Planning for the electrification of Australasian road transport

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Abstract

The research, development and marketing of EVs and associated components, especially batteries, is occurring globally at a rapid pace, in the major vehicle manufacturing nations of Europe, North America, China, South Korea and Japan. The quickly evolving new vehicle markets in these countries incorporate quantum leaps in new vehicle technologies and related social change, including more rapid adoption of the separate but related technology of driverless vehicles.

There is much research required to follow the implications of electrification on Australasian road transport. New vehicles and technologies are being unveiled around the world on a regular basis and the battle for market share and dominance is well underway. The Australasian public has already shown its willingness to adopt new EV related technologies. We have the largest domestic take up of solar roof installations in the world. People are buying electric bikes and personal mobility EVs in big numbers. The Australian mining sector is investing widely in deposits essential to the future EV transition like lithium, cobalt and copper.

1.Aims and Objectives of the Paper

The scale and scope of the topic is so vast it cannot be addressed in any meaningful detail by a single research paper at the current time. This paper is primarily a literature review which is attempting to define the current state of the EV transition in Australia, although this is constantly changing in recent years.

The paper identifies some solutions to the key problems faced by the EV transition currently in countries like Australia and New Zealand. There are many complex and inter-related problems which currently hinder the EV transition here, but there is much that can be learned from overseas experience, in particular by studying the responses of individual countries separately, as when the global data trends for the EV transition are combined this tends to mask the effects of any individual solution in any specific country.

Most advanced countries in Europe, North America and Asia are now embracing zero carbon emissions by 2050 and the phasing out of new fossil fuel driven vehicles by around 2030. The national governments are mandating the change, vehicle manufacturers are rapidly re-tooling and the infrastructure chain is rapidly switching to investments in renewable energy, battery storage and vehicle recharging networks.

Australia and New Zealand (NZ) combined are relatively small vehicle markets with 30 million people in total. By comparison Europe has 500 million, North America 400 million and China 1.4 billion people. However, the sea change of electric vehicles is beginning to hit our shores. A plethora of new cars, vans, buses, and trucks are rapidly being unveiled by existing companies and

new manufacturers like Tesla, Ford,Rivian and multiple Chinese manufacturers. Also, more ride sharing services over time, including driverless vehicles, can significantly reduce the overall demand for roads and parking space currently taken up by conventional internal combustion engine (ICE) passenger vehicles.

The options for the Australian and NZ governments playing any short term leadership role in change to our road transport and urban structures are limited as both countries have no significant car manufacturing capacity and are small markets further limited by the need to use right hand drive vehicles. The Australian Commonwealth Government has demonstrated little interest in policy leadership in this area and procrastinated in embracing globally compatible vehicle emission standards such as the Euro 6 (light vehicle) and Euro VI (heavy vehicle) emission standards.

There is an overwhelming short term need to undertake further research and planning for the EV transport revolution in Australasia at the national, state and local levels as roads and car parking are so significant to our economy and society and dominate our cities, taking up vast amounts of space and investment.

Chaos theory shows anything can and will happen over the next ten to thirty years as the seemingly inevitable electrification of road transport occurs. What future awaits us - dystopia or utopia? A global dumping ground for redundant models and second-hand ICE powered vehicles or driverless EVs, and Uber vehicles at call, signaling an end to mass vehicle ownership dominating our towns and cities.

In most countries it is likely that the Plug-in Hybrid electric vehicle (PHEV) will become an interim form of EV which will ultimately be phased out in favour of the Battery Electric Vehicle (BEV) or, potentially in the longer term, the Fuel Cell Electric Vehicle (FCEV) type, although it is likely to be many more years yet before that type of EV becomes widely available in Australasia.

Currently, the main deficiency of the PHEV type of electric vehicle in comparison to BEVs and FCEVs is the generally much lower operating range under electric power.

2. Global Outlook

2.1 National Totals of EV Passenger Car Fleets

The Summary “League Table” in Table 1 ranks countries by their electric vehicle fleets and the growth sales trends (Globally and for individual countries). The Global League Table compares countries by the size of their electric vehicle passenger car fleet compared to their global GDP Ranking from the “Economist” magazine.

