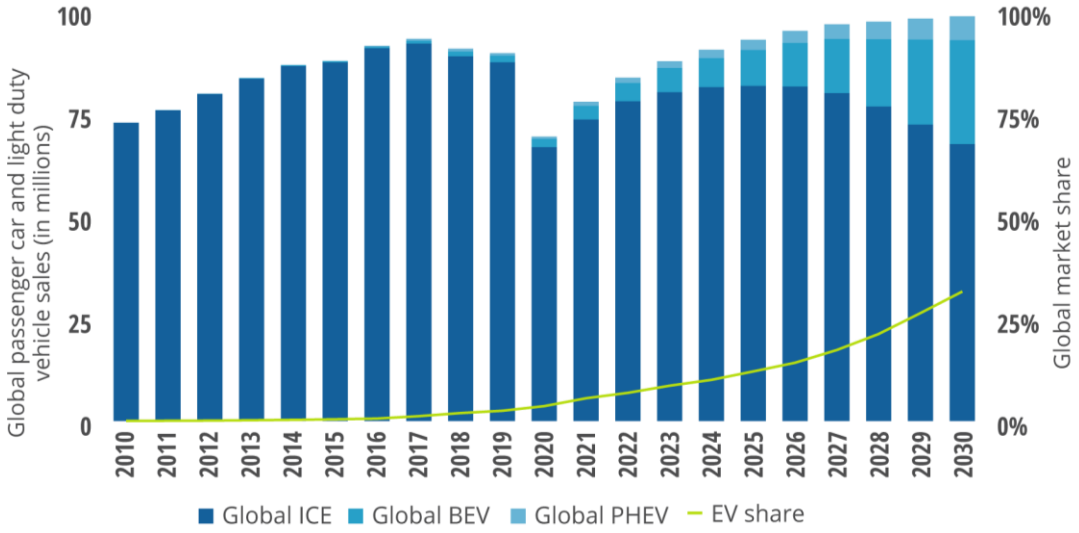


**Figure 1**: Outlook for annual global passer-car and light-duty vehicle sales, to 2030

Source: Deloitte (2020)[22]

[17] ClimateWorks (2018) The State of Electric Vehicles in Australia – Second report: driving momentum in electric mobility. ClimateWorks.
[18] Herbst, A., Toro, F., Reitze, F. and Jochem, E. (2021) Introduction to Energy Systems Modelling. Swiss J Economics Statistics 148, 111–135 (2012).
[19] Jochem, P., Gómez V., Jonatan J., Ensslen, A., Schäuble, J. and Fichtner, W. (2018) Methods for forecasting the market penetration of electric drivetrains in the passenger car market, Transport Reviews, 38:3, 322-348.
[20] Jochem, P., Gómez V., Jonatan J., Ensslen, A., Schäuble, J. and Fichtner, W. (2018) Methods for forecasting the market penetration of electric drivetrains in the passenger car market, Transport Reviews, 38:3, 322-348.
[21] Jochem, P., Gómez V., Jonatan J., Ensslen, A., Schäuble, J. and Fichtner, W. (2018) Methods for forecasting the market penetration of electric drivetrains in the passenger car market, Transport Reviews, 38:3, 322-348.
[22] Deloitte (2020) Electric Vehicles - Setting a Course for 2030. Deloitte Insights.

In Australia predictions have been made by AEMO, BITRE, and CSIRO – however the findings vary considerably due to differing assumptions and quality of input data, as can be seen from Table 1.

**Table 1**1: Summary of methods, key assumptions and predictions of Australian EV uptake studies

| Forecast | Method | Assumptions | 2030 | 2050 |
|---|---|---|---|---|
| AEMO (2017)[23] | Two parameter model using expected EV model availability and ROI. | – Model availability and ROI functional forms.<br>– Types of and sensitivities to government incentives.<br>– Negligible changes in depreciation/salvage. | 5% | 61.5% |
| BITRE (2019)[24] | Calibrating logistic curves derived from historic sales data using expected EV:ICV cost ratios. | – Uptake trajectory functional form.<br>– Constant internal combustion vehicle prices.<br>– National lag factors based on early adoption.<br>– Initial and maximum EV market saturation. | 27% | 65% |
| CSIRO (2020)[25] | Scenario planning with economic, infrastructure and policy drivers. | – Five scenarios of change with consideration of COVID-19 implications.<br>– Assumed values and sensitivities for each scenario. | 40% | 55% |

## Factors affecting Uptake of EVs

In 2020 Deloitte released the findings from a survey global of concerns regarding all battery-powered electric vehicles and identified a number of key concerns that may affect buyer interest, as summarised in Table 2.

**Table 2**: Summary of 2020 survey findings on concerns regarding all-battery-powered electric vehicles

| | US | Germany | Japan | Rep. Korea | China | India |
|---|---|---|---|---|---|---|
| Range Anxiety | 28% | 28% | 22% | 11% | 25% | 13% |
| Charging infrastructure | 25% | 22% | 29% | 32% | 20% | 26% |
| Price premium | 20% | 16% | 23% | 17% | 9% | 16% |
| Charging Time | 13% | 13% | 15% | 18% | 13% | 14% |
| Safety concerns | 8% | 12% | 10% | 19% | 29% | 25% |
| Lack of choice | 4% | 5% | 1% | 3% | 4% | 6% |
| Other | 2% | 4% | 0% | 0% | 0% | 0% |

*Source*: Deloitte, 2020[26]

For the purpose of this report the following factors have been selected for consideration as to their influence on the uptake of EVs:

– *Price Premium*: Concerns around the cost of EVs compared to internal combustion vehicles relate to the fact that electric vehicles are relatively new and have yet to reach economies of scale that will allow their purchase price to decrease, however prices are dropping rapidly. Between 2018 and 2020 concerns around price reduced by around a third in most countries surveyed, and this is likely to continue to reduce as the costs of

[23] Energeia (2018) 'Electric Vehicle Insights', www.arena.gov.au.
[24] BITRE (2019) Electric Vehicle Uptake: Modelling a Global Phenomenon, Australian Government Bureau of Infrastructure and Transport Research Economics (BITRE), 02 August 2019.
[25] Graham, P., and Havas, L. (2020) Projections for small-scale embedded technologies, CSIRO, June 2020.
[26] Deloitte (2021) Global Automotive Consumer Study 2021 - Australian perspective: Electric vehicles? Virtual sales? Maybe not so fast!, Deloitte.

