Climate Change Balmain-Rozelle
PO Box 890
Rozelle NSW 2039
w: climatechangebr.org
e: ccbalroz@gmail.com
ABN: 31 258 840 648

Submission from
Climate Change Balmain-Rozelle
to the
Select Committee on Fair Dinkum Power[1]

4/2/19

Who we are

Climate Change Balmain-Rozelle [CCBR] is an independent community group in inner west Sydney, promoting local and national action to reduce fossil fuel use, increase the adoption of renewable energy, and head off catastrophic global warming.
We count over 1000 supporters.

Summary

Electric Vehicles have a major part to play in the operation of a national power supply that is cheaper, healthier, more secure, and friendlier to the climate. Privately owned EVs[2] will allow the public to engage in the new order.

Governments have a role to play in coordinating this transition. A key aspect will be the alignment of EV power demand with PV supply.

We find that the issues raised touch on items a(i-iii), b, f and g in the terms of reference.

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1 https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Fair_Dinkum_Power
2 In this document, "EV" refers to a pure electric vehicle unless otherwise stated

Electric Vehicles[3]

A looming challenge for electricity networks is the adoption of electric vehicles. This is to be welcomed for many reasons:

- a reduction in directly harmful emissions,
- less noise pollution,
- in conjunction with the switch to renewable energy, a reduction of greenhouse gas emissions,
- reduced dependence on oil imports

Forecasts

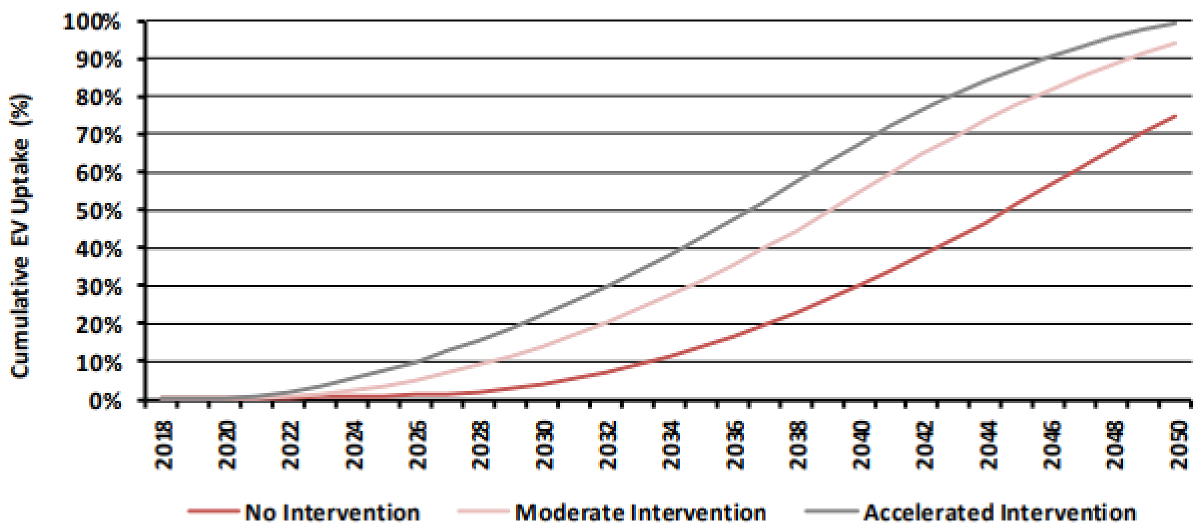
The AEMO's Integrated System Plan (July 2018) foresees little relevance of EVs in its 20 year horizon[4]. Yet between September 2017 and March 2018 the AEMO had doubled its prediction of EV uptake, reaching up to 30TWh/y of demand – 15% of current grid demand - by 2038[5].

Given the rapid pace of technological advance and the repeated failure of forecasters to comprehend it, even this upper limit foreseen by AEMO is likely too conservative.

Illustration 1 shows ARENA's 2018 forecast under three intervention scenarios[24].

3 In this document, this refers to Battery Electric Vehicles (BEVs), not HEVs or PHEVs
4 https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf
5 https://reneweconomy.com.au/aemo-just-doubled-forecast-ev-uptake-australia-66789/

Fleet Proportion



Source: Energeia Modelling

Illustration 1: ARENA's EV uptake forecast scenarios

The Moderate Intervention scenario reaches 50% penetration in 2039, also around 25-30TWh/y. However, it is underpinned by an estimate that 28% of new sales would be BEV/PHEV in 2026. That looks conservative in view of Illustration 2 and 3 on page 7.

Demand Profile

The scale and pattern of the resulting electricity demand presents opportunities; not least, the opportunity for *inadequate* planning.