Table 1 National Fleet Totals of Electric Cars at the end of December 2020

EV Rank	Country	GDP Rank	Total EV	BEV	PHEV	FCEV
1	China	2	4,514,114	3,512,477	996,191	5,446
2	USA	1	1,787,221	1,138,654	639,432	9,135
3	Germany	4	634,236	330,780	302,644	812
4	Norway	29	484,833	339,105	145,569	159

5	UK	5	435,293	207,441	227,624	228
6	France	6	416,585	281,603	134,607	375
7	Japan	3	297,181	136,700	156,381	4,100
8	Netherlands	17	291,447	182.481	108,652	314
9	Canada	10	209,171	127,487	81,588	96
10	Sweden	23	178,761	55,734	122,977	50
11	South Korea	12	138,082	119,691	8,350	10,041
12	Belgium	24	104,463	31,692	72,707	64
13	Italy	8	99,574	55,307	44,231	36
14	Spain	14	88,031	44,962	43,052	17
15	Switzerland	20	86,562	53,781	32,688	93
16	Denmark	38	61,727	31,892	29,718	117
17	Finland	43	55,319	9,697	45,621	1
18	Portugal	48	49,701	24,121	25,580	-
19	Australia	13	26,651	16,743	9,908	-
20	New Zealand	53	23,011	17,120	5,886	5

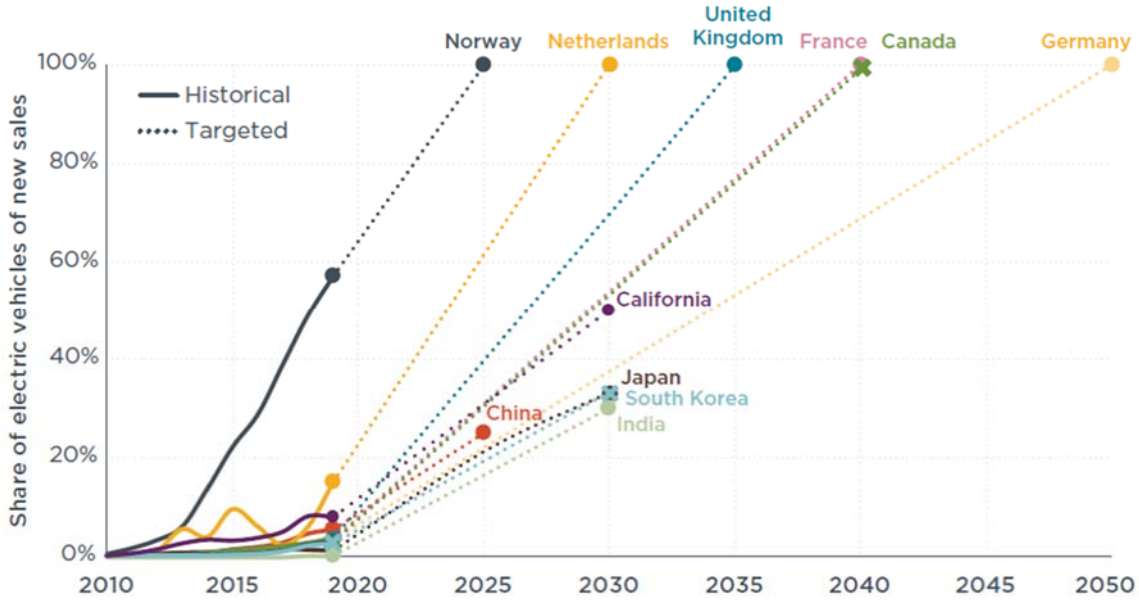
Source IEA, 2021 and The Economist Magazine, 2018

The Global League Table lists countries by the size of their passenger car EV fleet compared to their global GDP Ranking from the “Economist” magazine. Many countries are punching significantly above their weight in terms of their current total passenger car EV fleet, in particular the Scandinavian countries, where Norway is ranked 4th globally in terms of the size of the passenger car EV fleet, although it is ranked 29th in the world in terms of GDP.

