Considering Revenue Implications of EVs for Government and Transport Agencies

Synthesis Briefing - Module 2

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Table of Contents

EXECUTIVE SUMMARY **5**

INTRODUCTION **7**

ECONOMIC IMPLICATIONS OF ELECTRO-MOBILITY **8**

Overview 8

Government Operations 8

Fossil Fuel Security and Reliance *8*

Economic Benefits *9*

Standards Development *9*

Jobs Creation 9

Precinct Invigoration *10*

Foreign Investment *10*

Road and Transport Agencies 10

Tariffs for Road Usage *10*

Public Transport Authorities 14

Grid Services from EVs *14*

The Potential of Public Buses *15*

Park and Ride EV Charging *16*

Decommissioned Bus Batteries as Distributed Energy Resources *18*

Digitisation of Vehicles and Data Utilisation *18*

EXECUTIVE SUMMARY

The development of a set of interacting regulations, policies, standards and business models relating to electric vehicles has been shown to deliver substantial economic, social and environmental benefits in nations around the world that have been early to move. State governments in Australia are now anticipating the uptake and impact of electric vehicles, while the federal government is lagging. State initiatives include EV plans and strategies with varying levels of policy, actions and economic and technological considerations. In addition to modification of existing revenue streams, such as fossil fuel based taxes, EVs have potential for new forms of vehicle related revenue, such as finding their way onto the electricity grid and acting as distributed energy resources (DERs) to participate in energy markets. The transition to electro-mobility is seeing new economic levers being used by governments such as fines for manufacturer non-compliance to emissions standards as in the EU, or new taxes and tariffs for drivers of EVs in the USA and the UK.

Transport agencies can participate by tailoring tariffs for road usage, shifting the basis of revenue away from a declining fuel excise while drawing associated revenue collection away from federal governments. Australian states are in different phases of shifting to road user charges, with Victoria currently implementing system, and South Australia and New South Wales announcing plans for a delayed implementation, and WA not yet proposing a new charge. It is clear from public perception that the timing of implementation is essential. In the United States, the state of Oregon has implemented a variable road user charge for all vehicle types, maintaining equity for vehicle owners. The use of digital road user charging which is linked to the vehicle's location and route selection can not only provide an informed road user charge but also will provide valuable data to transport agencies. In fact such a digitised system provides the potential for a variable fee or incentive to be applied to every street, intersection and motorway, with vehicles comparing potential routes based on both trip time and road user charges, allowing real-time pricing interventions to encourage vehicles away from particular areas of the network into underutilised sections, while collecting road charges in real time.[1]

Transport authorities can also participate in new revenue opportunities created by electro-mobility through the electrification of shared transit fleets that both reduce running costs and provide distributed storage and discharge to the electricity grid, which is struggling to keep up with the uptake of rooftop solar energy generation (and may even require daytime curtailment). Park and ride facilities can now incorporate charging facilities to connect EVs to the grid during the day generating direct revenue from charging fees, grid services, and associated localised economic development in station precincts through greater use of shared transit. Given EVs can be used as Distributed Energy Resources (DERs) to store and discharge energy across the grid this can contribute to improved stability and reliability. In particular larger EVs such as buses and trains stand to provide valuable grid services while also being able to capitalise on fluctuating tariffs – currently being demonstrated at scale in London.

As this report will show, there are a range of other potential opportunities for revenue for government and transport agencies from the transition to electro-mobility that are being explored by governments and industry around the world, including the monetisation of charging related to transport data, reuse of decommissioned batteries as stationary DERs, and the use of electro-mobility as an activator for local economic development. The electrification of mobility will bring with it changes to the structure of costs and revenue for governments, and those that prepare well will reap the benefits of the inevitable transition. Industry can also reap huge rewards with the transition estimated to involve an increase in Australian GDP of $2.9 billion with the creation of z 13,400 jobs by 2030,[2] if the country follows Norwegian EV uptake rates. Economic and community precincts can find

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[1] Hargroves, K. (2021) Introducing the 'FreightSync Roadmap': A Pathway to Linking Freight Vehicles and Transport Systems – Final Industry Report', Sustainable Built Environment National Research Centre (SBEnrc), Australia.

[2] Electric Vehicle Council (2015) '*Recharging the economy. The economic impact of accelerating electric vehicle adoption*'. Electric Vehicle Council.

invigoration with utilising public charging stations to increase appeal to the public, while rural communities can attract travellers along charging highways.

The electrification of Australia's transport coupled with continued greening of the country's electricity generation will improve the nation's climate performance (for instance electrifying WA's fleet stands to lower state emissions by 16 percent) and strengthen foreign investment offerings that are now heavily scrutinising climate performance.[3] However given the shift to electro-mobility will have serious implications for electricity grids the transition needs to be designed in a manner that mitigates risk and captures rewards and is likely to involve a suite of regulatory, policy and business model measures that need to be harmonised. Following on from this investigation there are a number of key areas for consideration such as: how the decline of the hydrocarbon economy will affect WA's economic health; the quantifiable impact of charging stations in rural communities; demonstrations of improved tariff accuracy and equity; import revenue from new electric vehicles versus domestic production; and the need for increased electricity generation to accommodate vehicle charging loads.

[3] Hargroves, K. and James, B. (2021) Investigating the role of transport as part of Green Bond investment considerations, Sustainable Built Environment National Research Centre (SBEnrc), Australia.

INTRODUCTION

In response to the anticipated increase in uptake of Electric Vehicles (EV) this report considers a selection of associated revenue implications for government agencies and presents initial findings specifically related to transport agencies. The report covers a range of areas, including the opportunity to design equitable revenue streams for road usage that support ongoing transport infrastructure,[4] the opportunity to utilise government owned transport fleets to provide electricity grid services, and a range of secondary benefits. Given the uptake of EVs is closely aligned to aspirations to reduce greenhouse gas emissions and other pollution the uptake of EVs will be directly affected by the level of government ambition to reduce emissions and support fossil fuel free transport. Governments around the world stand to benefit in a number of ways from the transition to electro-mobility such as reduced air pollution (and associated health impacts), shifting from often foreign sourced fossil fuels to locally generated electricity, reducing running costs of vehicles for both the public transport and private fleets, and generating new local business opportunities for EV manufacture, charging and distributed energy resources. The implementation of effective policies and programs, such as government fleet commitments, emissions standards, EV rebates and financial incentives etc will see that states and nations are well placed to capture such benefits.