Photovoltaic solar power has become the cheapest option for new electricity generation[6], with its lead predicted to grow for decades yet, undercutting not only new but even incumbent coal and gas generators[7]. Its main limitation, of course, is its daily output profile. While storage can help match demand, that adds to the cost.

A key question is how EVs may affect the demand profile. The simplest way to recharge a private EV is overnight, while it is garaged at home, but that would exacerbate the profile mismatch.

Charging rate

An important part of the equation is the speed at which EVs can be recharged[8]. Three broad levels of charging technology exist.

6 https://reneweconomy.com.au/csiro-aemo-study-says-wind-solar-and-storage-clearly-cheaper-than-coal-45724/
7 https://about.bnef.com/new-energy-outlook/
8 https://www.evse.com.au/difference-between-levels-of-chargers

Level	Volts	kW	Charge rate[9], km/h	Effective speed[10], km/h	Charger cost, AUD	Added vehicle price, AUD
1	120/240 AC	1.4	7 to 14	7 to 12	-	-
2	240 AC	3.3 to 6.6	18 to 50	15 to 33	1,300[11]	-
3	500 DC	50-150	200 to 400	66 to 80	25,000-50,000	1000

Table 1: EV charging technologies

For journeys so long as to require a full recharge along the way, level 3 is the only realistic option. But for daily commutes of up to 100km round-trip, level 2 affords an off-road full recharge in under 6 hours. That fits well with PV supply peaking 9am-3pm.

For Australia in 2016, private vehicles drove 133bn km in urban trips, 75% of their total mileage[12].

Commuting

For those commuting entirely by public transport, the car can be left at home Monday to Friday, where it can recharge during peak PV output – their own or via the grid.

For those needing to drive, either to reach public transport or all the way to their place of work, the challenge is to enable recharging while the car is parked. E.g.

- Level 2 charge points throughout the carpark
- Grid power at off-peak rate (since PV will make daytime power cheap)
- Optionally supplemented by solar panels on the roof of the carpark or on neighbouring office blocks.

Most Australian commuters travel less than 20km to work; the average is 16km[13]. The electricity used for the round trip would be around 6kWh. With PV bringing grid power during the day down to 10¢/kWh retail, each car would be refuelled for 60¢ a day. A further 40¢ would cover the investment in the charging unit. This cost could be rolled into the all-day parking fee.

Grid firmness

In the normal course of market operation, cheap PV generation displaces conventional baseload - coal and gas. But a grid dominated by such renewables is less able to cope with network failures; if an interconnector trips, PV and wind do not naturally ramp up to cope. Large turbines can use their inertia ("synchronicity") to supply a little more.

As a result, SA introduced a cap on renewables supply to ensure enough gas powered

9 Range added per unit of time spent charging
10 Assumes long journey, driving speed of 100kph, finishing with same charge as starting. Computed as (charge rate x drive speed)/(charge rate + drive speed)
11 https://www.ohmhomenow.com/electric-vehicles/ev-charging-station-cost/
12 http://www.abs.gov.au/ausstats/Subscriber.nsf/LookupAttach/9208.0Data+Cubes-22.03.171/$File/92080DO001_1231201610.xls
13 http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/2071.0.55.001~2016~Main%20Features~Commuting%20Distance%20for%20Australia~1

plant was operational too. This is already leading to some curtailment of PV and wind[14].

This problem is being addressed by equipping grid-scale renewables with "synchronous condensers" (essentially flywheels), but this adds somewhat to the cost[15].

In principle, greater reliance could be placed on renewables by means of substantial overbuild. But building far more renewables than are needed most of the time would be even more expensive.

"Smart" EV charging can help to solve this. The charging infrastructure could respond to signals from the network and instantly cut demand on request[16]. Thus, the presence of a significant demand for EV charging allows a greater fraction of *other* demand to be met by renewables.

The NEM rewards Frequency Control and Ancillary Services (FCAS) that help to stabilise the grid. The level of reward is based on the FCAS supplied by traditional synchronous generators. A higher reward is appropriate for the lightning response that batteries and Demand Response (DR) offer[17,18]. A carpark could earn revenue merely by backing off demand.

Domestic charging could do likewise, but the charging units might be less sophisticated, or the householder insufficiently motivated to enable the feature.

EV2G can go further, feeding back into the grid temporarily.

Electric Vehicle to Grid (EV2G)

Potentially, electric vehicles can also provide a distributed storage service to the grid, providing an income to the vehicle owner and allowing a greater penetration of renewable energy into the grid. While there are technical difficulties, both for the car battery and the network, it is becoming a reality[19].

The ideal time for this service will be in the evenings (6pm-8pm now, but extending to 10pm as baseload power shrinks) when the feed-in would be worth 30¢/kWh or more. The electricity that could be fed in during that window may be constrained by:

- The capacity of the car battery (16kWh upwards[20] now, but will rise)
- The daily recharge of the battery
- The permitted kW rate of feed-in multiplied by the duration of the peak period

These limits will allow around 20kWh/day.