In percentage terms, EV passenger car sales in Norway have now reached 70% of total new car sales in 2020 and the country is well on track to achieve 100% of total new car sales by 2025. In terms of the overall size of the passenger car EV fleet, Australia is not doing too badly, ranked in 19th place globally compared to 13th place globally in GDP, but it is actually only one place ahead of New Zealand who are ranked in 20th place globally for overall size of the passenger car EV fleet despite only ranked in 53rd place in GDP.

One of the main differences between the new car sales markets in Australia and NZ is that sales and vehicle imports in Australia are still dominated by the motor vehicle manufacturers, while in NZ over 50% of all new or “nearly new” car sales are effectively “third party brokered” personal imports. This results in a much greater range of EV vehicle types being imported to NZ, compared to the smaller range of new passenger car EVs available in Australia (NRMA Website, 2021). The overall global trends in total passenger car EV fleet size and the passenger car EV annual sales (IEA, 2021) appear to show a smoothly increasing growth in both the global EV fleet size and global annual sales but this smooth trend masks some divergent trends in individual countries.

Figure 1 :Global Forecasts for the EV Proportions of new Passenger Car sales since 2010



Source ARENA and CEFC, 2018

Japan and South Korea are still major countries of innovation in EV vehicle design and are the only two countries in the world where the most advanced FCEV type of electric vehicles are also forming a significant proportion of the annual new EV sales in 2019 and 2020.

The individual country annual sales charts from the 2021 EV outlook report show that in many countries around the world, EV manufacturers are now in a research and retooling phase, developing their new EV models and building up their manufacturing capacity for the “watershed” period which is coming during the years 2022 to 2025.

During this period a massive wave of new vehicle models from a wide range of manufacturers will hit the global market, and transform all previous national market predictions of EV sales up until now, resulting in a “Big Bang” of transformation of national passenger car vehicle fleets.

2.2 Global EV Manufacturing Capacity

The total global manufacturing capacity for passenger car EVs was less than 2 million per year in 2019 and increased to approximately 3 million per year during 2020. The production capacity is now forecast to increase rapidly to over 4 million in 2021 and then at ever increasing rates over the following seven years to reach a capacity of over 16 million vehicles per year by 2028. China is consolidating its position as the clear global market leader in EV manufacturing and sales. Due to their regional proximity and rapidly increasing EV manufacturing capacity, countries such as China, South Korea and Japan are most likely to become the main suppliers to meet the forecast rapidly increasing demand for new passenger car EV sales in Australia and New Zealand over the next decade.

A range of Chinese vehicle manufacturers – such as BYD, SAIC, Great Wall, NIO, GAC, Chery and Xpeng – are now leading the global production of the more affordable EV models (EV Sales Blogspot,2021), but most of their products are still unavailable to consumers in Australia. The Chinese EV manufacturers are set to dominate the overall global manufacturing capacity for passenger car EVs within the next three to five years (LMC Automotive, The New York Times, 2021). Similarly in Europe, many new EV models are now available since 2020 (IEA 2021) from

many manufacturers, including new EV models from Ford, Peugeot, GM, Honda, Seat, Smart, Toyota and Volkswagen.These models are currently unavailable in Australia.