The Western Australian EV Action Plan (EVAP) is a comprehensive agenda that outlines a number of actions and timelines to support the uptake of EVs, including a focus on technology integration, tariffs and investment signals, managing 'Distributed Energy Resources' (DERs), and customer engagement.[5] According to the WA EV Action Plan, "*there are major gains to be made from early and coordinated action to support the integration of EVs while consumer norms are still being set prior to mass uptake*". According to the State Electric Vehicle Strategy for Western Australia, "*Electric vehicles also present an opportunity to help stabilise energy systems into the future. With vehicles already containing battery packs up to 100 kWh in capacity, and only being used a fraction of the time, there is the potential that the stored energy can be used for other functions such as providing vehicle-to-home or vehicle-to-grid energy services… Charging electric vehicles from solar energy during the middle of the day will provide multiple benefits of cleaner-powered transportation as well as soaking up excess cheap electricity generation and potentially reducing the need for network investment*." [6]

The transition to electro-mobility will call for the modification and creation of a range of new systems and approaches, to for instance, ensure that vehicles can interact with the electricity grid in a manner that is mutually beneficial. Benefits for vehicle owners from switching from internal combustion vehicles (ICVs) to electric vehicles (EVs) include both a reduction in travel costs,[7] along with the potential to provide services to the electricity grid while connected to generate income. For government agencies there are also a range of benefits as will be presented in this report, including: new taxes and tariffs, road user charges, revenue from grid services from fleets, data utilisation options, park and ride charging, and second life revenue from decommissioned batteries, along with improving job creation, industry growth, green investment credentials, and energy security. Western Australia is well placed to supplying minerals for electric vehicles (EVs) and is already supplying nearly half of the world's lithium[8] and is the world's second largest cobalt producer, while developing skills, infrastructure and industries to support value-adding options for export.[9] Hence it is likely that EVs will play a key role in the economic future of Western Australia both directly and indirectly and as such requires careful consideration of

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[4] Deloitte (2013) Road Pricing and Transport Infrastructure Funding: Reform Pathways for Australia Discussion Paper, Deloitte and Infrastructure Partnerships Australia.
[5] Energy Policy WA (2021) 'Electric Vehicle Action Plan' Government of Western Australia
[6] 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.
[7] Hargroves, K. and James, B. (2021) Perception and Capacity Factors affecting the Uptake of Electric Vehicles in Australia, A Report to the Sustainable Built Environment National Research Centre (SBEnrc), Australia.
[8] Chamber of Minerals and Energy WA (2021) Lithium and Battery Minerals, Chamber of Minerals and Energy Western Australia.
[9] Glacier Media Group (2020) Australia Cobalt Sector Set for Long-Term Growth-Report, Glacier Media Group, Mining.com.

the related implications. This report provides an initial overview of a range of such implications to inform further investigations. Note this report does not consider potential risks associated with capturing such opportunities.

ECONOMIC IMPLICATIONS OF ELECTRO-MOBILITY

Overview

It is clear that the transition to EVs is well underway and it will be important for governments at all levels to understand such implications and opportunities to best position themselves to capture benefits. Nations around the world have started introducing regulatory frameworks to underpin the transition to electro-mobility to both avoid the negative impacts of fossil fuel combustion and to capture the new opportunities. For instance the European Union has set a requirement that new cars registered in the EU from 2020 must emit less than 95g of carbon dioxide per kilometre, otherwise the manufacturer will be fined €95 (roughly AUD$150) per gram per kilometre over this minimum emission level. If this requirement was in place in 2019 this restriction would have generated some €34 billion (AUD$55 billion) in fines within Europe.[10] The fines however can be offset through the sale of EVs and other approved 'Zero Emission Vehicles' (ZEV) that earn the manufacturer credits, providing a meaningful incentive.[11]

Such government led incentives signal strong potential for future EV sales in the EU that has attracted the attention of EV manufacturers globally. Whereas the lack of meaningful incentives in Australia sends the signal that EV sales in Australia are likely to carry risk, hence EV manufacturers are hesitant to send their limited stock to dealers in Australia.[12] Nations are also using taxation mechanisms to discourage internal combustion vehicles. For instance, since 2001 the UK has imposed specific taxation levels for a vehicle's CO_2 emissions.[13] For the most common model vehicle on Australian roads - a Holden Commodore emitting 215g/km – this would equate to an emissions fee of $2,500 for the initial registration year and then $290 annually, in addition to other registration fees. Hence there are a number of economic considerations for governments around the transition to electro-mobility, which is now inevitable and unstoppable,[14] and each requires careful consideration. This report seeks to identify a number of such areas and provide initial guidance as to precedent and implementation based on world's leading practice in order to inform strategic approaches by transport agencies in Australia.

Government Operations

Before focusing on the potential revenue implications for transport agencies this part provides a snapshot of opportunities relevant to wider government operations.

Fossil Fuel Security and Reliance

In May 2021 Australia held 68 days' worth of crude oil reserves to refine into fuels including diesel and petrol, while it is recommended as a member of the International Energy Agency that at least 90 days is stored.[15] Australia's refineries are in Brisbane and Geelong – some 3,300 kilometres from Perth. As of 2020, WA produced 49 per cent of the world's lithium and held 21 per cent of the world's discovered lithium resources as well as other

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[10] JATO (2019) '2021 CO2 targets would generate €34 billion euros in penalty payments within Europe' JATO Dynamics

[11] European Parliament and Council (2020) Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011, European Parliament and Council, EUR-Lex.

[12] Purtill, J. (2021) Australians Want to Buy Electric Cars, But Car Makers Say Government Policy Blocks Supply, Australian Broadcasting Corporation.

[13] UK Government (2021) Vehicle Tax Rates, United Kingdom Government.

[14] Hargroves, K. and James, B. (2021) Perception and Capacity Factors affecting the Uptake of Electric Vehicles in Australia, A Report to the Sustainable Built Environment National Research Centre (SBEnrc), Australia.

[15] Zachariah, B. (2021) '*Government scrambles to maintain Australia's fuel security in Federal Budget*'. Drive.

minerals associated with battery manufacture, sourcing its electricity entirely inside the state.[16] This highlights that Western Australia is both the most vulnerable state to fossil fuel shortages, and the best positioned state to supply the global EV manufacturing market, especially when coupling battery vehicles for grid storage with the commitment to approaching 70 percent renewable energy by 2040.[17]

Economic Benefits

The replacement of personal Internal Combustion Vehicles (ICVs) with Electric Vehicles (EVs) can provide a range of economic benefits with, for instance, an average net benefit of $8,763 under Australian tax structures as of 2020, through financial savings and other channels such as reduction in emission of GHGs, pollutants and noise, while the replacement of a diesel bus with an electric bus can provide an average net benefit of $40,051.[18] With the transition of vehicles and energy systems away from fossil-fuel options there will be changes in the relative costs and revenues across the sector, both related to operational expenses such as fuel costs etc but also due to a shift to new business models that harness distributed energy resources such as micro generation and storage across cities.[19]

Standards Development

The Australian Standards referring to distributed energy resources (DERs) are yet to reflect the requirements to facilitate large scale EV integration into the grid.[20] Action is needed to update standards aimed at EV and other DER grid integration to simplify and streamline the implementation of revenue opportunities with respect to the parties involved. There are opportunities for local industries to be developed that support EV integration, in sectors of technology for vehicles and charging and transmission infrastructure, as well as supportive services through legislating third-party servicing providers. The WA EV Action Plan calls for Western Power's support and collaboration with AEMO and the Commonwealth Government to develop standards for the integration of EVs into the grid.[21] 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.[22]

Jobs Creation

A study by PricewaterhouseCoopers forecasts that if Australian EV uptake follows the rate of Norway, there will be a net increase of jobs from 2017 to 2030 of 13,400 and an increase to GDP of $2.9 billion.[23] Considering that EV prices are decreasing and pressure is mounting for the Australian Federal Government to introduce incentives that have been proven to kick-start uptake, it is very possible for Australia to follow the lead of Norway.[24] A study by Berkeley Economic Advising and Research (BEAR) predicted that in California the electrification of light-duty

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[16] WA Government (2021) Western Australia Battery Mineral Profile – March 2021; ga.gov.au. (2021) *Lithium | Geoscience Australia*, Government of Western Australia, Department of Jobs, Tourism, Science and Innovation www.ga.gov.au; WA Government (2021) *Electricity industry*. wa.gov.au.