EVs reduces. For instance the 'Dacia Spring' EV will be available in late 2021 in France at a cost of AUD$19,000 after purchase subsidies and has a range of 170-250km in the city depending on weather conditions, with home or workplace vehicle charging most likely to suffice most motorist needs.[27] It is also important to differentiate purchase price from running costs as despite typically higher current purchase prices for EVs, the RAC suggests that both the average energy costs and average servicing costs are in the order of 60 percent lower for EVs than internal combustion vehicles (ICVs).[28]

- *Range Anxiety*: Concerns around the distance electric vehicles can travel on a single charge can relate to the risk that a vehicle may not be able to travel far enough to return to a charging point. As can be seen from Table 2 this was a primary concern for a number of the countries surveyed in 2020. However according to the survey this concern reduced slightly since the previous 2018 survey in the majority of countries and it is anticipated that this will continue to reduce as the range of electric vehicles continues to increase. It is estimated that the median range of an EV has increased from 100 km in 2011 to 417 km in 2020, and interestingly in 2016 the minimum average range for ICVs was 386 km and the maximum range for EVs was 417 km, suggesting that even in 2016 there were models of EVs that had longer ranges than some models of ICVs.[29]

- *Charging Time*: The time required to charge an EV can vary from minutes to hours, depending on the type of battery and charger which are typically categorised as either a 'Slow Charger' (Level 1), 'Medium Charger' (Level 2) or 'Fast Charger' (Level 3). In the short-term slow charging times in the sporadic public charging facilities may discourage EV uptake, however as the increasing range of EVs raises the viability of slow charging at home overnight or at workplaces during the day, this slow charging is likely to become a dominant option, along with destination fast charging (such as at shopping centres) for those without access to chargers at home or at work. In 2018 it was estimated that some 70 percent of people in Australia with a car would be able to charge overnight at their home, with the remaining 30 percent restricted due to their residence – such as those with only street parking – and would need slow charging at work or rapid charging at a destination.[30] Hence, it is likely that the influence on uptake from charging times will reduce quickly.

- *Charging Infrastructure*: In the early stages of vehicle electrification the lack of on-road charging facilities may have slowed consumer uptake of EVs, but given the extended range of EVs today this is no longer a critical factor with the majority of EVs likely to be charged at home or at work. A 2018 study found that 99% of daily trips made in Australia were less than 50 km, implying a maximum round trip to return home of 100 km, which is now far less than the median range of EVs on the market – 417 km per charge.[31] In fact a reduced demand for public charging facilities has been seen in mature EV markets around the world, for instance Norway where a reduction in the number of drivers relying on public chargers each day drop from 10 percent in 2014 to just 2 percent in 2017.[32] Demand however will increase for on-road charging facilities to service regional and long-haul trips.[33] It is likely that the initial focus will be on amending building codes and associated standards to ensure appropriate charging facilities are provided in homes, apartments, workplaces, and public parking

[27] Davis, W. (2021) '2021 Dacia Spring EV: Europe's cheapest electric car', Car Advice.
[28] RACQ (2020) 'Car running costs', Royal Automobile Club of Queensland, RACQ.
[29] Nissan (2021) 'A New-Generation Electric Vehicle', www.nissan.com.au.
[30] Energeia (2018) 'Australian Electric Vehicle Market Study', www.arena.gov.au.
[31] Energeia (2018) 'Australian Electric Vehicle Market Study', www.arena.gov.au.
[32] Muzi, N. (2018) 'Only 5 Percent of EV Charging Happens at Public Charging Points', European Federation for Transport and Environment.
[33] Muzi, N. (2018) 'Only 5 Percent of EV Charging Happens at Public Charging Points', European Federation for Transport and Environment.

locations, and that the technology is standardised – as has been highlighted in the Electric Vehicle Strategy for Western Australia.[3435]

- *Electricity Grid Capacity:* The extent to which the grid capacity can support various levels of EV uptake is a significant factor to consider when attempting to predict future growth. Grid capacity could become a limiting factor if not managed properly, with inadequate planning likely to lead to more expensive networks and electricity costs as the *ad hoc* uptake of EVs continues.[36] In the short-term the *ad-hoc* nature of EV uptake is unlikely to be affected by grid constraints, however when such constraints are exceeded it is likely to result in higher energy costs that may affect the rate of further uptake. The current Australian electrical infrastructure with uncontrolled charging can support 5-10 percent electrification of the nation's fleet, while Western Australia can support up to 10 percent or roughly 200,000 EVs.[37] Hence, as the uptake of EVs increases there is likely to be the need for controlled charging mechanisms to allow time for upgrades to specific areas of the grid to enable greater EV uptake. It is likely that such measures will be politically unpalatable and may cause customers to seek alternative options. The location of charging facilities needs to consider a range of factors including the potential to create charging hotspots that can destabilise the grid.[38]

[34] Government of WA (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.
[35] AEMO (2020) 'Return to the World's Longest EV Super-Highway', Australian Energy Market Operator.
[36] ARENA (2021) 'Electric Vehicles', Australian Renewable Energy Agency.
[37] Li, M., and Lenzen, M. (2020) How many electric vehicles can the current Australian electricity grid support?, International Journal of Electrical Power & Energy Systems, Volume 117, 2020.
[38] Evenergi (n.d.) Managing the impacts of renewably power electric vehicles on electricity distribution networks, Evenergi.

# THEME 1: PERCEPTION-BASED FACTORS AFFECTING EV UPTAKE

## Factor 1: Comparative Purchase Price and Running Costs of EVs

### *What is the Factor?*

An increasing number of global car manufacturers are introducing new Electric Vehicle (EV) models or electrifying their existing product ranges, with the dominant middle and low-cost manufacturers increasing the availability and affordability of EVs in these markets.[39] In terms of government support, most developed nations' EV markets are more established than Australia's. This is due to decreasing cost and increasing acceptance of the vehicles as practical replacements for Internal Combustion Vehicles (ICVs), supported by government commitments and incentives. In Australia EVs are typically viewed as luxury vehicles, a perception reinforced by the Federal Government's Luxury Car Tax rebate being one of the few incentives applied to EVs. Such a slow response to supporting the uptake of EVs has resulted in reluctance from international car makers to export vehicles to Australia, with this trend likely to continue.