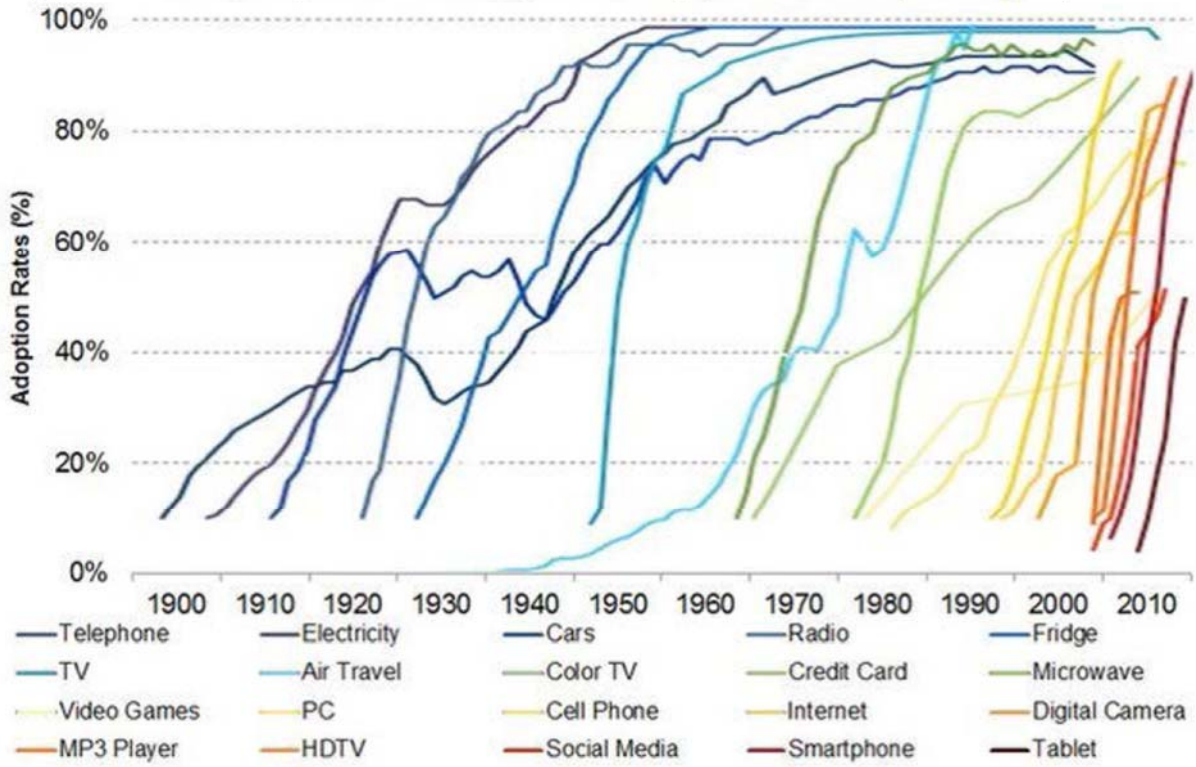
2.5 Consumer Subsidies

All the planning and industry development required to achieve a global transition is now effectively already in place, driven by the massive research and investment budgets of global car manufacturers. This transition is helped significantly by the increasing consumer subsidies for new EV vehicle purchases in many European countries, in particular in Germany and France (IEA 2021) where there are still large domestic car manufacturing industries, which the national governments will continue to support.

Historically, as shown by the following chart in Figure 2, the uptake of new products and technologies by consumers in the USA has been occurring at ever increasing rates over the past century. The latest new technologies such as smartphones and social media are now achieving effective full market coverage (between 90-100% consumer adoption) within a period of ten years or less from the first significant market breakthrough.

The first significant market breakthrough in EV sales has now already occurred and the following ten-year period (effectively the decade from 2020 to 2030) could potentially see an almost total replacement of new passenger car sales by EVs in most developed countries of the world. From the year 2030 onwards, a further ten to fifteen years will then be required to see the remnant ICE passenger car fleet fully replaced by EVs in most developed countries by 2045.

Figure 2. Historic adoption rates for new technologies in the USA (1900 to the present day)



Source: CASANZ 2021,Towards Net Zero Emissions in NSW,

3. Drivers and Trends

3.1 Regulations and Incentives

The primary international regulatory driver has been the multi-lateral country agreements on climate change like the latest Paris Agreement. Many European countries have set 2030 as the deadline for the sale of internal combustion engines and the switch to EVs. The UK government has progressively brought forward the banned sale of internal combustion engines from 2040 to 2035 and now 2030. Norway has a ban on internal combustion vehicle sales from 2025. It has the world's largest EV market penetration by market share, which is now over 70%.