[17] WA Government (2021) Whole of System Plan Information Sheet – August 2020, Government of Western Australia, Energy Transformation Taskforce, Perth.

[18] Ernest and Young (2020) 'Uncovering the hidden costs and benefits from Electric Vehicle', Ernest and Young.

[19] Clean Energy Council (2021) 'Clean Energy Australia Report 2021'. Clean Energy Council.

[20] Energy Policy WA (2021) 'Electric Vehicle Action Plan' Government of Western Australia.

[21] Energy Policy WA (2021) 'Electric Vehicle Action Plan' Government of Western Australia.

[22] ABCB (2021) 'NCC 2022 public comment draft (stage 2) consultation now open', Australian Building Codes Board.

[23] Electric Vehicle Council (2015) '*Recharging the economy. The economic impact of accelerating electric vehicle adoption*'. Electric Vehicle Council.

[24] Glenday, J. and Doran, M. (2021) '*Labor promises cheaper electric cars and cash for solar powered batteries, if it wins next federal election*'. abc.net.au; Hargroves, K. and James, B. (2021) Considering the role of Transport Agencies in the Electro-Mobility Transition, A Report to the Sustainable Built Environment National Research Centre (SBEnrc), Australia.

vehicles can create economic growth resulting in a Gross State Product (GSP) increase of between $US82 billion and $US142 billion by 2030. It similarly predicts an increase in jobs by between 400,000 and 500,000 by 2030.[25]

Precinct Invigoration

Bi-directional charging management can provide immediate income from tariffs on consumers, though there is potential for utilising tariffs and infrastructure designs to encourage specific user behaviour, to encourage people into areas beneficial to authorities and stakeholders in EV uptake. Initiatives can include balancing loads and generation in the electricity grid or enticing consumers to economic hubs to stimulate local economies - such as cheaper charging when generation is higher or cheaper charging at shopping and entertainment precincts. Shopping centres are often first to move to install charging facilities, motivated to increasing competitiveness by increasing services, increasing time spent in shopping centres and raising their green credibility.[26] The WA Government is investing $20M to establish Australia's longest electric highway, facilitating travel north from Perth to Kununurra, along the south west coast to Esperance and east to Kalgoorlie.[27]

Foreign Investment

As wealthier nations seek more environmentally sustainable investments motivated by environmental motives and long term economic security amidst declining fossil-fuel markets, governments can attract greater interest with the development of net-zero emission initiatives. Foreign investors such as central banks are encouraging decarbonised economies through choice of investment, with the European Investment Bank directing investment towards more environmentally sustainable initiatives such as e-mobility.[28] Sweden's Riksbank is increasingly directing its foreign investment towards green bonds, which has led them to pull out of its investments in Western Australia and Queensland in 2019.[29] Its measure for investment in Australian state government bonds is whether a state's GHG emissions is below that of the national average, which both Qld and WA currently exceed.[30] The WA's transport sector accounts for 16 per cent of GHG emissions, equivalent to 14.9Mt CO_2e per year,[31] which can be largely mitigated through the transition away from internal combustion vehicles to electric vehicles, especially with such vehicles able to store renewable energy generation to support the grid.

Road and Transport Agencies

Tariffs for Road Usage

The majority of Australians own and operate private internal combustion vehicles (ICVs) for most of their transport needs. This is largely as a consequence of the current transport system in cities having moved away from the system of buses, trams and trains that often built them towards a focus on accommodating private vehicles. The economics of the transport sector is now based on regular purchase of fossil fuels which provides revenue for government, however the transition to electro-mobility will see this revenue reduce and taper off, while demand for electricity ramps up, with a number of implications for the electricity sector. Building on early concerns around environmental performance and energy security the next stage in the electro-mobility transition will be driven by the potential for significant cost reductions due to innovation from the private sector. For instance the average

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[25] Next 10 (2020) '*CLEAN TRANSPORTATION. An Economic Assessment of More Inclusive Vehicle Electrification in California*'. www.next10.org.
[26] EVSE Australia (2021) '*The exciting trend of Shopping Centre EV charging stations in Australia*'. evse.com.au.
[27] Energy Policy WA (2021) 'Electric Vehicle Action Plan' Government of Western Australia
[28] European Investment Bank. (2019). '*EU Bank launches ambitious new climate strategy and Energy Lending Policy*'. www.eib.org
[29] Sverige Riksbank. (2019) '*Riksbank selling bonds for climate reasons*'. www.riksbank.se
[30] Hargroves, K. and James, B. (2021) Investigating the role of transport as part of Green Bond investment considerations, A Report to the Sustainable Built Environment National Research Centre (SBEnrc), Australia.
[31] National Greenhouse Accounts 2019. (2019) '*National Greenhouse Accounts 2019*'. www.industry.gov.au

energy cost for ICVs is 14c per km compared to an Electric Vehicle (EV) which is 4c per km, representing a saving of around 70 percent.[32]

Currently revenue related to vehicle use is collected by state governments in the form of vehicle registration, licensing and road tolls, while the Federal Government collects revenue from fuel excise.[33] Hence the shift in vehicle technology to electrification will call for a reconsideration of road user charges which is likely to draw associated revenue collection away from federal government and to the states. The most recent Australian Federal Budget estimates that the fuel excise tax will contribute $20.9 billion in government revenue in 2021-22.[34] As this is a tax applied to the sale of fossil fuels the resulting revenue will reduce over time, calling for changes to the way road users contribute to the cost of the system. It is not clear as to the best way to revise such charges with early efforts including the Victorian Government introducing a road user charge exclusively for EVs and zero-emission vehicle users,[35] and the Government of Oregon designing a trial to test a road user charge that would be applicable to all road users,[36] and some 13 other US states developing similar trials.[37] There is some precedence for the use of road user charges in Australia with heavy vehicles charged at 26.4 cents per litre of diesel in 2021.[38] As heavy vehicles are mostly used for commercial purposes the tax that is collected in the fuel excise is then credited back to operators and the road user charge is imposed in its place.[39]

The cost of fuel to consumers in Australia is comprised of components set by two parties: the fuel vendor covering their product and operational costs; and the federal government implementing a fuel excise and GST, from which the state governments receive funding in amounts controlled by the federal government. For instance Western Australia received an average investment for roads of 28 cents for every dollar generated from FY2005-06 to FY2016-17.[40] In the financial year 2019-2020, the Federal Government received $19.7 billion in revenue from fuel excise[41] from the sale of some 46.9 billion litres of fossil fuel, equating to an expenditure of some $63.56 billion by vehicle owners in a single year.[42] Hence as part of the transition to electric vehicles there is considerable interest in finding ways to redirect a proportion of this existing cost towards government revenue rather than it being provided to EV owners that avoid purchasing fossil fuels.

The Victorian Government has started taxing EV owners based on the distance they travel. From July 1, 2021, EV owners will be charged $0.025/km, while Plug-in Hybrid EV (PHEV) owners will be charged $0.02/km, while still paying the federal fuel excise tax.[43] In 2020 the average ICV in Australia used approximately 11.1 litres of fuel per 100km of driving,[44] which at a Fuel Excise level of 42.7 cents per litre would have contributed $4.74 per 100 kilometres to the fuel excise, which is an average of 4.74 cents per kilometer, compared to the proposed 2.5c per kilometre for EVs. The Victorian Government considered this reduction in cost per kilometre to take into account

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[32] Corby, S. (2021) 'Do electric cars actually save you money?' Carsguide, Carsguide.com.au; Alternative Fuels Data Center (n.d.) 'Charging Plug-In Electric Vehicles at Home' U.S. Department of Energy, United States of American Government; Queensland Government (2021) 'Hitting the road with your EV' Queensland Government

[33] Australian Automobile Association (2021) How Fuel Excise Pays for Our Roads, Australian Automobile Association.