Generally the cost of EVs can be broken into two categories, the 'Purchase Price' and the 'Running Costs'. Currently the purchase price of EVs is relatively high as the technology is in relatively early stages of development. Considering running costs, it is widely understood that costs such as registration, energy (fuel), servicing and tyres are lower for EVs than comparable ICVs. For instance the RAC suggests that both the average energy costs and average servicing costs are 60 percent lower for EVs.[40] This suggests that the current main barrier to cost parity for EVs is the purchase price of the vehicle, which is likely to reduce over time as scale of production increases globally – much like any new technology.[41]

Early movers in this space are Toyota who have extensive experience with hybrid electric vehicles which can be seen as effective options to bridge the gap between fully internal combustion and fully electric vehicles in the early stage of the transition. In 2021 Toyota released the Camry Ascent Sport Hybrid and the Toyota RAV4 GX Hybrid both with purchase prices just $3,000 higher than the ICV versions.[42] The Hybrid Camry can provide estimated fuel savings of $627 per year, which means that it will become cost effective after only four years.[43] Hence even Hybrid EVs that are not able to be plugged in and charged are out performing ICV alternatives.

### *How is it likely to affect uptake?*

> ***The purchase price of EVs is likely to continue impeding initial uptake, however as the price reduces over time this will raise levels of uptake and be primarily affected by the level of government leadership.***

Comparing countries with high EV uptake rates it is clear that the level of government leadership is a consistent factor in higher uptake. A lack of leadership to support the transition to EVs is being seen by international EV makers as a sign that associated domestic markets are weak, meaning that the affordable models are exported to other countries with stronger government leadership (such as price incentives, government fleet commitments, climate change and other policies). For instance, the Dacia Spring EV will be available in late 2021 in France at a cost of AUD$19,000 after purchase subsidies and has a range of 170-250km in the city (depending on weather conditions) sufficient to meet most motorists' needs with home charging.[44] Meanwhile the cheapest EV available in Australia as of July 2021 was the MG ZS EV at a cost of $45,000.[45]

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[39] Wagner, I. (2020) Leading passenger electric vehicle models in EU by fleet size 2020, Statista.
[40] RACQ (2020) 'Car running costs', Royal Automobile Club of Queensland, RACQ.
[41] Rezvani, Z., Jansson, J. and Bodin, J. (2015) 'Advances in consumer electric vehicle adoption research: A review and research agenda', *Transportation Research Part D*, vol. 34, pp. 122-136.
[42] Toyota (2021) 'Camry Price', Toyota.com.au.
[43] Astbury, H. (2020) 'How much extra do you pay for a hybrid vehicle?', Savings.com.au.
[44] Davis, W. (2021) '2021 Dacia Spring EV: Europe's cheapest electric car', Car Advice.
[45] Dowling J (2021) '2021 MG ZS EV: Australia's cheapest electric car price rises after the introduction of tax incentives', Drive.com.au

Furthermore, Australian buyers cannot access the most popular EV in Europe – the Volkswagen ID3 – due to the current lack of emissions reduction policies and associated perceived demand. According to the Volkswagen Group Australia Managing Director, "*Every six months we do an update with a board meeting on the EV environment in Australia. They are sitting in waiting for something to change, you know, but nothing ever changes*", clarifying that the company is not asking for subsidies but rather "*a firm signal from the Australian Government that it wants to cut carbon emissions from the transport sector by a set amount by 2030, and planning guidelines from state governments to ensure all new public buildings come with charging stations*."[46]

### *How is it likely to change over time?*

> ***It is very likely that EV uptake will increase over time with greater appreciation of the significantly reduced running costs and decreasing purchase price and eventually achieves cost-parity, however this could be accelerated with government support.***

The country with the highest uptake rate of EVs is Norway with an estimated 56 percent new market share, followed by the Netherlands at 15.1 percent, and Sweden at 11.4 percent, each with progressive government policies and mechanisms – ahead of Australia at 1.1 percent. The Norwegian Government plans to phase out all cars that produce emissions by 2025, including hybrid vehicles.[47] As part of the plan there are a range of incentives to encourage the purchase of EVs, which have seen uptake levels rise from less than 1 percent in 2009 to 56 percent in 2019.[48] For instance, company car taxes for EVs have been reduced by 40 percent and an exemption has been granted from the 25 percent Value Added tax (VAT) on purchases since 2001.[49] The plan has already seen over 50 percent of new car purchases in 2020 being EVs.[50] For instance the EV version of the Volkswagen Golf can be purchased for 33,287€ compared to the internal combustion version which, when including $CO_2$ and $NO_x$ emissions, weight, and VAT, has a cost of 34,076€.[51]

However in Australia, the only incentive for EVs is the Federal Government 'Luxury Car Tax', which is levied at 33 percent of the value of the car above a certain threshold. In the 2021-22 financial year the threshold for internal combustion vehicle was $69,152 (reducing marginally each year thereafter), however the threshold for 'fuel efficient vehicles' was $79,659 (again reducing marginally thereafter). This means that an EV with a purchase price under $79,659 is not subject to the tax, however an ICV with a purchase price over $69,152 would be. However when both types of vehicles are over $79,659 the tax payable on the EV is only marginally less than the ICV.[52]

Along with Government leadership the other factor likely to affect the purchase price of EVs is the cost of component technologies, particularly the battery technology, however this is likely to have a short lived impact on uptake as costs decrease.[53] Looking back over the last 10 years the price of lithium-ion battery packs has fallen some 89 percent from US$1,100/kWh to $137/kWh, with BloombergNEF forecasting that by 2023 the average price will be close to US$100/kWh.[54] In Western Europe, where EV adoption is at some of the highest rates in the world, it is expected that ICVs and EVs will reach price parity in 2024-2025, largely due to stringent emission control policies forcing a market shift. In Australia, however, it is unclear when this parity will be reached as emission controls are much weaker and less ambitious, but it is estimated to occur closer to 2030.[55] However

