Australasian Transport Research Forum 2021 Proceedings
8-10 December, Brisbane, Australia
Publication website: http://www.atrf.info

Measuring the distributive impacts of electric vehicle policies

Vincent Benezech[1], Nancye Ng[1], Adam Basile[1]

[1]Veitch Lister Consulting, Level 6, 46 Kippax St, Surry Hills, NSW 2010

Email for correspondence: vincent.benezech@veitchlister.com.au

Abstract

The number of battery electric vehicles (BEVs) sold in Australia is low compared to other Organisation for Economic Co-operation and Development (OECD) countries, primarily because of a historic lack of supportive policies. However, several Australian States have recently announced or are developing electric vehicle (EV) policy packages to boost BEV uptake. Veitch Lister Consulting (VLC) has developed a model to assess the impacts of EV policies. This paper introduces a spatial EV uptake model and illustrates how it can be used to assess the aggregate and distributive impact of policies.

This paper explains the methodology behind the model and presents its key inputs and parameters. The impacts of two potential EV-related policies are also analysed: the introduction of road-user charging and an exemption of EVs from transfer duty.

1. Introduction

Context

Representing less than 1% of all light-vehicle (from here on, vehicle) sales in 2020, the number of BEVs sold in Australia is low compared to other OECD countries. The absence of supportive policies can explain most of the low uptake. An EV buyer in Europe can receive up to $20,000 of direct subsidies, while Australian buyers had to, until recently, absorb all of the additional cost of an EV purchase on their own.

However, several Australian states have announced or are considering policy packages supporting BEVs. NSW, for instance, recently released its EV Strategy (NSW Government, 2021). These packages aim to support the transition of the vehicle fleet to BEVs to reach net zero emissions by 2050 or earlier. This includes incentives to support the initial purchase cost of EVs, such as transfer duty exemptions, as well as supporting infrastructure to improve user convenience, such as fast charging networks.

Governments are also considering the introduction of road-user charging (RUC) for EVs to make up for the loss of fuel excise revenues associated with the transition. RUC, where drivers pay for each kilometre driven, is likely to disincentivise the uptake of EVs, creating a tension with Net Zero ambitions.

Objective

This paper introduces a new spatial model to assess the impact of EV policies. This model can be used to help Australian States calibrate efficient EV policies, striking the right balance between revenue raising via RUC and bolstering EV uptake with incentives.

This model projects EV adoption up to 2036, based on socio-economic, technology, mobility and policy inputs. The model aims to capture the distributive impacts of any policy on top of the aggregate impacts. It enables the identification of the winners and losers of any policy, through the analysis of the spatial distribution of uptake.

The principles on which the model is built are general enough to be applied to any jurisdiction. It relies on data that is generally available, at least for metropolitan areas. In this paper, all illustrations are supplied for the State of New South Wales (NSW), Australia.