[34] Commonwealth of Australia (2021) Securing Australia's Recovery, Budget 2021-22, Commonwealth of Australia.

[35] VicRoads (2021) 'ZLEV road-user charge - Learn more about the road-user charge for Victorian registered zero and low emission vehicles (ZLEVs)'. Vicroads.

[36] OReGO (2021) 'How does OReGo Work?', Oregon Department of Transportation.

[37] US Senate (2021) 'Testimony of Peter J. Basso Chairman, Mileage-Based User Fee Alliance', US Senate Committee on Environment and Public Works, United States of America Government

[38] NTC (2021) 'Road User Charges', National Transport Commission, Australian Government.

[39] ATO (2021) 'Blends Used for Heavy Vehicles Travelling on Public Roads', Australian Taxation Office, Australian Government.

[40] RAC (2018) Road User Charging Survey 2018, The Royal Automobile Club of Western Australia.

[41] Commonwealth of Australia (2021) Budget 2021-22 Budget Strategy and Outlook, Budget Paper No.1 2021-22, Commonwealth of Australia

[42] AIP (2021) AIP Annual Retail Price Data, Australian Institute of Petroleum.

[43] VicRoads (2021) 'ZLEV road-user charge - Learn more about the road-user charge for Victorian registered zero and low emission vehicles (ZLEVs)'. Vicroads.

[44] ABS (2020) 'Survey of Motor Vehicle Use, Australia - Estimates of; kilometres travelled, tonne-kilometres travelled, tonnes carried and fuel use'. Australian Bureau of Statistics, 30 June 2020.

the reduced pressure on the environment from the vehicle.[45] In 2020, the ABS estimated that the average vehicle in Victoria travelled 12,400km over the preceding 12 months,[46] so an average EV owner would need to pay $310 under the Victorian road user charge, while an average ICV owner would pay $588 in fuel excise tax.

The Victorian EV road user charge received significant public backlash given EV capital prices are still high and minimal operating costs act to offset this for early adopters, and this has influenced other state governments to reconsider early implementation.[47] For instance NSW plans to introduce a road use tax by 2027 or when EV uptake rates reach 30 percent, whichever occurs first,[48] and the South Australian Government has extended its planned implementation to 2027 after consultation with industry on the creation of a fair road user charge scheme.[49] The Victorian road usage charge was also met with strong opposition from car manufacturers like Volkswagen and Hyunda[50] based on concerns that the policy would hinder the early uptake of EVs. A survey by the Australia Institute in 2021 found that 69 percent of respondents in South Australia would be less likely to purchase an EV if the state government implemented a similar road usage charge to Victoria - despite almost three quarters of people agreeing that EVs "*reduce pollution and are good for the climate, environment, and healthy cities*".[51] The Federal Chamber of Automotive Industries has suggested that a "*uniform, simplified road user charging approach [would have] the potential to eliminate charges such as vehicle registration, sales tax, luxury car and sales taxes*" replacing them all with a single charge.[52]

Hence there are a number of considerations to be made when designing and implementing a program to ensure that road users make an appropriate and equitable contribution to the development of maintenance of the transport system, for instance:

- Is the system applicable to all vehicle types at differing rates or just EVs?
- Should vehicle owners be able to choose which option is cheapest for them?
- Should there be a lump sum amount for all EVs and should vehicle owners be able to pay a distance based fee up to this lump sum amount?
- How can the charges be applied in a way that does not penalise low income travellers that commute long distances? (as a more efficient car will not reduce such costs as it would with a combustion fuel)
- How can state based approaches complement and leverage Federal approaches and programs?
- How can the market be stimulated appropriately and what role should government play compared to the private sector?

In Utah they have adopted a fixed fee of US$120 per year for all EVs, however the vehicle owner can opt to pay a fee of US$0.015/mile up to this amount should they have low road usage.[53] In New Zealand, petrol users are

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[45] VicRoads (2021) 'ZLEV road-user charge - Learn more about the road-user charge for Victorian registered zero and low emission vehicles (ZLEVs)'. Vicroads.
[46] ABS (2020) 'Survey of Motor Vehicle Use, Australia - Estimates of; kilometres travelled, tonne-kilometres travelled, tonnes carried and fuel use'. Australian Bureau of Statistics, 30 June 2020.
[47] NRMA (2021) The Latest Incentives for EV Drivers in NSW and the ACT, National Road and Motorists' Association; Zachariah, B. (2021) Victoria Passes Road-User Tax for Electric Vehicles, Industry Reacts, Drive.com,au.; Opie, R. (2021) Electric Vehicle User Charge Put on Hold as SA Government Monitors Similar Taxes Interstate, Australian Broadcasting Corporation.
[48] Rabe, T. (2021) NSW to Abolish Stamp Duty on Electric Cars in an Effort to Boost Uptake, The Sydney Morning Herald.
[49] Lucas, R. (2021) Electric Vehicle Road User Charge Consultation to Begin, Government of South Australia; Lucas, R. (2021) $3,000 Subsidies to Drive Electric Vehicles Take-Up, Government of South Australia.
[50] Zachariah, B. (2021) Victoria Passes Road-User Tax for Electric Vehicles, Industry Reacts, Drive.com,au.
[51] The Australia Institute (2021) Polling: Electric Vehicles in South Australia, The Australia Institute.
[52] Federal Chamber of Automotive Industries (2021) Road User Charging Presents an Unprecedented Opportunity for Government Tax Reform, Federal Chamber of Automotive Industries.
[53] UDOT (2021) 'Frequently Asked Questions', Utah Department of Transport, Government of Utah.

charged NZ$0.07024/L of petrol as a petrol excise duty.[54] Diesel, hydrogen, ethanol, and electric vehicles are instead charged under a road usage charge of NZ$0.076/km,[55] which is typically equivalent to the petrol excise duty under average conditions. While EV owners are included in this road user charge, light EVs are exempted from paying the charge until March 31, 2024, while heavy EVs are exempt until December 31, 2025.[56] In 2019, the average distance travelled by light passenger vehicles in New Zealand was 10,690km,[57] which would incur a petrol excise duty payment of approximately NZ$795 (NZ$1 = AUD$0.96 in November 2021).