[46] O'Malley, N. (2021) 'VW boss says 'embarrassing' rules stop cheap electric car imports', Sydney Morning Herald, March 23, 2021.
[47] NMT (2021) 'Norway is Electric', Media Release, Norwegian Ministry of Transport www.regjeringen.no.
[48] IEA (2020) 'Global EV Outlook 2020', International Energy Agency, www.iea.org.
[49] NECA (2021) 'Norwegian EV Policy', Norwegian Electric Car Association, https://elbil.no.
[50] Rodriguez, J. (2020) 'The Volkswagen ID.3 Finds its Footing in Norway', Jalopnik, https://jalopnik.com.
[51] NECA (2021) 'Norwegian EV Policy', Norwegian Electric Car Association, https://elbil.no.
[52] Australian Taxation Office (2021) 'Luxury Car Tax Rate and Thresholds' www.ato.gov.au.
[53] The Senate, Commonwealth of Australia (2019) Select Committee on Electric Vehicles 'Report', Chapter 2 www.aph.gov.au.
[54] Scott, M. (2020) 'Ever-Cheaper Batteries Bring Cost of Electric Cars Closer to Gas Guzzlers', Forbes, www.forbes.com.
[55] Newton, B. (2019) 'Nissan: Aussie EV Pricing Parity Years Away', Carsales, www.carsales.com.au.

there are signs of increasing uptake with EV purchases in Australia doubling in 2019,[56] and it is estimated that EVs in Australia could be up to 15 percent cheaper than ICVs by 2030 with appropriate measures taken.[57] According to the State Electric Vehicle Strategy for Western Australia, "*It is anticipated that BEVs will reach price parity with comparable internal combustion engine vehicles about the mid-2020s, differing somewhat depending on the vehicle type and jurisdiction. Some calculations estimate that total cost of ownership of BEVs is already close to internal combustion engine vehicles given their lower maintenance and operational costs*".[58]

[56] Infrastructure Victoria (2020) 'Victoria's Draft 30-Year Infrastructure Strategy', www.infrastructurevictoria.com.au.
[57] The Senate, Commonwealth of Australia (2019) Select Committee on Electric Vehicles 'Report', Chapter 3, www.aph.gov.au.
[58] Government of WA (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.

## Factor 2: Range Anxiety - How long can an electric vehicle travel on a single charge?

### *What is Range Anxiety?*

Range anxiety is the concern that a vehicle will have insufficient range to reach its destination, calling for lengthy recharging stops, which affects driver perception of vehicle reliability. When comparing Electric Vehicles (EVs) and Internal Combustion Vehicles (ICVs), anxieties often arise over perceived differences in their range, the time needed to refuel/recharge, and the availability of charging options. When considering range, it is important to understand that range requirements differ for different users. For instance in Perth, the average commuting distance is just under 30 km per day round trip,[59] suggesting that even when considering other domestic trips for shopping, etc., an EV with a range of 100 km could easily meet range requirements if charged each night, and perhaps even every second night for the average commuter. In a survey conducted in 2020, the Electric Vehicle Council found that Australian consumers typically underestimate the range capability of EVs, suggesting it is not fully realised that most EVs now have the capability to meet daily needs.[60]

Although most trips made in cars are significantly shorter than the maximum range of the vehicle, consumers can be hesitant to purchase an EV without the recharge time and vehicle range being directly comparable to that of an ICV. According to the US Department of Energy in 2016 the median range of an ICV in the USA was 660 km (estimated to be 763 km in Australia in 2020[61]), compared to the median range for electric vehicle being 135 km (which was up from 100 km in 2011). By 2020 the median range of EVs had increased to 417 km with an average maximum range of 647 km (which is up from 150 km in 2011).[62] Interestingly, in 2016 the minimum range for ICVs was 386 km and the maximum range for EVs was 417 km, suggesting that even in 2016 there were models of EVs that had longer ranges than some models of ICVs. Hence the rapid development of electric vehicle technology in the last decade has seen the range of EVs substantially increase – for instance, according to Nissan the range of the Nissan Leaf increased from 160 km in 2011 to 385 km in 2021.[63]

### *How is it likely to affect uptake?*

> ***In the early stages of EV adoption, the issue of range anxiety - which is attributable to the low ranges and slow recharge times of early EV models - can result in slower levels of uptake.***

The automotive industry has responded partly through the development of electric and internal combustion hybrid vehicles that include a lower range battery that is complemented by a small internal combustion engine, reducing overall fuel consumption without sacrificing range, which has alleviated this concern to some degree.[64] So far, EV adoption has mostly occurred in high-density regions such as northern and western Europe where there is also a high density of supportive public charging infrastructure.[65] This is also potentially the result of cultural attitudes toward new technology and environmental concerns. According to a 2016 study, EV adoption has been

[59] Australian Government (2015) 'Australia's Commuting Distance: Cities and Regions', Australian Department of Infrastructure and Regional Development, www.bitre.gov.au.
[60] Electric Vehicle Council (2020) 'State of Electric Vehicles August 2020' wwwelectricvehiclecouncil.com.au.
[61] Guthrie, S. (2020) 'What's in a Tank of Fuel? The Cars with the Best (and Worst) Driving Range in Australia', Car Advice, www.caradvice.com.au
[62] US Department of Energy (2016) 'Fact #939: August 22, 2016 All-Electric Vehicle Ranges Can Exceed Those of Some Gasoline Vehicles', US Department of Energy, www.energy.gov.
[63] Nissan (2021) 'A New-Generation Electric Vehicle', www.nissan.com.au.
[64] Krupa, J., Rizzo, D., Eppstein, M., Lanute, D., Gaalema, D., Lakkaraju, K. and Warrender, C. (2014) 'Analysis of a consumer survey on plug-in hybrid electric vehicles', *Transportation Research Part A: Policy and Practice*, vol. 64, pp. 14-31.
[65] Falchetta, G. and Noussan, M. (2021) 'Electric vehicle charging network in Europe: An accessibility and deployment trends analysis', *Transportation Research Part D: Transport and Environment*, vol. 94, art. 102813.

shown to stagnate in places with cultural attitudes that are sceptical of new technologies, as well as in cultures that are reluctant to support efforts towards environmental improvement.[66]