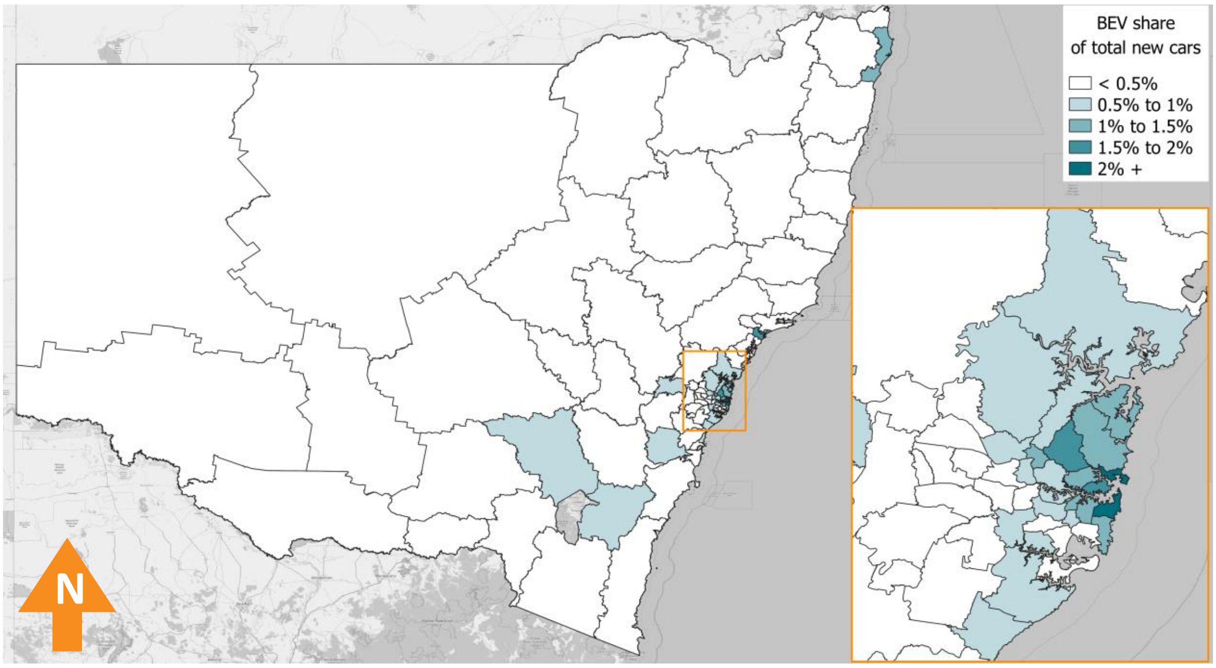
Paper outline

The remainder of the paper is organised as follows. Section 2 further motivates the need for a spatial model by analysing the current patterns of EV uptake in NSW. Section 3 outlines the model methodology and details the key inputs and parameters. Section 4 describes our reference uptake scenario, while Section 5 illustrates how the model can be applied for policy assessment by investigating the impact of two policies: road-user charging and exemptions from transfer duty.

2. EV uptake in NSW

At less than 1% of sales, EV uptake is much lower in NSW (and in Australia) than in other OECD countries, with EVs representing 75% of sales in Norway and 11% of sales in the UK in 2020 (IEA, 2021).

Figure 1. BEV share of new cars in NSW by SA3, Australian Bureau of Statistics Motor Vehicle Census 2020



Note: New cars are defined as cars manufactured in 2019 or 2020.

The distribution of BEV sales in NSW, shown in Figure 1, illustrates three of the key barriers to adoption that need to be overcome to enable a wider diffusion of EVs: the price gap between internal combustion engine vehicles (ICEs) and EVs, perceptions regarding EVs, and the lack of EVs available for some vehicle type. The following paragraphs present a brief outlook for each of these items.

Price gap between ICEs and EVs

The highest BEV shares of new cars in 2020 are achieved in two of the wealthiest areas of Sydney, the Eastern Suburbs and around Manly. More broadly, there is a strong overlap between EV sales and average income, showing the barrier represented by the price gap between ICEs and BEVs.

European countries make EVs affordable to a wider range of people by offering large direct subsidies, up to $20,000 when combining subsidies offered at different levels of government in France, for instance. While such levels of subsidies remain unlikely in an Australian context, declining prices should render BEVs affordable to a larger part of the population in a few years.