Commuter type:	Car-using	Public Transport only	Public Transport only + Domestic PV
Power source	Grid, commercial	Grid, domestic time-of-use	5kW Rooftop PV
Location of car in	Carpark, workplace	Home	Home

14 https://reneweconomy.com.au/wind-and-solar-curtailment-jumps-as-renewables-reach-record-levels-76368/
15 https://reneweconomy.com.au/siemens-to-deliver-australias-first-solar-farm-synchronous-condenser-29609/
16 https://cleantechnica.com/2018/02/24/current-ev-charging-equipment-market-innovation-trends-part-2/
17 https://reneweconomy.com.au/inside-the-tesla-big-battery-how-it-made-money-and-cut-prices-15167/
18 https://www.smh.com.au/business/the-economy/tesla-claims-it-s-being-shortchanged-for-providing-power-too-quickly-20180321-p4z5hw.html
19 https://thedriven.io/2018/10/24/nissan-says-new-leaf-will-be-both-a-car-and-a-power-station/
20 https://batteryuniversity.com/learn/article/electric_vehicle_ev

Commuter type:	Car-using	Public Transport only	Public Transport only + Domestic PV
daytime	or transport hub		
Daily recharge	20kWh	20kWh	20kWh
Daily discharge for driving	6kWh	0	0
Available as feed-in	14kWh	20kWh	20kWh
Revenue @ 30¢/kWh[21]	$4.20	$6.00	$6.00
Per kWh cost of recharge	$0.12	$0.15	$0.09[22]
Cost of recharge	$2.40	$3.00	$1.80
Profit/day[23]	$1.80	$3.00	$4.20

Table 2: Potential earnings from EV as grid storage

An alternative potential use of a car's battery is the ultimate empowerment of the electricity consumer - to go off-grid.

Typical domestic batteries store less than 20kWh, which for most households would be only a day or two of supply, even being careful. This would not provide enough certainty. An EV available as a back-up could add 30kWh.

The Barriers

To bring about these scenarios, both incentives and changes to regulations may be appropriate. A useful international study of these was made for ARENA and the CEFC[24].

Lifetime Cost of EVs

At the lower end of today's market, EVs can cost more than double the equivalent Internal Combustion Engine (ICE) car in Australia. Table 3 compares vehicles of similar niche from the same manufacturer, but ignores maintenance costs[25].

Make and model	*Renault Clio Zen*	*Renault Zoe Life*
Engine	ICE	EV
Price (Aus)	$20,000	$48,000
Urban mileage	6.6L/100km	10km/kWh
Fuel price	$1.30/L	~14c/kWh
$/100km	$8.70	$1.40

21 Victoria mandates a minimum of 29c/kWh; retail price of peak power exceeds 50c/kWh
22 https://www.solarchoice.net.au/blog/current-levelised-cost-of-energy-solar-australia
23 Allowance should be made for wear on the battery
24 https://arena.gov.au/assets/2018/06/australian-ev-market-study-report.pdf
25 Mostly, EVs require less maintenance, but at present that is outweighed by the cost of battery replacement.

Table 3: Example comparison of ICE and EV costs

Even at a zero discount rate, the price difference of $28,000 would only be recovered after 380,000km - more than 20 years of average driving. The battery would need replacing in about ten.

The high price owes most to the lithium and cobalt content of the batteries, raising the concern that increasing demand will push the price higher. But that has not stopped the battery price falling 70% from 2010 to 2017, and the technology race is far from over.

EVs are predicted to be cheaper to buy than ICE by 2025[26,24].

Illustration 2 combines several analyses from 2015-2017[27].