Table 1: Summary of road user charging metrics

Policy	Rate*	Ave. Annual Driving Distance in Region	Annual Charge(AUD)	Who is Charged
OreGo (Oregon, US) [58] [59] [60]	AU$0.015/km	19,663 km	$300	ALL road users
US Gas Tax [61] [62] **(Oregon + Fed Taxes)**	AU$0.0125/km	19,663 km	$250	Petrol/diesel cars
Vic ZLEV Road Charge[63] [64]	AU$0.025/km (zero-emission) AU$0.02/km (plug-in hybrid)	12,400 km	$310 $248	Zero-Emission or Plug-in Hybrid drivers
Australian Petrol Excise[65] [66]	AU$0.433/L (AU$0.048/km)	12,100 km (Aus) 12,400 km (Vic)	$580 $595	Petrol/diesel cars
NZ Fuel Excise [67] [68] [69]	AU$0.074/km	10,690 km	$795	Petrol cars
NZ Road User Charge [70] [71] [72] **(note: EVs exempt until 2024)**	AU$0.073/km	10,690 km	$775	EV, hydrogen, ethanol, diesel cars (EVs exempt up to 2024)

* Currency Conversation as of November 2021

[54] Ministry of Transport (2020) 'Rates of Petrol Excise Duty and Road User Charges', Ministry of Transport, New Zealand Government.
[55] Ministry of Transport (2020) 'Rates of Petrol Excise Duty and Road User Charges', Ministry of Transport, New Zealand Government.
[56] Ministry of Transport (2020) 'Buying a Light Vehicle', Ministry of Transport, New Zealand Government.
[57] Ministry of Transport (2019) 'Fleet Statistics', Ministry of Transport, New Zealand Government.
[58] MyOReGO (2021) 'How Does OReGO Work?', Oregon Department of Transportation, Government of Oregon.
[59] Covington T (2021) 'Average miles driven per year by Americans', The Zebra
[60] Federal Highway Administration (2021) 'Highway Statistics 2019', US Department of Transportation, United States of America Government
[61] Department of Transportation (2020) 'Current Fuel Tax Rates', Oregon Department of Transportation, Government of Oregon
[62] Alternative Fuels Data Centre (2020) 'Average Fuel Economy by Major Vehicle Category', U.S. Department of Energy, United States of America Government
[63] VicRoads (2021) 'ZLEV Road-User Charge', VicRoads, The Government of Victoria
[64] ABS (2020) 'Survey of Motor Vehicle Use, Australia', Australian Bureau of Statistics, Australian Government
[65] ATO (2021) 'Excise duty rates for fuel and petroleum products', Australian Taxation Office, Australian Government
[66] ABS (2020) 'Survey of Motor Vehicle Use, Australia', Australian Bureau of Statistics, Australian Government
[67] Ministry of Transport (2020) 'Buying a Light Vehicle', Ministry of Transport, New Zealand Government
[68] Ministry of Transport (2020) 'Rates of Petrol Excise Duty and Road User Charges', Ministry of Transport, New Zealand Government
[69] Ministry of Transport (2020) '2019 Annual Fleet Statistics', Ministry of Transport, New Zealand Government
[70] Ministry of Transport (2020) 'Buying a Light Vehicle', Ministry of Transport, New Zealand Government
[71] ABS (2020) 'Survey of Motor Vehicle Use, Australia', Australian Bureau of Statistics, Australian Government
[72] Ministry of Transport (2020) 'Rates of Petrol Excise Duty and Road User Charges', Ministry of Transport, New Zealand Government

The use of road user charges raises equity concerns for lower-income drivers that commute long distances. While the fuel excise similarly is inequitable for these people using more fuel for longer journey times, there is opportunity for them to use a more fuel-efficient car to decrease this cost. Hence it may be the case that some consideration could be given to subsidising road user charges based on a means test to be deemed equitable. The development of a system for equitable levies is difficult and complex, stemming from the situation of typically lower income people needing to travel further to reach economic hubs, as well as them being further from purchasing more economical ICVS – or EVs at all.[73] Moving from a fuel based system to a road use base system will also introduce the ability to influence driver behaviour through variable pricing, which could be used to subsidise low income road users. This could involve applying an additional congestion charge in CBD areas and applying different levels of charges depending on time of day or on specific routes that benefit overall traffic management. Such charges can act as a way to encourage commuters to use the most effective method and provide an economic incentive to opt for shared transit services.[74]

Public Transport Authorities

The electrification of transport will be adding loads to the currently limited electricity grid and taking customers and revenue from the hydrocarbon sectors. 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. With controlled charging nationally, it is modelled that 60-70 percent fleet electrification can be achieved. [75] [76]

Grid Services from EVs

The Western Australian electricity grids are evolving, largely triggered by increased renewable energy generation and the need to develop accommodating strategies across the networks. In March 2021 renewable energy generation capacity totalled some 2,783 MW which is nearly double the entire coal fired power plant capacity of the state of 1,610 MW. The renewable capacity includes 1,203 MW of large scale generation from wind and solar farms (up 144 percent over two years) and 1,580 MW rooftop solar capacity (up 51 percent over two years). The recent growth in the penetration of rooftop solar systems has already affected the electricity grids, for instance it has caused the minimum grid load to reduce by 25 percent as of March 2021 creating control issues. The large centralised energy generators have difficulty reacting quickly to changes in rooftop solar supply, which leads to instability in the grid. The Western Australia government has suggested that EVs could act as a set of distributed storage devices that could smooth quick generation changes as part of the 'WA EV Action Plan',[77] however this will require EV owners to be incentivised to connect vehicles to the grid during the day rather than just charge overnight at home.

The WA government is well underway with efforts to understand how to take advantage of distributed renewable energy generation and storage which is good for transport agencies in the state as they have ownership of large EVs, such as busses and trains, along with facilities such as station parking areas. The WA Government is currently undertaking over 20 technology trials across the state to demonstrate the orchestration of distributed energy

[73] Dosser, R. (2016) 'Revenue from Road Use', Parliamentary Library Briefing Book - 45th Parliament, Parliament of Australia.
[74] Hargroves, K. (2021) Introducing the 'FreightSync Roadmap': A Pathway to Linking Freight Vehicles and Transport Systems – Final Industry Report', Sustainable Built Environment National Research Centre (SBEnrc), Australia.
[75] Mullan, J., Harries, D., Bräunl, T. and Whitely, S., (2011) 'Modelling the impacts of electric vehicle recharging on the Western Australian electricity supply system'. *Energy Policy*, 39(7), pp.4349-4359.
[76] Li, M. and Lenzen, M. (2020) 'How many electric vehicles can the current Australian electricity grid support?'. *International Journal of Electrical Power & Energy Systems*, 117
[77] Energy Policy WA (2021) 'Energy Transformation Strategy, Stage 2: 2021-2025' Government of Western Australia; Energy Policy WA (2021) 'Electric Vehicle Action Plan' Government of Western Australia.

resources (DERs), including ways to coordinate energy generation, storage and balancing. Technologies include communal power banks, new tariff pilots, creation of microgrids, upgrades to inverters and the creation of virtual powerplants.[78] The communal battery trials will serve a set of houses and act to balance the grid and avoid or differ infrastructure investment.[79] A series of communal battery systems dubbed the 'PowerBank' have been trialled by Western Power and Synergy over a three year period, with a third PowerBank initiated in 2021 to serve 600 households. The initial PowerBank was an Australian first for communal electricity storage, saving $11,000 per year in power bills across 44 households – an average of $228 each, with 95 percent of households making a saving. On average each participant stored 7.3kWh per day, (approximately 13 percent of a Nissan Leaf's battery capacity or 45km driving range) and withdrew 5.2kWh selling the remainder into the grid.[80] Other communal batteries have since been implemented across Australia, including the NSW first in the Northern Beaches Council facilitated by Ausgrid in early 2021, to support the council to achieve 50 percent of households having rooftop solar by 2030.[81]

With the growth in EV uptake globally attention is now turning to how vehicles can participate in the electricity grid to provide energy storage and discharge to help balance loads given fluctuating renewable energy generation.[82] Coordination of such distributed energy resources therefore becomes a critical consideration with early planning essential ahead of the likely rapid uptake in Australia.[83] Transport agencies around the world now have a new opportunity to utilise slack vehicles for such services and generate new forms of revenue. For instance vehicles such as buses and trains that are fitted with high capacity batteries can be used to store excess renewable energy to be discharged during times of peak demand. However as with private vehicles, shared transit vehicles will need to be able to undertake bi-directional charging rather than just receive charge as with many of the early models. Bi-directional charging, also referred to as the capacity for 'Vehicle to Grid' (V2G) energy flow, allows for stored energy in EVs to be sent back to the grid, calling for appropriate grid infrastructure, especially the management of grid power factor.