Currently, there is very little federal government-provided incentives or policy measures to support the uptake of EVs in Australia,[67] with this position often citing range anxiety as a reason for delaying the provision of incentives. This is despite technological advancements that have now largely reached range parity and even provide greater ranges than ICVs at much lower running costs.[68] Australian travellers also face large distances between urban centres and limited public transport infrastructure. Australia's prominent driving culture and tradition of outback exploration also exacerbate anxieties over limited range, which are no longer founded.[69]

### *How is it likely to change over time?*

> ***Range anxiety will likely decline rapidly as the range of EVs increases to meet and in some cases exceed that of comparable ICVs.***

In the short-term, consumers can maintain their ICV for infrequent long journeys while using a lower-range, affordable EV for most of their travel – especially commuting – that can be charged at home using off-peak rates. Improvements in the availability and speed of charging infrastructure will reduce range anxiety for journeys that are further than 400km, as well as help to increase the EV adoption rate in rural areas, where long trips are often a necessity. As EVs with longer ranges become more affordable, range anxiety will likely fade. However, it is important to consider that cultural attitudes may require more encouragement to change to favour EV adoption.

[66] Lance, N. and Sovacool, B. (2016) 'Why Did Better Place Fail?: Range Anxiety, Interpretive Flexibility, and Electric Vehicle Promotion in Denmark and Israel', Energy Policy, 94. pp. 377-386. ISSN 0301-4215.
[67] Foley, B., Degirmenci, K. and Yigitcanlar, T. (2020) 'Factors affecting electric vehicle uptake: Insights from a descriptive analysis in Australia', *Urban Science*, vol 4, iss. 4, p. 57.
[68] Lance, N. and Sovacool, B. (2016) 'Why Did Better Place Fail?: Range Anxiety, Interpretive Flexibility, and Electric Vehicle Promotion in Denmark and Israel', Energy Policy, 94. pp. 377-386. ISSN 0301-4215.
[69] Whitley, A., and McKay, G. (2021) 'Not even Tesla can overcome Australia's hostility to electric cars', Sydney Morning Herald, www.smh.com.au.

## Factor 3: Charging Rate – How long does it take to charge an EV

### *What is the Factor?*

The time required to charge an EV can vary from minutes to several hours, depending on the battery and type of charger. Therefore, the charging rate of EVs is a common point of comparison with ICVs, as the latter can be reliably refuelled in minutes at numerous easily accessible locations. There are three typical levels of EV chargers:[70]

*Level 1 - Slow Charger:* This involves a single-phase connection using a standard 10 Amp or modified 15 Amp domestic power point, which adds between 10 and 20 km of range per hour of charge, capable of fully charging an EV overnight at home, or during the day in a car park facility without expensive equipment.

*Level 2 - Medium Charger:* This involves a 32 Amp single-phase connection using a dedicated charging equipment installed by an electrician which typically adds 40 km of range per hour of charge, which can fully charge a vehicle or provide top up charging.

*Level 3 - Fast Charger:* This involves a 40 to 500 Amp three-phase connection using a commercial charger which adds at least 150 km of range per hour of charge, enough to fully charge an EV in 1-2 hours.

Western Australia currently has 209 dedicated EV charging locations, of which 27 are Level 3 chargers, ranking 4th for states in Australia for charging station penetration.[71] However, in metropolitan Perth there are just nine Level 3 chargers which is lagging behind other Australian capital cities, particularly Melbourne, Adelaide and Brisbane.[72] However as previously pointed out the early majority of EV owners are more likely to charge vehicles at home using a slow charger and taking advantage of off peak tariffs.

### *How is it likely to affect uptake?*

***In the short-term slow charging rates in sporadic public charging facilities may discourage EV uptake, however as the range of EVs increases, the viability of overnight charging at home will improve and it is likely to become the dominant option, followed by daytime charging associated with commuting.***

According to the Electric Vehicle Council, 70 percent of Australian's rank the availability of fast charging as 'important' and just 13 percent judge it to be 'unimportant', with home charging considered to be important by 86 percent of responders.[73] A 2018 study by Energia found that 70 percent of people in Australia with a car would be able to charge an EV at their home, with the remaining 30 percent currently restricted due to their residence, such as those with only street parking.[74] This suggests that the majority of early EV owners would be buyers that have access to home charging with slow to medium charging being sufficient given the long overnight charging period. On the other hand, buyers that are unable to access home charging are likely to be reluctant to purchase EVs until suitable charging facilities are available at their residence, workplace, or at short stay destinations such as shopping centres.[75]

[70] Electric Vehicle Council (2021) 'Types of EV chargers' www.electricvehiclecouncil.com.au.
[71] Electric Vehicle Council (2021) 'Types of EV chargers' www.electricvehiclecouncil.com.au.
[72] Foley, B., Degirmenci, K. and Yigitcanlaret, T. (2020) 'Factors Affecting Electric Vehicle Uptake: Insights from a Descriptive Analysis in Australia', Urban Science, 2020, 4(4), 57.
[73] Electric Vehicle Council (2019) 'State of Electric Vehicles August 2019' wwwelectricvehiclecouncil.com.au.
[74] Energeia (2018) 'Australian Electric Vehicle Market Study', www.arena.gov.au.
[75] Energeia (2018) 'Australian Electric Vehicle Market Study', www.arena.gov.au.

### *How is it likely to change over time?*

*Given that the majority of EV charging is anticipated to be undertaken at home or at work it is likely that the influence on uptake of charging times will reduce over time.*

Along with the likely provision of charging facilities in homes and workplaces (or parking structures) the range and energy-economy of EVs are expected to increase with future improvements in vehicle design and battery technology,[76] allowing drivers to charge less frequently. Furthermore, the distribution of Level 3 chargers in public parking areas will increase proportionally with the rising demand for EVs, improving the availability of convenient fast charging for those without other options.[77] This may however develop affordability issues with such charging likely to be at a higher cost than home charging options. From an energy utility point of view the charging of EVs has different implications when considering charging at home overnight compared to a workplace or public facility during the day, namely:

a. If charged slowly at home at night during an off-peak tariff (which is likely to be the cheapest option) this will increase the base load that can be sold by energy companies without competing with other demands.

b. If charged slowly at work during the day this will increase the demand on energy services while also providing a storage solution that may allow intermittent sources like wind and solar energy to be stored and then used by the grid during peak times.

c. If charged rapidly during peak times this will increase the peak demand and associated costs for energy utilities and should be discouraged.