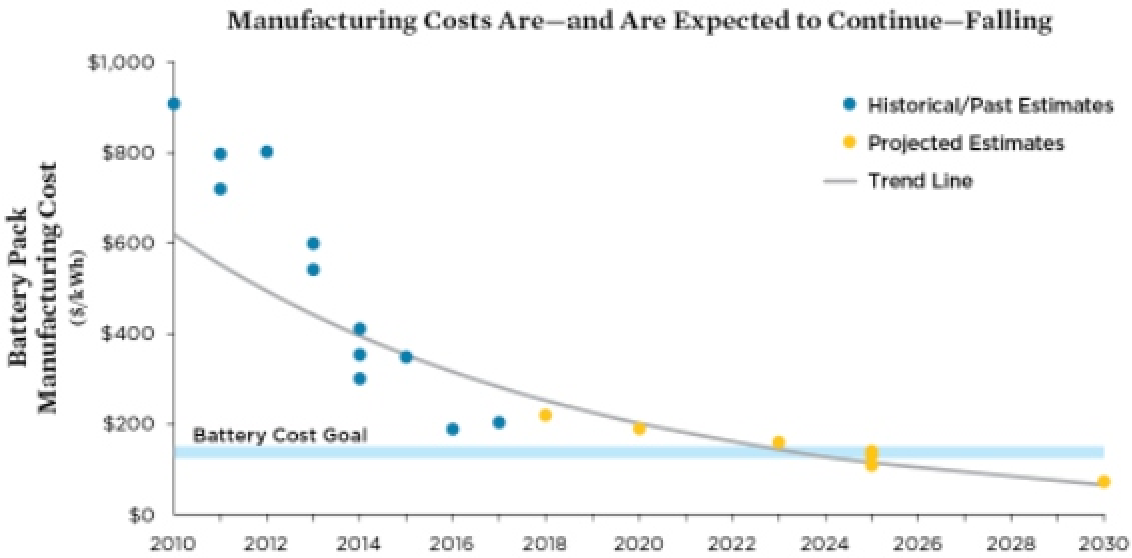


Illustration 2: Historic and predicted battery costs. "Goal" is car lifetime cost parity.

But that is already out of date. By end of 2018, EV battery production costs had fallen under USD180/kWh and are predicted to beat USD150 in 2019[28]. Moreover, the trend line in Illustration 2 is not a good fit to the historical data.

Including the new data and applying a negative exponential fit produces Illustration 3.

26 https://www.ucsusa.org/clean-vehicles/electric-vehicles/electric-cars-battery-life-materials-cost
27 https://www.ucsusa.org/sites/default/files/attach/2017/09/cv-factsheets-ev-incentives.pdf
28 https://about.bnef.com/blog/transition-energy-transport-10-predictions-2019/

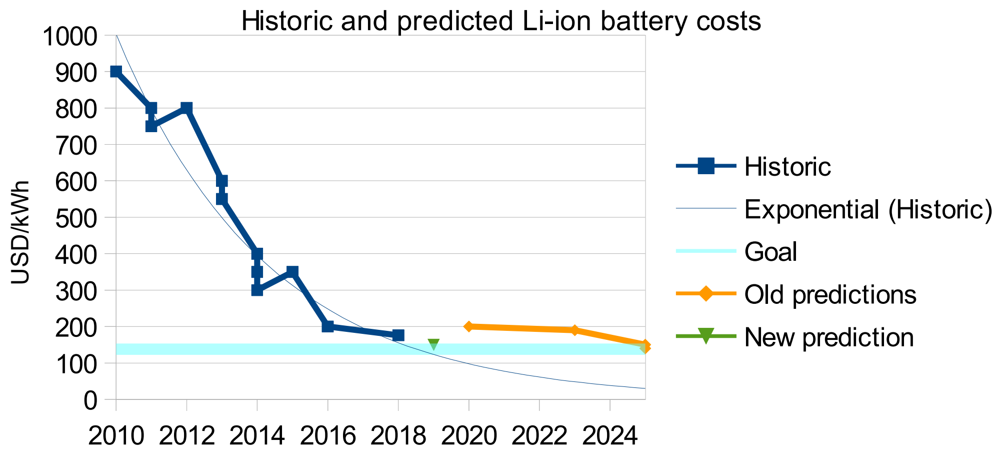


Illustration 3: Historical and projected EV battery costs as at Jan 2019

This implies lifetime cost parity will be achieved by 2020, opening the floodgates for a transition to EVs. But without suitable planning now there may be a shortage of charging infrastructure, a mismatch with electricity generation, and an incumbent fleet of still-new ICE vehicles of rapidly declining value.

Range Anxiety

While this submission centres on urban driving, drivers will not want to need an ICE or hybrid on hand for longer journeys, or to have to rent one for the occasion. Even for a driver who never undertakes such, it would be a psychological barrier. A fast-charging highway network will also be needed.

Within urban areas, while EV charge points remain rarer than conventional fuel stations, mobile apps showing nearby points will be essential. These are starting to appear[29].

Emissions Standards

Australia lags on standards for emissions of particulates and noxious gases from ICE vehicles[30]. This has been defended on the basis of keeping car ownership cheap, but the resulting tax burden to pay for the health harm makes it a poor bargain.

Would catching up on international standards help nudge towards EVs, or lead, on the one hand, to a slower retirement of the worst offenders, and on the other, to a more expensive stranded asset of ICE? The views of vested interests should be treated with caution[31].

The flaw is that raising standards (and hence price) for new cars is not the most appropriate. New cars are likely less polluting than old ones already, and encouraging drivers to hold on to older vehicles would be counterproductive.

Combining raised standards with "cash for clunkers" is more effective, but also unfair, rewarding those who have not voluntarily cut pollution.