The Potential of Public Buses

Electric buses can both reduce running costs and provide services to the electricity grid as they have large batteries which can be charged or discharged to suit route operational requirements and economical electricity management. Trials of Vehicle to Grid (V2G) discharging with electric buses have been undertaken in Asia, Europe and America, with the Shenzen Bus Group having operated a fleet of just over 6,000 fully electric buses since June 2017 and in 2020 Transport for London initiating a 'Bus2grid' project.[84] As part of London's electrification of 300 buses by 2020, 33 electric buses will be fitted for V2G and a bus depot will be outfitted with a capability for 2.64 MW bi-directional charging.[85] The project aims to demonstrate the capabilities and value of V2G for grid managers and public transport agencies, and to inform in the creation of new business models between these parties. An immediate benefit of the project will be capitalising on charging buses with cheap electricity at night - beyond

[78] Energy Policy WA (2021) 'Energy Transformation Strategy, Stage 2: 2021-2025' Government of Western Australia
[79] Kurmelovs R (2021) 'Community batteries: what are they, and how could they help Australian energy consumers?', The Guardian.
[80] Nissan (2021) 'A New-Generation Electric Vehicle', Nissan.
[81] Northern Beaches Council (2021) 'Northern Beaches home to the first NSW Community Battery', Northern Beaches Council.
[82] Li, M. and Lenzen, M., (2020) 'How many electric vehicles can the current Australian electricity grid support?'. *International Journal of Electrical Power & Energy Systems*, 117,
[83] Energy Policy WA (2021) 'Electric Vehicle Action Plan' Government of Western Australia,
[84] Li, X. *et al* (2020) 'A cost-benefit analysis of V2G electric vehicles supporting peak shaving in Shanghai', Electric Power Systems Research; Luo L (2020) 'Coordinated allocation of distributed generation resources and electric vehicle charging stations in distribution systems with vehicle-to-grid interaction', Energy; St. John J (2020) 'Electric School Bus Fleets Test the US Vehicle-to-Grid Proposition', Greentech Media, Wood Mackenzie.
[85] UKRI (n.d.) 'Bus2Grid', UK Research and Innovation.

storage requirements for a shift - and discharging excess energy in the day to sell during higher tariffs.[86] This can serve to accelerate the payback period of shifting to electric fleets especially given the UK has some 11 GW of offshore wind capacity that will also generate energy at night and is targeted to grow to 40 GW by 2030.

Given that along with wind, the Australian grid is likely to have a substantial proportion of solar energy, with the world's highest rate of household uptake of 30 percent,[87] it also makes sense to encourage day time charging of all forms of EVs. As rooftop solar in Australia is increasingly supplying dwellings directly, with AEMO expecting 40 percent of WA household to have rooftop solar by 2030,[88] overall network demand will likely decrease yet peak network loads may remain high. This is shown in Figure 1, referred to as the 'duck curve', where the demand on the grid has reduced significantly during the period between 9am and 3pm while the evening peak has increased.[89]

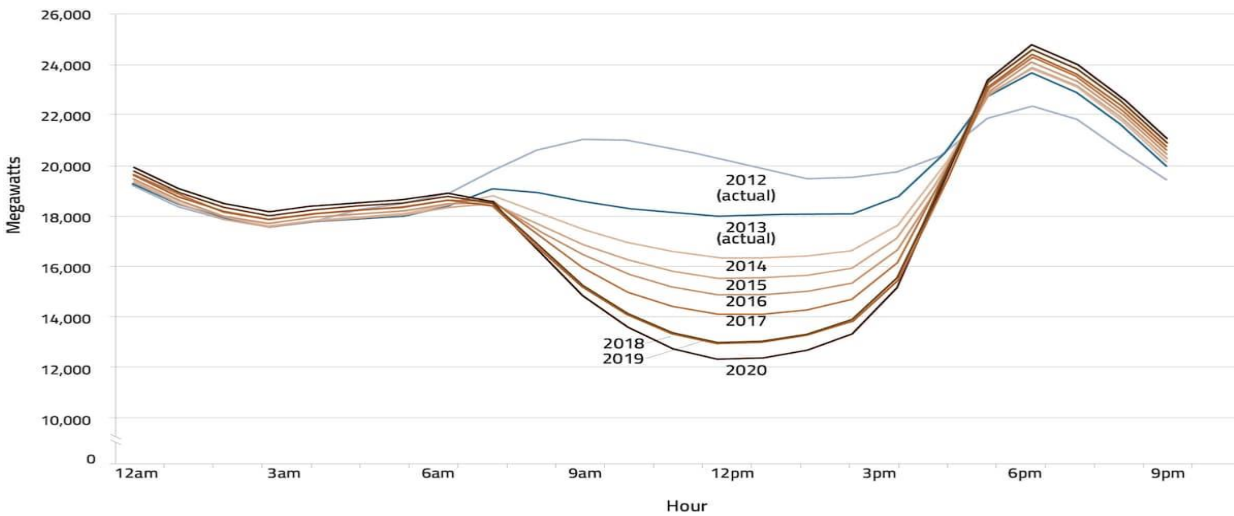

Figure 1: The 'Duck' Curve showing decreased grid demand during periods of high solar generation and slightly increasing peak demand in the evening

Source: AGL, 2020[90]

This increasing gap between the base, or minimum, load and a fairly consistent, or slightly increasing, peak load poses increasing strain on network generation attempting to balance the grid. Hence there is great interest in how energy storage options, such as stationary and mobile batteries, can be used to shift excess solar generation during the day to contribute to the evening peak, presenting opportunities for government agencies with fleets of vehicles.

Park and Ride EV Charging

Early public EV charging stations are being shown to have long pay pack periods, in the order of 10 years, and will rely on complementary activities to improve financial viability.[91] Business models for improving the financial viability of public charging involve the inclusion of other stakeholders, such as car manufacturers to provide a supportive network which would encourage their product sales; or sharing revenue with businesses in precincts

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[86] Stone T (2020) 'London bus garage becomes world's largest vehicle-to-grid site', Traffic Technology Today; Spencer Jones J (2021) 'Bus-2-Gri to Launch in London', Smart Energy International

[87] Energy.gov.au (2021) 'Solar PV and Batteries', Department of Industry, Science, Energy and Resources, Government of Australia.

[88] Matich B (2021) 'AEMO analysis finds Western Australia on the fast track to energy system transformation', pv magazine.

[89] AGL Energy (2020) 'Explainer: The Duck Curve', The Hub, AGL Energy.

[90] AGL Energy (2020) 'Explainer: The Duck Curve', The Hub, AGL Energy.