Therefore electricity authorities will need to prepare for and balance this additional and highly fluctuating load through smart dynamic management of charging loads across the grid. This may occur in the form of variable tariffs across a 24-hour period to encourage users to charge their vehicles when loads suit the most efficient grid power balance.

[76] IEA (2020) 'Global EV Outlook 2020', International Energy Agency, www.iea.org.
[77] Muzi, N. (2018) 'Only 5 Percent of EV Charging Happens at Public Charging Points', European Federation for Transport and Environment, www.transportenvironment.org.

# THEME 2: CAPACITY-BASED FACTORS AFFECTING EV UPTAKE

## Factor 4: Charging Infrastructure - The level of provision of charging facilities

### *What is the Factor?*

With the inevitable merging interests of the energy, transport, and development sectors there is a need to re-evaluate how urban fabrics and energy systems across the wider built environment are designed and operated. While the energy sector is feeling the pressure from decentralised energy generation and its effect on the existing grid – largely from rooftop solar – it may be the case that EVs are a key part of the solution as they can provide distributed storage to reduce pressure on the grid if properly managed, in an energy sharing capability referred to as 'Vehicle-to-Grid' or V2G.[78] Two factors that may affect the success of a V2G solution are that the battery cycling involved may lead to accelerated degradation, and the additional load may further destabilise the current largely centralised grid infrastructure.[79] A 2009 study in the US found that automobiles were on the road for just 5 percent of the time, with some 90 percent being parked in parking lots during the day.[80] With the shift to EVs these vehicles stand to become an asset to the electricity grid that can assist in maintaining grid stability however they need to be plugged into the grid at the right times such as during the day to store excess solar energy, overnight to store excess wind generated energy, and during peak times to contribute to peak loads – energy resource logistics is critical.

Although it was the case in the early uptake stages that the shorter range of EVs would likely require substantial on-road charging infrastructure, this is no longer the case with the range of EVs now comparable to internal combustion options (with a median range in 2020 of over 400 km per charge[81]). Options for charging facilities currently being discussed include home charging, charging coupled to existing businesses and destinations, charging at car parking spaces and structures, and long-haul route charging (See Factor 3 for more detail). The capacity of charging facilities ranges from (up to) 3.6kW from an existing standard power point that provides 10-20 kilometres of range per hour of charge, to 350kW from a three phase power connection which can provide up to 1600 kilometres per hour.[82] Although the range of EVs is now comparable with Internal Combustion Vehicles (ICVs), in Australia some 30 percent of residences do not allow EV charging due to lack of access to suitable parking infrastructure and will require facilities either at work or in short stay destination charging locations.[83]

### *How is it likely to affect uptake?*

> ***In the early stages of uptake, the lack of on-road charging facilities may have slowed EV uptake but given the extended range of EVs this is no longer a major factor with the majority of EVs likely to be charged at home - however it will slow uptake among those unable to access charging at home.***

It is likely that the majority of drivers in Australia would not be impacted by the current availability of public charging stations due to the increasing range of EVs. The median range of EVs has increased rapidly from roughly

[78] Bibak, B., and Tekiner-Moğulkoç, H. (2021) 'A Comprehensive Analysis of Vehicle to Grid (V2G) Systems and Scholarly Literature on the Application of Such Systems', Renewable Energy Focus, vol. 36.
[79] Uddin, K., Dubarry, M., and Glick, M. (2018) 'The Viability of Vehicle-to-Grid Operations from a Battery Technology and Policy Perspective', Energy Policy vol. 113.
[80] Sovacool, B., and Hirsh, R. (2009) 'Beyond batteries: An Examination of the Benefits and Barriers to Plug-in Hybrid Electric Vehicles (PHEVs) and a Vehicle-to-Grid (V2G) Transition', Energy Policy vol. 37.
[81] US Department of Energy (2016) 'Fact #939: August 22, 2016 All-Electric Vehicle Ranges Can Exceed Those of Some Gasoline Vehicles', US Department of Energy, www.energy.gov.
[82] Electric Vehicle Council (2021) 'Types of EV chargers', Electric Vehicle Council, www.electricvehiclecouncil.com.au.
[83] Energeia (2018) 'Australian Electric Vehicle Market Study', Energeia, www.arena.gov.au.

100 km in 2011 to 417 km in 2020,[84] while most daily drives are far less than this distance. An Energia study in 2018 found that 99% of daily trips made in Australia were over distances of less than 50 km, implying a maximum round trip to return home of 100 km.[85] This falls far below the modern median range of EVs, suggesting that home charging would be sufficient for almost all journeys. This may not however be the best option for the electricity sector or the transport sector with the potential for using EVs to store excess solar energy during the day – or to be used for balancing loads – being lost with overnight home charging.

Given that the increased range of EVs has happened quite rapidly it is not yet fully recognised by the market and there are still some that consider the lack of on-road charging as a critical factor affecting uptake rates. For instance a Global Auto Consumer study conducted by Deloitte in 2020 indicated that an average of 27 percent of participants listed lack of charging infrastructure to be their greatest concern, however the preferred location was not asked.[86] Similarly according to a 2020 Electric Vehicle Council study, some 52 percent of survey respondents indicated that they were actively discouraged from purchasing an EV due to insufficient access to charging infrastructure, with home charging considered to be important by 86 percent of responders.[87] Hence as it becomes understood by consumers that EVs have extended and capable ranges, the concern around the provision of on-road charging is very likely to significantly diminish. Those EV owners that cannot charge at home however will be concerned about the cost of public charging facilities at either car parking facilities or at destination charging stations, such as shopping centres. Additionally, those road users that require extra-long trip distances will likely be hesitant, despite it being less economical to use fossil fuel options, and are likely to continue to use ICVs until such time as on-road fast charging is provided adequately along highway routes. Addressing this, in 2021 the WA Government has committed to "*invest up to $20 million to support the creation of an electric vehicle charging infrastructure network facilitating travel north from Perth to Kununurra, along the south-west coast to Esperance and east to Kalgoorlie*".[88]