The fairest approach is to raise the cost of driving polluting cars generally. This has been

29 https://www.theverge.com/2018/10/16/17983986/google-maps-electric-car-charging-tesla-superchargers
30 https://reneweconomy.com.au/australias-weaker-emissions-standards-allow-car-makers-to-dump-polluting-cars-67691/
31 https://www.abc.net.au/news/2018-04-04/motoring-lobby-warns-against-too-strict-emissions-standard/9617044

done in London[32] and is proposed for 20 other UK cities[33].

Location, location

Since the primary location of the electricity demand for EVs will be in the cities and suburbs, that may be the optimal place to produce the extra power. If EV adoption lags the general shift to renewables, the resulting balance between grid-scale and suburban rooftop PV may be suboptimal. This suggests benefits of a continuing SRES scheme.

Matching Demand to Supply

1. Time of Day

   Scenarios that recharge EVs from grid power reach optimum when the growth of PV has reclassified the 9am-3pm[34] period (10am-4pm in summer) as off-peak.

2. Volume

   Australian electricity consumption is 260TWh/y[35], and that of petrol/Diesel is 32GL/y[36]. At the 10kWh/6.6L equivalence in Table 3, full conversion to electric[37] of today's transport would add 48TWh/y[38] to demand, about 20%.

   At average output of 4kWh per nominal kW PV per day, that is 33GW of PV panels; we are at 10GW now[39].

3. Trajectory

   While market forces will eventually bring these changes about, the adoption of EVs will likely lag behind. Until that catches up, PV generation risks being curtailed for lack of midday demand. This will in turn delay the roll-out of PV.

EV2G

EV2G is not yet a commercial reality[40]. It requires three technological developments[41]:

- Circuits in the vehicle which support bidirectional flow
- Circuits in the charger which support bidirectional flow
- Software in the charger that monetizes the transaction

Presently, only one commercially available vehicle[42] supports it and there are no chargers certified for general use. Nevertheless, a major Japanese power company[43] has announced a joint venture to pursue this.

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32 https://www.theguardian.com/uk-news/2017/oct/23/london-10-pound-t-charge-comes-into-effect-toxic-car-fumes
33 https://www.buyacar.co.uk/cars/economical-cars/523/clean-air-zone-charges-where-are-britains-low-emission-zones
34 Increased interconnectivity may extend this, with SA, WA supplying PV into the Eastern evening.
35 https://www.energy.gov.au/sites/default/files/australian_energy_update_2018.pdf#page27
36 http://www.abs.gov.au/ausstats/abs@.nsf/mf/9208.0/
37 Which may include shifting some from road to rail
38 This makes no allowance for transport growth
39 https://reneweconomy.com.au/seven-australian-solar-facts-to-make-your-jaw-drop-30669/
40 https://www.evconsult.nl/wp-content/uploads/2018/10/Final-Report-UKPN001-S-01-I-V2G-global-review.pdf
41 https://cleantechnica.com/2019/01/26/electric-vehicle-to-grid-technology-gears-up-for-the-mass-market-cleantechnica-interview/
42 https://cleantechnica.com/2018/11/29/nissan-using-vehicle-to-grid-technology-to-power-us-operations/
43 https://www.fermataenergy.com/post/fermata-energy-announces-2-5m-strategic-investment-from-tepco-ventures

The economics[44] depend principally on

- The cost of the degradation to the battery from the extra cycles. This will come down as the batteries become both cheaper and more robust.
- The value placed on the service to the grid[18]
- The additional cost of the equipment

EV2G at public charging points faces several further challenges. The driver must be sophisticated enough to understand the costs and benefits of the contract being entered into. The charge point provider must operate an algorithm which makes certain guarantees to the driver and rewards the driver fairly.

Moreover, since the most useful time for EV2G feed-in is the evening, it may be of little value for public charge points to have this capability. Exceptions may arise at certain venues, but, rightly or wrongly, drivers may be fear becoming stranded.

In a domestic context, householders may be more motivated by viewing the car battery as an alternative to a standalone domestic battery, supplying their own needs.

Recommendations

Promote Uptake of EVs and their Daytime Charging

For the benefit of public health, grid efficiency, emissions reduction and balance of trade, steps should be taken to encourage the uptake of EVs, bringing it more into line with the potential growth of PV.

To reap these benefits, it is essential that EV charging is substantially aligned with PV output. This will involve, *inter alia*, engaging with those bodies which set tariff periods.

Public Charging Points

Governments can assist the general transition to renewable energy by encouraging not only the roll out of urban charging points but, specifically:

- Level 2 charging
  - At Transport Hubs

    This forms a natural part of efforts to decentralise cities, such as in the Greater Sydney Region Plan[45].