[91] Mortier, T. (2020) How to Make EV Charging Pay, Ernest and Young.

receiving the benefits of increased patronage.[92] It is also likely that EV owners that cannot charge their vehicle at home or work will prefer to charge at locations that they are likely to attend of their own accord, such as shopping and entertainment precincts, rather than at service stations or other standalone charging facilities.[93] For instance shopping centres are increasingly installing EV charging stations to attract EV drivers and encourage them to stay longer, however rates need to be carefully set.[94]

Park-n-Ride (PnR) locations around shared transit facilities can similarly generate revenue by offering charging services for parked vehicles and providing services to the grid, creating a 'Park, Charge and Ride' (PCR) location.[95] Charging EVs during the day can help to use excess solar energy to manage the 'duck curve' (see Figure 1). The modelling in Figure 2 suggests that for higher levels of solar generation, greater portions of EVs, say in public fleets, will have a greater mitigating effect, raising the lowest network load by almost 25 percent.[96] Hence there is strong potential for profitable collaborations between government agencies and Energy Utilities.

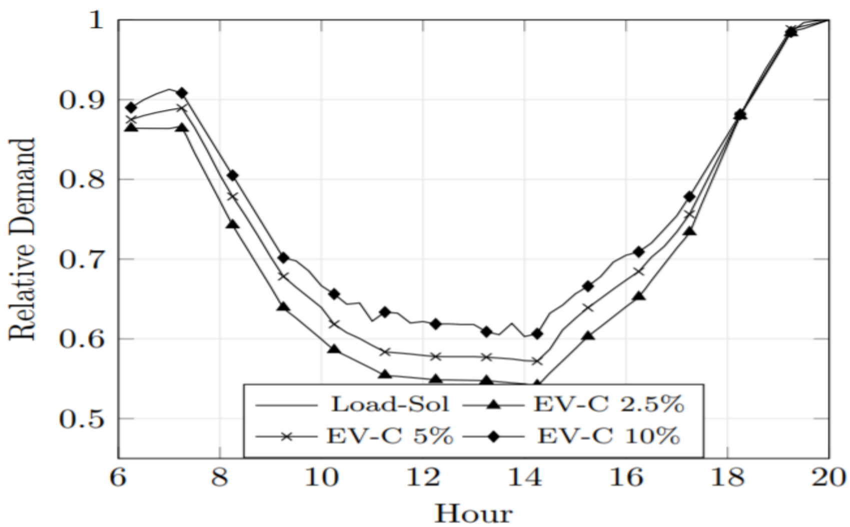

Figure 3: Grid Demand Drop Mitigation with Electric Vehicles

Source: Jovanovic and Bayram, 2019[97]

A number of cities around the world are seeking to identify the most cost-effective locations for park, charge and ride facilities based on predicted journey routes, likely vehicle parking duration, and suitability to the electricity grid, however there is currently little data available to undertake detailed modelling.[98] For instance, Los Angeles

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[92] Nigro, N., Welch, D. and Peace, J. (2015) 'Strategic Planning to Implement Publicly Available EV Charging Stations: A Guide for Businesses and Policymakers', Center for Climate and Energy Solutions

[93] Hargroves, K. and James, B. (2021) Perception and Capacity Factors affecting the Uptake of Electric Vehicles in Australia, A Report to the Sustainable Built Environment National Research Centre (SBEnrc), Australia.

[94] EVSE (n.d.) 'The exciting trend of Shopping Centre EV charging stations in Australia: Shopping Centre EV Chargers', EVSE.com.au; Shopping Centre News (2019) 'Mirvac takes EV charging to the next level' Shopping Centre News; EVup (2020) 'Shopping Centres: Increase spend time & spark loyalty in the growing EV community', evup.com.au.

[95] Jovanovic, R. and Bayram, I. (2019) Scheduling electric vehicle charging at park-and-ride facilities to flatten duck curves. In Proceedings of the 2019 IEEE Vehicle Power and Propulsion Conference, 2019—Proceedings, Hanoi, Vietnam, 14–17 October 2019; Brenna, M., Foiadelli, F., Longo, M. and Grillo, S. (2016) Charging optimization for electric vehicles in large Park & Ride areas. In Proceedings of the IEEE Power and Energy Society General Meeting, Boston, MA, USA, 17–21 July 2016.

[96] Jovanovic, R. and Bayram, I. (2019) Scheduling Electric Vehicle Charging at Park-and-Ride Facilities to Flatten Duck Curves, *2019 IEEE Vehicle Power and Propulsion Conference*, 2019, pp. 1-5.

[97] Jovanovic, R. and Bayram, I. (2019) Scheduling Electric Vehicle Charging at Park-and-Ride Facilities to Flatten Duck Curves, *2019 IEEE Vehicle Power and Propulsion Conference*, 2019, pp. 1-5.

[98] MBTA (2017) Sustainability Report, Massachusetts Department of Transportation; Ai, N., Zheng, J. and Chen, X. (2018) Electric vehicle park-charge-ride programs: A planning framework and case study in Chicago. *Transp. Res. Part D Transp. Environ*. 2018, 59, 433–450.

Metro created park and ride facilities at five stations in 2013 which were selected for their proximity to major transport hubs and high traffic areas. The initiative was designed to encourage public transport use in various regions of the city and was expanded to 15 stations in 2017, with Level 2 chargers providing a full charge for $US3.[99] In the world's growing cities, park-n-rides will be an essential part of the mobility system providing a way for commuters to take advantage of fast corridor based shared transit and convenience private car connections.[100] Hence, effectively implemented, park-charge-n-ride stand to encourage greater use of shared transit services, reducing congestion and lowering environmental impact, while stimulating local economic growth around station precincts.[101] Hence there is an opportunity for transport agencies to both collaborate with energy utilities and with economic centres and communities around station precincts to create energy-transit-development nodes for mutual benefit.

Decommissioned Bus Batteries as Distributed Energy Resources

As EV batteries decline in range when they repeatedly cycle through charging and discharging, their ability for storing energy declines, lowering the range of the vehicle. This typically occurs after roughly eight years, when a vehicle can have its battery changed. Used lithium batteries are difficult to recycle – but processes are developing to accomplish this – so repurposing aged batteries is a viable option for extending their use. Aged batteries can be given a second life by creating energy storage facilities within commercial buildings to provide frequency control and store or sell excess solar power from solar panels on building rooftops.[102] Also, governments can find extra revenue in providing services to the grid with old bus and train batteries. In China, for instance, the Shenzen Bus Group (SZBG) has operated a fleet of just over 6,000 fully electric buses since June 2017. The expected lifetime of the batteries is 7-8 years and following this they will be repurposed into solar PV storage systems capable of storing excess solar energy during the day and charging EV's at night. In Sweden, BatteryLoop has an agreement with Volvo to repurpose their bus batteries into stationary energy storage for various types of infrastructure in their 'BLISS' systems.[103] Such a system could be implemented in Australia, with governments generating revenue by providing community batteries as demonstrated by Western Power with their 'PowerBank' systems.[104]

Digitisation of Vehicles and Data Utilisation

Electric vehicles can be used to directly support the grid using vehicle-to-grid (V2G) technologies and the associated data can inform efforts to integrate such vehicles into the grid from both a technical and a behavioural point of view, which may even be able to be appropriately monetised.[105] However the shift to electric vehicles will also likely see the digitisation of vehicles through the deployment of a plethora of sensors that will provide access to a great deal of new data which can inform vehicle owners as to maintenance requirements and potential failures, vehicle manufacturers as to the performance of the design and materials elements of the vehicles, and transport agencies in the areas of traffic management and transport planning.