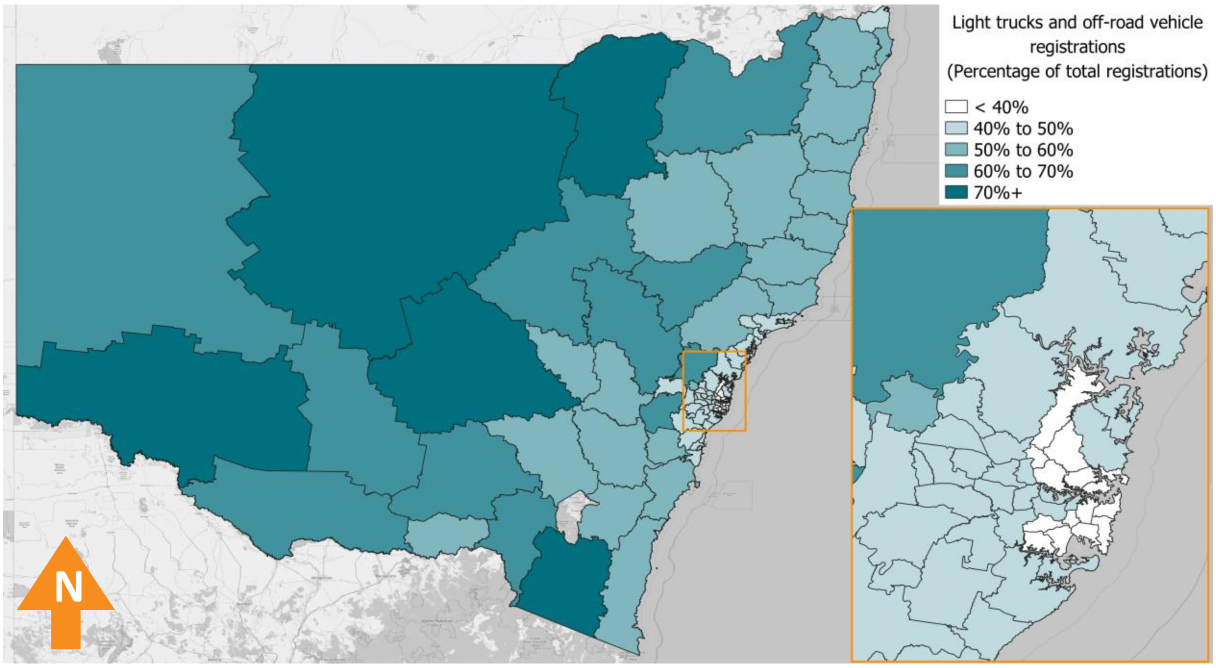
EV perceptions

BEVs are notably absent from rural areas and concentrate in the inner city. On top of an income effect, this reflects current perceptions and preferences towards EVs, which have been shown to correlate with education levels and political preferences (Sovacool et al. 2018; 2019). It can be expected that, as EVs become more mainstream, perceptions will shift and EV acceptance will rise. This may, however, take time.

Lack of EVs available for some vehicle types

A lack of available BEV models is a strong barrier to wider EV adoption. Outer urban areas of Sydney, regional NSW, and industrial areas display the highest proportions of light commercial vehicle (LCV), utility vehicles (utes) and sport utility vehicle (SUV) ownership, as shown in Figure 2.

Figure 2 Proportion of new light truck and off-road vehicle Service NSW registrations by SA3, 2020



Recent research shows that car manufacturers are planning to deliver an expanding range of SUV models (IEA, 2021). Model availability for utes, which constitute 15% of sales in NSW is, however, likely to remain limited in the short term, as these models are not very popular in Europe and North Asian markets.

3. EV uptake model

VLC has developed a model to forecast the uptake of EVs. The model is highly disaggregate, producing results at an SA3-level for 13 vehicle types (see Table 2 in Appendix A) and 3 fuel types (ICE, EV and plug-in hybrid electric vehicles (PHEV)).

3.1. Model overview

The model reflects the joint determination of supply and demand of EV uptake. The model can be used to test various policy interventions and behavioural changes related to the private vehicle market:

- **Vehicle prices**, with BEV prices expected to decline strongly in the coming decade and reach price parity with ICEs sometime between now and 2035. Rebate schemes directly affect the vehicle price.
- **Running costs,** consisting of maintenance, energy and, if applicable, a road-user charge.
- **Overall preferences for BEV** capture the non-financial components of purchase decisions. The preference curve can be altered in scenarios, for instance when considering fast-charging network investment scenarios.
- **Model availability** is an index describing the constraints on the number of EV models available, which limit consumer choice and the uptake of EVs. EV-support policies indirectly influence model availability: it is assumed that car manufacturers will be incentivised to bring additional models to the Australian market as the size of that market grows.