    In the initial stage, with EVs being still rare, only a few clusters of car spots need be equipped with chargers. The cost of the energy and infrastructure would be covered by a small premium charged on using those parking places, thereby discouraging their occupancy by ICE vehicles.

    Consideration should also be given to installing roofs with PV panels, providing shade for the cars and contributing to the power.
  - At Public and Private City Carparks

44 https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/24630/3/Dickerson_V2G%20paper%20-%20BG.pdf
45 https://www.planning.nsw.gov.au/Plans-for-your-area/A-Metropolis-of-Three-Cities/A-Metropolis-of-Three-Cities

While commuting all the way by car is not to be encouraged, Australian cities have not done well at cutting congestion. It is likely to remain a fact of life for some time yet. Accepting this, City authorities could mandate/subsidise a minimum level of provision of charging points.

    - Demand Response

      Ideally, these level 2 charge points would be sensitive to signals from the grid. Some guarantee would need to be made to the drivers that, say, 10kWh will be delivered within 6 hours.

- Level 3 charging on Highways

  While the bulk of the journeys are urban, a national network of fast charging stations, 150km apart at most[46], will be needed to encourage owners to go fully EV. 150km might seem sparse, but in the year or two before EVs challenge ICE on cost their range is sure to increase.

Coordinating EV and PV growth

We urge COAG and the Federal Government to engage consultants[47] to advise on how these complementary transitions can be coordinated to best effect.

The present roll-out of PV in Australia is about 3.5GW/y[48]. After Liddell's retirement in 2022 (2GW), no further coal power plants in the NEM are planned to retire before 2035[49].

With no increased demand for power, the rapid growth of PV is unlikely to continue beyond another few years. To maintain momentum, it would be good to have at least 1GW/y demand for EVs by 2023. That implies 3% of the road fleet.

The average age of a car on Australian roads is ten years[50]. Thus, ideally, 30% of new cars should be electric by 2023.

How much incentive will be required depends on the rate of decline in battery costs. Illustration 1 Implies substantial incentives will be required, Illustration 2 suggests modest intervention, while Illustration 3 implies none at all, beyond removal of the various other barriers.

California's ZEV[51] (Zero Emissions Vehicle) and China's NEV[52] (New Energy Vehicle) schemes promote EVs by setting a minimum ratio of EV to ICE sales for each manufacturer. This is analogous to Australia's LRET scheme for renewable energy.

These schemes have the merit of automatically becoming neutral if falling costs make them unnecessary.

46 https://reneweconomy.com.au/ev-fast-charging-network-to-roll-out-in-australia-after-funding-boost-13345/
47 We draw attention to the sorry history of Australian governments' consultants woefully underestimating the pace of change. It will be important to base the choice on track record.
48 https://reneweconomy.com.au/booming-solar-market-triples-in-2018-set-to-deliver-hazelwood-liddell-by-2020-2020/
49 https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Coal_fired_power_stations/Final%20Report/c02
50 https://www.caradvice.com.au/574207/australia-average-vehicle-age-is-10-1-years/
51 https://www.transportpolicy.net/standard/california-zev/
52 https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111

More Total Demand, lower Power Prices

The growth of domestic PV has cut demand. In the fixed tariff that most consumers use, a large portion of the per-kWh charge actually funds the network. The reduced demand is forcing up the prices[53].

Adding a significant electricity demand for EVs will help sustain total demand and hold power prices down. California[54] has found that state-funded EV chargers have had a net economic benefit for the wider public.

FCAS, Demand Response and EV2G

A fair market in FCAS, properly valuing rapid response, would stimulate the provision of charging points that supply these services.

Likewise, AEMC rules need to allow a broader Demand Response market[55].

For public charge points, some standardisation of contracts would assist driver comprehension and trust.

For domestic charging, governments may have a role in encouraging the installation of charge points that are DR and/or EV2G ready.

For EV2G specifically, government agencies such as ARENA, CSIRO and the CEFC need to stay abreast of developments and support trials.

53 https://reneweconomy.com.au/rooftop-solar-takes-another-big-bite-out-of-origin-electricity-sales-31732
54 https://cleantechnica.com/2019/02/01/utility-funded-ev-charging-networks-benefit-all-rate-payers/
55 https://reneweconomy.com.au/whos-afraid-of-demand-response-71616

Appendix on Taxing Road Vehicles Fairly

Summary

Charging all road users fairly for the economic cost to the country would result in the fuel excise dropping from 40c/L to around 30c/L for ICE cars and 1c/L-equivalent for EVs, while the bulk of the road maintenance bill would go to HGVs.

Charging fairly for the economic cost to the world of the Greenhouse Gas emissions would double the price of fossil fuels.