### *How is it likely to change over time?*

> ***It is likely that the majority of EVs will be charged at home or at work with a small percentage requiring on-road charging options that will be facilitated over time, with the use of ICVs lingering for long-haul users.***

As it is realised that EVs now have comparable ranges to ICVs, driver behaviour will favour charging vehicles at home, or at work, meaning that the importance of public charging facilities in cities will decline. The reduced demand for public charging facilities has been seen in the mature EV markets around the world, with Norway seeing a reduction in the number of drivers relying on public chargers daily drop from 10 percent in 2014 to just 2 percent in 2017.[89] Demand however will increase for on-road charging facilities to service regional and long-haul trips with a 2018 study suggesting that one fast charging station every 34 km of motorway would be sufficient to cover the majority of journeys made between cities in Europe.[90] Although the demand for on-road charging in cities is likely to decrease, it is also likely that this infrastructure will still be used by EV owners that cannot charge at home or at work, and hence will need to be destination based with fast charging options – with a preference for destinations such as shopping, arts or dining precincts rather than service stations. It is also likely that

[84] Guthrie, S. (2020) 'What's in a Tank of Fuel? The Cars with the Best (and Worst) Driving Range in Australia', Car Advice, www.caradvice.com.au.
[85] Energeia (2018) 'Australian Electric Vehicle Market Study', www.arena.gov.au.
[86] Hamilton, J., Walton, B., and Ringrow, J. (2020) 'Electric Vehicles Setting a Course for 2030', Deloitte, www2.deloitte.com.
[87] Electric Vehicle Council (2020) 'State of Electric Vehicles August 2020' wwwelectricvehiclecouncil.com.au.
[88] WA Government (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.
[89] Muzi, N. (2018) 'Only 5 Percent of EV Charging Happens at Public Charging Points', European Federation for Transport and Environment, www.transportevironment.org.
[90] Muzi, N. (2018) 'Only 5 Percent of EV Charging Happens at Public Charging Points', European Federation for Transport and Environment, www.transportenvironment.org.

electricity utilities will seek to encourage EV owners to charge during the day to enable the grid to make use of the storage capacity in the vehicles rather than them simply acting as an additional base load overnight.

It is likely that the initial infrastructural focus will be on amending building codes and associated standards to ensure appropriate charging facilities are provided in homes, apartments, workplaces, and public parking locations, and that the technology is standardised.[91] For instance in 2021 the Australian Building Codes Board (ABCB) began consultation on building code changes that increase the ease of retrofitting EV charging equipment to more frequently visited buildings, including those used for apartment and multiple dwelling, non-residential, office, retail and business, storage, factories and public facilities.[92] Also the WA Government has stated, "*The incorporation of adequate electrical infrastructure at the time of building construction – particularly for multi-use dwellings, apartments and workplaces – will significantly reduce the cost associated with installing charging stations at a later date*". Furthermore, the 2021 Electric Vehicle Strategy for Western Australia includes a requirement for the provision of charging infrastructure in "*new public building capital works projects, including government office accommodation, hospitals, schools, TAFE colleges, sports facilities and a range of other building types to make them 'EV ready'.*" [93]

Such efforts will be complicated by the fact that a variety of parties are involved in the transactions associated with such charging options, such as private third-party providers and vehicle owners, electricity authorities, government and traffic authorities, all of whom will need to collaborate effectively to deliver mutual benefits. It is likely that government agencies will need to implement policies requiring that new apartment buildings be constructed with access to appropriate charging stations for residents, such as King County in Washington, USA recently requiring charging facilities in new developments.[94] There is also a need to ensure that the charging and storage profiles are suitable for the electricity grid and that it does not cause unintended consequences.

[91] AEMO (2020) 'Return to the World's Longest EV Super-Highway', Australian Energy Market Operator.
[92] ABCB (2021) 'NCC 2022 public comment draft (stage 2) consultation now open', Australian Building Codes Board.
[93] Government of WA (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.
[94] Stiles, M. (2021) New King County law requires EV chargers in new and refurbished apartment buildings, Puget Sound Business Journal, 14 July 2021.

## Factor 5: Grid Capacity - Ensuring the grid can handle EVs

### *What is the Factor?*

The grid capacity required to support EV encompasses public and private generating capacity, load management facilities, and charging and discharging infrastructure. As the uptake of EVs increases this capacity will need to be adjusted to avoid negative consequences. It is important that this be accomplished in a manner that positions the grid to capture benefits associated with EVs and other forms of distributed energy resources (DERs) while reducing the associated risks. The extent to which the grid capacity can support various levels of EV uptake is a significant factor to consider when attempting to predict future growth. Collaboration between energy retailers, operators and managers is necessary to ensure that the electricity grid has sufficient capacity for EVs, to provide equity of cost and location, and optimise the grid for power quality and balance of loads. Grid capacity could become a limiting factor if not managed properly, with inadequate planning likely to lead to more expensive networks and electricity costs as the *ad hoc* uptake of EVs continues.[95] The Norwegian national power regulator found that the need for significant power grid upgrades to accommodate EVs can be reduced if charging can be appropriately scheduled.[96]

Although at first this seems like an issue for the energy sector alone, it has implications for the transport sector with the potential to use EVs - especially fleets - as storage and balancing nodes across the grid. According to the WA Distributed Energy Resources Roadmap, "*At current uptake rates EVs are not expected to have a material influence on the grid prior to 2025. This is highly variable depending on local and national policies as well as actions from EV vendors. However, it is likely Western Australia will be able to learn from other jurisdictions with higher EV numbers and uptake rates on how to best integrate EVs to the grid. Vehicle-to-grid technology is also likely to be more mature by the time mass deployment occurs in Western Australia*".[97]

### *How is it likely to affect uptake?*

> *In the short-term the ad-hoc nature of EV uptake is unlikely to be affected by grid constraints, however when such constraints are exceeded it is likely to result in higher energy costs that may affect the rate of further uptake.*