In particular, when considering the electrical aspect of EVs, this will provide invaluable data on battery function for fleet charging management and integration of the transport and electricity networks – the nexus of transport,

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[99] LA METRO (n.d.) Plug in and Go Metro. Los Angeles Metro; Ai, N., Zheng, J., and Chen, X. (2018) Electric vehicle park-charge-ride programs: A planning framework and case study in Chicago. *Transp. Res. Part D Transp. Environ*. 2018, 59, 433–450.

[100] Ortega, J., Tóth, J. and Péter, T. (2021) Planning a Park and Ride System: A Literature Review. *Future Transp*ort. 2021, 1, 82-98.

[101] Ai, N., Zheng, J., and Chen, X. (2018) Electric vehicle park-charge-ride programs: A planning framework and case study in Chicago. Transp. Res. Part D Transp. Environ. 2018, 59, 433–450;

[102] ABC (2018) Electric Bus Batteries Used to Store Solar Energy, Australasian Bus and Coach, 21 December 2018.

[103] Sustainable Bus (2020) Volvo Buses, the focus on reuse of bus batteries. A cooperation with Batteryloop, Sustainable Bus, 14 September 2020; Electrive.com (2020) Volvo Buses and Batteryloop take e-bus battery recycling global, electrive.com.

[104] UNC (2019) The First and Largest 100 Percent Electric Bus Fleet: Shenzhen Bus Group, University of North Carolina, Institute for the Environment.

[105] UITP (2018) The Value of Data for the Public Transport Sector, International Association of Public Transport.

energy and development. Such data will include information on charging patterns such as the location the vehicle is charged and the duration of charge which will inform predictive forecasting of grid load. Access to this data can also be used to monitor the efficacy of programs to encourage EV owners to make their vehicles accessible to the grid during the day, and hence provide greater utility to the grid, rather than charging at home overnight.

Modern EVs have been built with a range of sensors and computers that allow vehicle owners to voluntarily share information with the manufacturer or other organisations. As far back as 2013, cars like the Chevrolet Volt, Nissan Leaf, and various Tesla models all could communicate data collected from the vehicle computer.[106] With the growing popularity of vehicle connectivity technologies, such as Android Auto and Apple Car Play, more and more vehicles, including ICVs, will be able to contribute to an immense pool of data on vehicle usage. As part of user agreements drivers take advantage of enhanced routing, smart roadside assistance, and vehicle maintenance reporting, in return for releasing a range of data types.[107] As EV uptake increases, replacing older, disconnected ICVs, this growing pool of data will be invaluable to transport authorities. Through the utilisation of big data analytics and machine learning, a range of projects would be possible, such as predictive congestion management.[108]

This data could be combined with other sources of data to inform and train an artificial intelligence driven traffic flow model that would have benefits ranging from traffic flow optimisation, road planning, and road maintenance.[109] Various researchers have simulated traffic flows, either through the utilisation of data collected from the in-built sensors, or through leveraging external sensors such as security cameras and toll-road data.[110] Benefits derived from this would depend on the implementation, but could include providing real-time journey recommendations to drivers which would optimise traffic flows,[111] allowing simulations of the impact new roads and highways would have on traffic, visibility of high traffic areas which would require regular maintenance, and the potential disruptions caused by such maintenance projects.[112] Optimising the traffic flows through real-time journey recommendations could have an additional benefit of reducing traffic and wear on high-traffic roads, potentially reducing the maintenance requirement and cost.

A smart integrated multi-modal public transport system could be developed through data collected from both passenger vehicles and public transport users. Journey planning applications currently rely on location data from the user and the transport option(s), as well as published timetables, while estimating walking and travel times.[113] Collating and using real-time data could improve the effectiveness of these planning tools, as estimates and timings could be based on current conditions, including traffic, roadworks, delays of public transport, weather, etc. The planner could even access the current availability of space in the bus/tram/etc., factoring the possibility of the vehicle being at capacity into its recommendations for users. For a transport authority, the ability to produce detailed statistical modelling of public transport interactions would allow for determinations to be made in regards to accessibility of key spots in the city, e.g. hospitals, entertainment districts, and ease of travel

[106] Stewart, J. (2013) 'Electric cars: Big data helps designs shift gears', BBC, 16 October 2013.
[107] BMaaS (2017) 'One for the road — big data & the automobile industry', Business and Mobility-as-a-Service, 19 December 2017.
[108] Hargroves, K., Stantic, B. and Allen, D. (2020) Exploring the Potential for Artificial Intelligence and Blockchain to Enhance Transport', Sustainable Built Environment National Research Centre (SBEnrc), Australia
[109] Hargroves, K., Stantic, B. and Allen, D. (2020) Exploring the Potential for Artificial Intelligence and Blockchain to Enhance Transport', Sustainable Built Environment National Research Centre (SBEnrc), Australia
[110] Bowman, C. and Miller, J. (2016) 'Modeling traffic flow using simulation and Big Data analytics'. *2016 Winter Simulation Conference*, 2016, pp.6583-6592.
[111] Shengdong, M., Zhengxian, X. and Yixiang, T. (2019) 'Intelligent Traffic Control System Based on Cloud Computing and Big Data Mining'. *IEEE Transactions on Industrial Informatics*, 15(12), pp.6583-6592.
[112] Bowman, C. and Miller, J. (2016) 'Modeling traffic flow using simulation and Big Data analytics'. *2016 Winter Simulation Conference*, 2016, pp.6583-6592.
[113] Public Transport Victoria (2021) *Journey planner - Public Transport Victoria*. www.ptv.vic.gov.au/journey.

throughout the city.[114] Potential chokepoints could be identified, and routes and timetables could be optimised based on the modelling produced.

There is a large market for big data, where organisations can purchase access to the immense pools of data generated through any internet-connected activity. If transport agencies were able to position themselves as the primary collection point for multi-modal transport data in their jurisdiction, or as a collator of data from different sources, they could provide reliable, trusted, unbiased datasets of global relevance. This could be provided as a freely accessible dataset, or at a fee for access. It should be noted that the benefit of connectivity is not exclusive to EVs, as through the use of technologies such as Apple Car Play and Android Auto becoming standard, most new passenger vehicles manufactured since 2016 (including ICVs) are now sold with connectivity options included, or can be added.[115] The benefit in regards to EVs derives from the fact that the proprietary solutions that have been built in to the EVs can provide access to further vehicle usage information that would not necessarily be shared with the third-party solution (e.g. Android Auto or Apple Car Play). As an example, data relating to the battery charge level during a journey, or what level it was charged to, are accessible in data produced by integrated solutions developed by the vehicle manufacturers and would not be shared through the third-party provider.[116] This data could be used to optimise future public charging station planning, by gaining an insight into the usual travel between charges.

[114] Faizrahnemoon, M., Schlote, A., Maggi, L., Crisostomi, E. and Shorten, R. (2015) 'A big-data model for multi-modal public transportation with application to macroscopic control and optimisation'. *International Journal of Control*, 88(11), pp.2354-2368.
[115] Naidoo, V. (2018) '*What are Apple CarPlay and Android Auto?*'. CarsGuide.
[116] Stewart, J. (2013) '*Electric cars: Big data helps designs shift gears*'. BBC.com.