Health Costs

Health costs per Litre of fuel in Table 4 are taken from "**Health impacts of transport emissions in Australia: Economic costs, 2005**[56]**"** *(Dept Infrastructure and Regional Devt)*

> *"The economic cost of this premature mortality was between $1.1 billion and $2.6 billion (central estimate $1.8 billion). In addition, the estimated economic cost of morbidity was between $0.4 billion to $1.2 billion (central estimate $0.8 billion). "*

Unfortunately, it does not separate the Diesel per litre harm from that of ULP. Evidence from around the world suggests this was historically underestimated, and Diesel likely has the higher impact of the two.
The history of international estimates of the health harm from air pollution exhibits a clear upward trend. Over time, more and more ailments are found to be linked to fossil fuel combustion[57].

Australian fuel usages in Table 5 are taken from "**9208.0 - Survey of Motor Vehicle Use, Australia, 01 Nov 2004 to 31 Oct 2005"**[58] *(ABS)*

Fuel	Used (GL)	$bn (low)	$bn (high)	$/L (low)	$/L (high)
ULP	17.8				
Diesel	8.7				
Total	26.5	1.5	3.8	0.06	0.14

Table 4: Health costs per L of fuel in internal combustion engines

However, this looks very conservative against more recent European analysis. The EU uses about 3.10^6TJ of ULP (80GL) and 8.10^6TJ (220GL) Diesel annually[59]. A 2018 study put the health harm at €70bn/y, 75% of which is from Diesel[60]. That translates to $A0.30/L for ULP, $A0.38/L for Diesel.

For the purposes of this document, we compromise at 25c/L.

56 https://bitre.gov.au/publications/2005/files/wp_063.pdf
57 E.g. https://www.theguardian.com/environment/2019/jan/11/air-pollution-as-bad-as-smoking-in-increasing-risk-of-miscarriage
58 http://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbyTopic/66E24E957EB09229CA2571E10077D71D?OpenDocument
59 https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/road_vehicle_fuel_consumption_en.pdf
60 https://epha.org/ce-delft-health-impacts-costs-diesel-emissions-eu/

Climate Cost

Peer-reviewed research[61] has found that the economic impact ("Social Cost of Carbon") of current CO_2 emissions is over USD400/tCO_2e for the world as a whole. The impact on individual countries varies greatly, but for Australia it is put at USD1-USD10 per tonne.

Fuel	kg CO_2/L[62]	Climate cost to Australia AUD/L	Climate cost to World AUD/L
Diesel	2.68	0.02	1.6
ULP	2.31	0.02	1.4
LPG	1.51	0.01	0.9

Table 5: Social Cost of Carbon

It may be argued that using an electricity grid dominated by fossil fuel power obviates the climate benefits of EVs, but that is not an inherent property of the vehicle. EVs can be charged using non-greenhouse power.
The equitable way to cover that is to reintroduce a price on carbon.

Combining the direct health costs with the longer term climate costs to Australia alone we arrive at a median figure of around 27c/L for petrol and Diesel. This compares with the current excise of 40c/L[63].
Including world social carbon cost would double the price of fossil fuels.

Road Maintenance

The Public Transport Users Association puts the annual bill for road damage at $17bn (and the GST on fuel and vehicle sales at $5bn)[64].

The standard rule of thumb is that the road damage per km per axle rises as the fourth power of the axle load[65].

Table 6 is extracted from "**Revised vehicle operating cost models for Australia**" *(ATRF, 2015)* [66]. The damage done is expressed in terms of "standard axles".

Vehicle class	*Gross vehicle mass (t)*	*Standard axles*
Large Car	1.6	0.0010
Courier Van-Utility	2.15	0.0031
4WD Mid Size Petrol	2.73	0.0081
Light Rigid	3.75	0.0100
Medium Rigid	10.4	0.6900
Heavy Rigid	22.5	3.5900
Heavy Bus	19	2.3200

61 https://www.nature.com/articles/s41558-018-0282-y
62 https://people.exeter.ac.uk/TWDavies/energy_conversion/Calculation%20of%20CO2%20emissions%20from%20fuels.htm
63 https://www.ato.gov.au/business/excise-and-excise-equivalent-goods/fuel-excise/excise-rates-for-fuel/
64 http://www.ptua.org.au/myths/petroltax/
65 http://www.nvfnorden.org/lisalib/getfile.aspx?itemid=601
66 http://atrf.info/papers/2015/files/ATRF2015_Resubmission_168.pdf

Vehicle class	Gross vehicle mass (t)	Standard axles
Artic 4 Axle	31.5	5.0700
Artic 5 Axle	39	5.6500
Artic 6 Axle	42.5	4.9700
Rigid + 5 Axle Dog	59	7.0400
B-Double	62.5	6.3500
Twin steer + 5 Axle Dog	64	7.5800

Table 6: Relative per km road damage by vehicle class

Table 7 provides the ABS figures for road usage by class for 2010[67].