Australia has no significant policies regarding the introduction of EVs. The state of NSW has been a leader in committing to net zero emissions by 2050. The transport sector, however, will be critical to meeting any new emissions target, as it contributes around 20% of the nation's greenhouse gas (GHG) emissions. One of the world's largest automobile manufacturers, General Motors, will make only zero-exhaust emission cars and trucks by 2035. It is working with the US Environmental Defense Fund to build around 500,000 EV charging stations and to convince customers to switch to EVs.

China has proactive policies promoting EVs in recognition of trends in Europe and the US, where it has vehicle manufacturing investments, and in response to the need for emissions reduction generally and to clean up air quality in its cities. Government policies will require most cars sold in China to be EV by 2035. They are also examining ways to connect all cars to the internet using a nationwide planned rollout of 5G mobile communications. In 2008 China made 2,100 EVs, in 2020 it made 931,000 (NYT,2021)

In Europe widespread adoption of EVs is anticipated when the purchase price of EVs is similar to that of ICE vehicles, and this is anticipated to occur in the mid-2020s. Prior to this, many European governments have introduced incentives of up to $10,000 (EV Council, 2021) to equalise prices. China and Europe are both expected to have around 72% of all new passenger car sales as EVs by 2030 due to their increased regulatory and policy measures. (Bloomberg, 2020).

Another key driver for the EV introduction and take up globally is the recognition by government and industry of the economic stimulation such dramatic re-tooling and innovation can have to national and regional economies. This can be a boost to the renewable energy investments which have similar benefits in terms of economic diversification and innovation whilst helping to achieve national and global emission-reduction targets. Stimulus packages in Europe and the US in response to the global financial crisis and the recent COVID-19 recession have also included incentives for investment in renewable energy and EVs.

3.2 EV Trends

Most manufacturers have now commenced making EVs, undertaken mergers and acquisitions, purchasing or joint venturing with related technology, research and component companies. This has occurred across a range of EV types including cars, trucks, buses and personal mobility vehicles. New manufacturers like Tesla have emerged to dominate the traditional car manufacturers in terms of capital value based on expected earnings. Technology companies like Apple, Google, Microsoft and Uber have invested in EV research and development.

Motor vehicles are evolving beyond commuting and mobility functions to become mobile work stations with a variety of digital communications and entertainment options included. Most EVs are the new technology leader in motor vehicle utility, with the epitome of intelligent vehicles representing a new status class. The number of overseas manufacturers having EVs for sale in Australia is extremely limited, demonstrating a lack of confidence currently in the sales potential in this market. To date Australia has effectively been treated as a test marketplace for EV products and in recent years, sales have been limited in number and dominated by the high-end manufacturers

such as Tesla, Audi, BMW, Jaguar, Porsche and Mercedes. In the short to medium term future to 2025-2028, the percentage of EV sales and the total EV percentage of the passenger car fleet in Australia are both likely to remain low (ARENA and CEFC, 2018) without significant government intervention to stimulate sales.

In 2020 there were just 6,718 EVs sold in Australia, which was significantly less than 1% of annual passenger car sales. Many earlier types of EVs sold in Australia by mainstream manufacturers such as the Holden Volt, Mitsubishi iMEV, Nissan Leaf (Type 1) and Renault Zoe are now no longer available as new vehicles. Understandably the take-up rate for EV sales in Australia has also been low as there have been no significant government incentives or regulation to date to promote EV sales as is happening in many overseas countries.

However, there are some early adopters responding to corporate climate change commitments. Canterbury Bankstown Council has some 46 EV/hybrids on a path to make their entire fleet of 345 vehicles EVs by 2025. It has a reported annual saving of $11,000/vehicle in maintenance and fuel costs (SMH, February 2021). AGL has committed to replacing its 400 vehicle fleet by 2030.

The analysis by (ARENA and CEFC, 2018) shows without intervention, the total % EV in the Australian passenger car vehicle fleet will still only be around 4% by 2030, while with maximum intervention it will increase to around 24%, which will be a big difference in terms of the future national emissions performance and national fuel security for Australia in the years after 2030.