Currently in Australia EVs pose negligible load, with approximately 18,000 registered plug-in EVs in 2020 – representing some 0.1 percent of the total fleet.[98] However, AEMO predicts it is likely that there will be some 4 million EVs in Australia by 2040, and points out that with uncontrolled charging this will cause serious issues for the national grid.[99] This concern is reinforced in the Australian Government's Future Fuels Strategy that cautions that accelerated EV uptake could exacerbate electricity demand peaks if charging occurs in peak periods.[100] As with WA – based on EV forecast uptake rates in South Australia – SA Power Networks anticipates implications on the network due to EVs by 2025, and recognise that the network will need to be ready for potentially higher-than-forecasted demand by this time. [101]

Hence there is no time to spare to explore appropriate ways to accommodate EVs and other forms of DERs, in a manner that is beneficial to the grid and to EV owners and managers – with the new 'Reliable and Clean Energy'

[95] ARENA (2021) 'Electric Vehicles', Australian Renewable Energy Agency.
[96] DNV (2020) Norwegian electric vehicles revolution drives grid investments and managed EV charging can save millions, DNV.
[97] Government of WA (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.
[98] ABS (2021) Motor Vehicle Census, Australia, Australian Bureau of Statistics.
[99] Energeia (2018) 'Electric Vehicle Insights', www.arena.gov.au.
[100] DISER (2021) 'Future Fuels Strategy: Discussion Paper', Australian Government, Department of Industry, Science, Energy and Resources.
[101] Evenergi (n.d.) Managing the impacts of renewably power electric vehicles on electricity distribution networks, Evenergi.

(RACE) for 2030 CRC including a heavy focus in this area.[102] This is likely to include measures to avoid dangerous surges, potentially in the form of smart load management to spread loads within network capacity. According to Infrastructure Victoria, providing incentives for people to charge EVs during off-peak periods could potentially save $2.5 billion in extra infrastructure investment.[103] However this is likely to encourage overnight charging which will forgo the potential benefits that EV batteries can provide the grid during the day.

According to the CSIRO and Energy Networks Australia there is a need to redefine the structure and architecture of the electricity system to meet the requirement for flexibility and agility in the future grid.[104] Infrastructure Australia suggest that this could see the need for an investment in the electricity sector between $2.2 billion and $9.7 billion by 2046.[105] In relation to EVs this may include equipment and upgrades to handle charging facilities at various locations across cities and towns (especially for those that cannot charge at home or work), fast chargers along long-haul routes, and equipment to manage the potential for demand hotspots to form that could have detrimental impacts on the grid. Such efforts will likely build from existing efforts to accommodate rooftop solar across the grid, such as grid-forming inverters to connect renewable generation in order to provide safe generating frequencies to match grid loads.[106] This is in replacement of grid-following inverters in conventional steady-supply generators which match electricity properties to the grid load, proving unfeasible in highly fluctuating grids.[107]

### *How is it likely to change over time?*

> ***As the uptake of EVs increases there is likely to be the need for controlled charging mechanisms to allow time for upgrading specific areas in the grid to enable acceleration of uptake. It is likely that such measures will be politically unpalatable and may cause customers to seek alternative options.***

Currently the low level of uptake means that the impact of EVs on the electricity grid is negligible, however as uptake increases electricity grids will experience stability and supply issues if not well managed, requiring early strategic action. Grid capacity is set to grow with increasing electricity demand regardless of EV uptake – the introduction of EV charging to the grid only exacerbating this demand. This is likely to raise serious questions about the location of charge-discharge points and the time of day that EVs can access the grid. The location of charging facilities needs to consider a range of factors including the potential for charging hotspots across the grid that can destabilise the grid, for instance:

- *Low Hotspot Risk*: Areas of low risk of creating hotspots include shopping centres, workplace charging, apartment buildings, hotel parking, and local on-street parking, each with an anticipated charger size ranging from 7 to 22 kW.
- *Medium Hotspot Risk*: Areas of medium risk of creating hotspots include street level residential, university campuses, airport parking, public carparks, ride sharing fleets and car sharing fleets, with charger size ranging from 7 to 330 kW, and the majority at 22 kW.
- *High Hotspot Risk*: Areas of high risk of creating hotspots include highway charging, pool vehicles, taxi fleets, bus fleets, and clusters of local, fleet, and destination chargers, with charger size ranging from 7 to 330 kW.[108]

[102] See: https://www.racefor2030.com.au/race-for-networks/project/
[103] Infrastructure Victoria (2020) Victoria's Draft 30-year Infrastructure Strategy, Volume 1, Infrastructure Victoria.
[104] CSIRO and ENA (2017) Electricity Network Transformation Roadmap: Final Report, CSIRO and Energy Networks Australia.
[105] The Senate, Commonwealth of Australia (2019) Select Committee on Electric Vehicles Report, www.aph.gov.au.
[106] EERE (2021) Powering On with Grid-Forming Inverters, US Office of Energy Efficiency and Renewable Energy, 04 January 2021.
[107] Parkinson, G. (2021) Groundbreaking solar inverter solution points way to grid free of fossil fuels, Renew Economy, 29 June 2021.
[108] Evenergi (n.d.) Managing the impacts of renewably power electric vehicles on electricity distribution networks, Evenergi.

In response to issues associated with the timing of charging, the ability to limit charging to grid-favouring times may provide a short-term mitigation method, allowing time for the grid to be upgraded or overhauled to handle a greater level of EV uptake. COAG has suggested that demand response capability should be considered in all household electric vehicle charging equipment by mid-2026.[109] ARENA is funding investigations into EV time-of-charging strategies with AGL and Origin to identify appropriate charging management protocols well before the rapid uptake of EVs begins to cause issues with the grid.[110] The trial findings will be important to inform grid management approaches that may lead to capital investment deferral and even demand curtailment as the level of EV uptake grows[111] – such as tariff reform to encourage charging during low demand periods or during periods of surplus renewable generation.[112]

[109] EVC (2020) State of Electric Vehicles, Electric Vehicle Council, August 2020.
[110] ARENA (2020) AGL Electric Vehicle Orchestration Trial, Australian Renewable Energy Agency, November 2020.
[111] Parliament of Australia (2020) Increased EV uptake and use—benefits and challenges, Chapter 3, Parliament of Australia.
[112] Origin (2020) Origin to launch EV smart charging trial, Origin, 07 August 2020.