Class	Average 1000s km /vehicle year	Number of vehicles
Passenger vehicles	13.2	12,341,262
Light commercial vehicles	17.5	2,441,929
Rigid trucks	20.8	433,258
Articulated trucks	85.0	81,376
Non-freight carrying trucks	9.8	21,538
Buses	27.9	72,509

Table 7: Road usage by class

While the vehicle classes do not match perfectly with those in Table 6 we can roughly combine these to produce Table 8:

Vehicle class	Avg travel / vehicle	Vehicles in class	Avg Standard axles	impact per vehicle year	impact per class year	% impact by class	Share of damage bill per class	fair charge per vehicle
	1000kms/ year	1000s		1000km x std axles			$m	cents / km
Passenger	13.2	12341.3	0.003	0.03	407	0.7%	116.86	0.07
Light commercial	17.5	2441.9	0.007	0.11	280	0.5%	80.32	0.19
Rigid trucks	20.8	433.3	1.430	29.74	12887	21.8%	3697.9	41.03
Articulated trucks	85.0	81.4	5.924	503.54	40976	69.2%	11758.15	169.99
Buses	27.9	72.5	2.320	64.73	4693	7.9%	1346.77	66.57
Total	*164.4*	*15370.3*			*59243*	*100.0%*	*17000*	

Table 8: Fair charge per km for road maintenance

Thus, the fuel excise appropriate for cars just to cover road damage is only 1c/L.

While an EV adds 200-400kg for the battery, the road damage per km still comes in at one five thousandth that of a B-Double. Compounding this, HGVs enjoy a fuel tax credit of

67 http://www.abs.gov.au/ausstats/Subscriber.nsf/LookupAttach/9208.0Data+Cubes-15.10.151/$File/92080DO001_1231201410.xls

13.6c/L[68], roughly one third of the excise.

Of course, road maintenance is not just a matter of repairing damage done by use; weather also takes a toll. But on this evidence it would seem that charging fairly to fund major roads would put almost the entire burden on HGVs, perhaps leading to a far greater uptake of rail freight, and a reduced need for new roads.

Revenue

Fuel Excise is only one of many revenue sources. It accounts for about 50% of the total (Table 9). An Electric Vehicle only avoids the fuel excise, so already contributes 50% of what a petrol car does.

Revenue source	***$m***
Excise, net of rebates	8686
Rego	3051
Stamp duty	2026
GST on new car purchase[69]	3000
GST on commercial vehicle purchase[70]	500
Tolls (public+private)	1462
Total	*18725*

Table 9: Revenue sources

68 https://www.ato.gov.au/Business/Large-business/In-detail/Business-bulletins/Articles/Fuel-tax-credit-rates-change-from-1-July-2016/
691m vehicles x $30,000 x 10%; Luxury car tax not included.
70 $5bn x 10%. See http://www.mtaa.com.au/images/docs/Commercial_Vehicle_Wholesaling_in_Australia.pdf

Glossary

AEMC	Australian Energy Market Commission	Sets the rules for the NEM, *inter alia*
AEMO	Australian Electricity Market Operator	Operates both the NEM and its WA equivalent
ARENA	Australian Renewable Energy Agency	
BEV	Battery Electric Vehicle	i.e. Pure electric, no ICE
CEFC	Clean Energy Finance Corporation	
DR	Demand Response	An arrangement whereby electricity consumers can be rewarded for cutting demand at critical times.
EV	Electric Vehicle	(in this document, BEV unless otherwise stated)
EV2G	EV to Grid	Using the battery of a parked EV as a source of power to the grid
FCAS	Frequency Control Ancillary Services	Some of the stabilising services that generators and storage can supply to the grid
GL, GJ, GW, GWh	Giga-litre, -joule, -watt, -watt-hour	= 1,000 ML, MJ, MW, MWh
ICE	Internal Combustion Engine	Burns ULP, Diesel or LPG
LRET	Large scale Renewable Energy Target	Requires a proportion of power generated to be from large scale renewables
MJ	Megajoule	1kWh=3.6MJ
ML	Megalitre	= 1,000,000 Litres
MW, MWh	Mega-watt, -watt-hour	= 1,000 kW, kWh
NEM	National Electricity Market	The wholesale spot market for electric power that connects all states and territories except WA and NT
PHEV	Plug-in Hybrid EV	Can operate as either ICE or BEV
PV	Photovoltaic	
SRES	Small scale Renewable Energy Scheme	Subsidises small scale renewables, e.g. PV installations up to 100kW
TJ, TW, TWh	Tera-joule, -watt, -watt-hour	= 1,000 GJ, GW, GWh