In the Australian car sales statistics, a lot of 4x4 commercial utility vehicles, eg Toyota Hilux, Ford Ranger, Mitsubishi Triton are still currently classified as passenger vehicles, so the EV transition for passenger cars in Australia must also include equivalent new EV models to replace the current ICE versions of these vehicles. An Australian manufacturer, ACE plans to launch a range of light EV commercial vehicles and cars in 2021 for trade and city customers. This Queensland-based company has international partners. Its vans will be able to be assembled from flat packs and will also recharge power tools.

3.3 The EV Transition for Other Commercial Vehicles

In NSW, as shown in (CASANZ 2021, Towards Net Zero Emissions from Transport in NSW), the passenger car and light commercial vehicle fleets are currently responsible for 62% of the total GHG emissions from the transport sector combined.

The processes, procedures and community support for the EV transition for passenger car EVs are now already in place in most developed countries of the world (and arguably also in Australia).The future planning for the EV transition for heavy commercial vehicles and buses should probably be the main focus of future research from now on. For longer distance EV freight vehicles, the possibility of battery swap stations being established, will be a key factor in enabling the speedy recharge of these types of vehicles.

Electric Buses in Sydney (TfNSW, 2021) have been operating in the CBD and Inner City areas for over 18 months. now. Each electric bus is capable of operating for up to seven hours on a full charge. Brisbane is introducing two new Inner City routes of guided electric Metro-buses, with multiple recharge points localed along each route.

4.Goverment Policy and Planning Initiatives

Government and industry collaboration has led to the rapid rollout of EV policies, vehicle manufacturing, infrastructure development and customer take-up in many countries. Research

regarding EVs is a rapidly evolving and continually changing field, with many researchers working collaboratively in countries like the USA, China, the UK and in Europe. The US government has recently announced a suite of policies encouraging EV take up including a $10,000 rebate for new EV purchasers (EV Council, 2021) and the roll out of 500,000 charging stations. The US government's Green Stimulus Fund of $2 trillion includes subsidies for EV manufacturing to create one million jobs across the automotive sector.

There are clear economic benefits for Australian governments to allocate funds to EV and component research and component manufacture and banning imports of ICE cars as early as feasible, by the year 2026 potentially. Australia, particularly WA, has about 60% of the world's supply and/or production of Lithium for car batteries so Australia is well placed to benefit from the global transition to EVs.

The privately funded rollout of a network of public and private, fast and slow EV chargers throughout Australia is going well and should help to boost the consumer take-up rate for passenger car EVs, regardless of what the Australian Government does or does not do. Additional economic benefits can occur from the transformation and diversification of the national fleet conversion from ICE to EVs including greater opportunities for electrical grid flexibility and local expansion of capacity from the uptake in home/work/other charging points powered from rooftop solar panel installations.

The Australian Government will inevitably need to bow to international pressure and support the EV transition due to the weight of international commitments to introduce new car technology and to agree to and meet 2050 net zero emissions targets. Research into EV related areas in Australasia has been undertaken in an ad hoc fashion at national and provincial levels principally based on international experience. This has been hampered by the reduction in research and development budgets of road agencies and in tax incentives. An area of primary concern to government is the expected decline in fuel excise revenues which led to the publication by Infrastructure Partnerships Australia of *Road User Charging for Electric Vehicles* (IPA, 2019).

It can be expected that there will be an acceleration in EV associated research and planning in Australasia as EVs share of new sales increases in international markets, unit vehicle costs reduce and there are technology breakthroughs in critical areas such as battery cost, size and capacity and in charging capacity and convenience, including home storage from rooftop generation.

The gradual introduction and conversion of global vehicle fleets to EVs over the next five to twenty years to EVs will also facilitate the ultimate transport paradigm shift to the use of driverless vehicles. This technology is already being incorporated in many types of EVs including passenger cars, trucks, buses and vans and is being extensively trialed and monitored in the US and other countries by the likes of Tesla and Volvo. The implications of this technology on road transport generally and the shape and functioning of cities and regions are profound should it be introduced. It would more than likely reduce the need of current mass vehicle ownership.
Future research for the three tiers of Australian government is now urgently required in the following typical areas;

Commonwealth Government Responsibilities

- Ability to help meet national emissions targets and international treaty obligations
- Size and terms for new EV purchase incentives
- Reduction in fuel excise revenue
- Introduction of road user charging
- Impacts on road funding scope

- Need for remote area and long-distance fuel subsidies
- Fleet purchasing incentives
- The implications for national strategic fuel storage and exploration
- The implications of the catalyst for more widespread internet coverage

State Government Responsibilities

- EV Impacts on road funding planning, design and operations
- Grid capacity and charging rates
- Potential for EV battery storage to augment the grid
- EV charging infrastructure
- Vehicle registration and regulations
- Urban redesign of roads and car parking (with an ultimate scenario)
- Fleet purchasing incentives

Local Governments Responsibilities

- Installation of EV charging infrastructure
- Urban redesign- roads and car parking (with an ultimate scenario)
- Fleet purchasing

Local government agencies in Australia can help immediately by mandating infrastructure to support the installation of EV charging points for all new homes and commercial car parks which have "long stay" parking. It can the retro-fitting of all existing home garages and some commercial car parks to install EV charging points, preferably driven by solar panels, to minimise the future demands on the external energy supply infrastructure.

5. Summary and Conclusion

5.1 EV Take Up Rates for Australasia

The take-up rate of EVs in Australasia over the next 5-20 years and the need for associated infrastructure and research funding can be categorised on a spectrum from no intervention (Slow take up), to moderate intervention (Rapid take up) to accelerated intervention (Ultimate take up).

- Slow take up will occur with factors like weak economic conditions, higher EV cost and lack of government support through regulations and incentives.

- Rapid take up will occur with the opposite factors being strong economic conditions, lower EV cost and government support.

- Ultimate take up will facilitate the widespread introduction of all types of EVs including driverless vehicles at call, bringing an end to the age of mass personal vehicle ownership, except where vehicles are essential for personal or business reasons.

There is expected to be increasing pressure on Australasian governments to reduce national emissions and to comprehensively meet Paris Agreement targets for GHG emissions from both international and domestic sources. The public is becoming increasingly aware of imminent threats from existing levels of CO2 induced climate change and the consequent need to move as quickly as

possible away from reliance on fossil fuels. This is now happening rapidly in the energy generating sector and can be expected to accelerate rapidly in the transport sector as well.

Other local economic variables will also affect the EV take up rate. Lower home battery costs will influence people with rooftop solar generation to purchase EVs to gain advantage from low to zero daily fuel recharge costs. Industrial, commercial and retail businesses may also follow this model of independent energy generation, storage, and fleet charging.

5.2 Meeting International Targets and initiatives for EVs

Research tasks required will depend on a suite of factors like EV take up rates discussed in the next section. However, agencies with capital works planning horizons for 10-30 years such as in road and energy network planning and construction need to be considering them now. There are many unknowns as the implications can be expected to be momentous and widespread. It can be expected that crossovers can occur between industry sectors challenging the current forms of infrastructure silo governance. In the early development phases of electricity distribution tram networks were used to promote such electricity distribution and marketing. Today retail energy companies regularly sell telecommunication packages.

There has been virtually no government financial help to date for private purchase of an EV in Australia. The situation in NSW is due to change later this year with the introduction of a $3,000 subsidy for the first 25,000 EVs sold, for vehicles priced under $68,000 and the removal of stamp duty for electric vehicles priced under $78,000, but linked with the likely introduction of similar road user charging to other Australian states from the year 2027 onwards (SMH June 2021). In comparison due to government intervention;

- In Norway, 100% of New Car Sales will be electric by 2025
- In the UK, 100% of New Car Sales will be electric by 2030
- In the USA 100% of new car sales will be electric by 2035

5.3 Public Health Benefits of increased EV uptake

There are public health benefits from the EV transition in Australia in addition to reducing climate change impacts. These are from reducing particulate, NO2 and hydrocarbon fuel emissions from fossil fuel burning in urban areas, in particular along heavily congested transport corridors.

Due to the complex processes of quantifying adverse health outcomes, there are problems in actually quantifying the numbers of people affected each year and the ongoing community cost of deaths and illness for urban populations subject to exposure to motor vehicle exhaust emissions.

Even in a country like Australia this impact is probably at least 1,000 avoidable deaths every year, which is probably more significant in most states than the actual motor vehicle accident road toll.

Also, the collision avoidance technology in most new EVs in Australia should help to reduce the high rate of pedestrian injuries and fatalities from motor vehicles in urban areas as well, which is another net community health and economic benefit to support the introduction of EVs in Australia.

5.4 Road User Charging Principles for EVs

Australian governments are concerned about neutralizing the revenue loss from existing fuel taxes and levies, once EVs form a significant proportion of the motor vehicle fleet and want to replace lost revenue by new distance and time based tolling for all vehicles, instead of fuel excise taxes.

Both Victoria and SA have recently committed to introducing state-based taxes for distance-based tolling of EVs at about 2.5 cents per km, and there is strong budgetary pressure for other states including NSW to now follow suit.

There are many contrasting views in the main media channels and elsewhere on the proposed (and already approved in some states) measures to introduce uniform distance-based tolling systems for all passenger vehicles (IPA,2019), (EV Council, 2021), (SMH, May 2021), (Open Road NRMA Magazine, March/April 2021).

However, if distance-based tolling for EVs reduces early take up rates, this will clearly negate the potential environmental benefits of a more rapid transition to passenger car EVs in Australia.

5.5 Economic and Environmental Benefits

US manufacturers primarily showcase the high end EVs for their prestige value. The Chinese, Indian, Japanese, Korean and European manufactures are all working on the next generation of affordable EV models without frills.

A comparison of the EV and ICE car running costs in Australia vs the UK (where petrol or diesel fuel is effectively twice the price) would suggest that EVs will become a more financially attractive proposition for car drivers much earlier in the UK, than in countries like Australia and the US, where relatively cheap petrol and diesel fuel still dominates the price sensitive consumer purchasing decisions even for low to mid-priced passenger cars.

For reasons such as this, tougher vehicle emissions regulations in the major urban areas of Australia will also be necessary to enforce a greater uptake of EVs. The situation in Australia is similar to that in many other large cities in Asia, where the need to control motor vehicle exhaust pollution is still a major economic and public health objective.

5.6 Conclusion

The widespread introduction of EVs to Australasia is inevitable following international trends and efforts to reduce carbon emissions. Globally, vehicle manufacturers are retooling their factories to produce EV cars, trucks and commercial vehicles. ICE vehicle manufacturing is being phased out.

Australasian consumer markets have historically been responsive to adopting some innovative technologies such as rooftop solar installations, where this has been supported by appropriate subsidies in the early stages of the transition. Future Australasian research efforts should now concentrate on supporting the early adoption of the most successful EV vehicle manufacturing and infrastructure technologies being developed internationally for EVs including battery charging, commercial vehicles and grid security. It will be highly beneficial for our national governments to be proactive and introduce EV subsidies to support the early take up of EV private vehicle and fleet purchasing and related battery charging research, development and production, like we once supported ICE car production.

The motor vehicle is increasingly being used for other functions as well as transport, especially with the advent of digital technology. Today vehicles are also used as offices, mobile workshops and for onboard entertainment. This trend will accelerate with future vehicle manufacturers retooling for EVs, greater involvement of the technology companies and more widespread use of satellites for broadening internet coverage.

Tesla now has real-time monitoring of all its vehicle performance statistics worldwide. Driverless vehicles will become the ultimate step up in smart vehicle technology allowing for their use for a range of functions in addition to transport. The adaptation and implications of digital technology in motor vehicles will be significantly accelerated by the evolution of EVs. Only time will tell us how.

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