Model parameters are estimated with a Stated Preference survey carried out among potential vehicle buyers in NSW (see Appendix A for more details) and the model is calibrated with observed data from the Australian Bureau of Statistics 2020 Motor Vehicle Census and produces forecasts up to 2036.

Conceptually, the model consists of two main components, described in more detail in the following sections:

- A vehicle stock / sales model
- An EV uptake model.

3.2. Vehicle stock and sales model

3.2.1. Number of vehicles on the road

The number of vehicles on the road comes from two separate modules.

An econometric model (multinomial logistic regression, see Table 3 in Appendix A for the model coefficients) which relates household car ownership with demographics and land-use variables such as household size, income, density or public transport accessibility. This model, calibrated using 2011 and 2016 data, produces forecasts of the number of vehicles for private use at an SA2-level.

The number of fleet vehicles increases in line with gross state product forecasts, with an elasticity of 0.6, which is the average observed between 2016 and 2019[1].

The stock forecasts initially combine all light-duty vehicles. The vehicle stock is disaggregated by vehicle type results by applying the distribution of the stock in 2020 and the distribution of sales over the forecast years.

3.2.2. Stock / sales

The total number of new vehicles sold is the sum of the change in the number of vehicles on the road and the number of existing vehicles scrapped. Vehicle sales are then broken down by vehicle type accounting for two trend assumptions (also see Figure 9 in Appendix A):

- The share of SUVs increases from 50% of all light vehicle sales in 2020 to more than 60% in 2036.
- The share of LCVs and utes increases slightly in line with the historical trend.

Once the fuel-type model has divided the sales of new vehicles into the three available fuel types, the stock / sales model predicts how these new sales will penetrate the vehicle stock and computes the stock of vehicles for each fuel type. This part of the model also predicts how second-hand cars will enter the market.

3.3. Fuel type model

The fuel type model predicts EV sales as a proportion of total new car sales, by vehicle body-type and SA2. It uses a logit discrete choice model to proportion total vehicle sales into each fuel type (EV, PHEV or ICE), according to utility functions based on purchase and running cost components for each vehicle body-type and engine type. Purchase costs and running costs are sourced from multiple automotive industry publications, such as the Royal Automotive Club of Queensland (2019), with electricity and petrol price forecasts from NSW Treasury and Australian Energy Market Operator (2017).

This model is similar to a Total Cost of Ownership model, with two main differences.

The various cost components do not all have the same weight, which reflects survey evidence that there are differences in the perception of costs by vehicle users. One dollar spent on purchasing the vehicle is not the same thing as one dollar spent on maintenance or fuel. The parameters for the cost/utility components come from a survey of prospective car buyers in NSW, as shown in Table 1.

The utility can include non-monetary cost components as well. In the survey, for instance, people were asked about their perceptions of fast charging availability. It was found that being able to charge a BEV as conveniently as an ICE is refuelled currently was equivalent to a decrease in the BEV purchase price of around $7,500.

In the model, this translates into a constant that can apply to BEV which represents intrinsic preferences for BEVs compared to ICEs. Without policy intervention, this constant is negative in 2020, as indicated in Table 1. However, the constant slowly increases to 0 in 2036. By that date, the model assumes that buyers are powertrain agnostic when making their purchase decisions and all issues related to charging have been solved. This preference curve can be altered in scenarios, for instance in the case of investment of charging infrastructure.

[1] Elasticities for previous years were lower, or even negative, due to a decrease in the provision of company vehicles to individuals, with companies preferring alternative arrangements, such as novated leasing.

Table 1. Model parameters

Variable	Coefficient
Alternative Specific Constant ***EV, ICE as the referent case***	Varies between -1.0 (null household income) and 0 (household income greater than $230,000)
Purchase price ($k)	-0.071
Fuel costs ($k/year)	0.2
Maintenance costs (compared to fuel costs)	2.5
Road-user price (compared to fuel costs)	1.4
Fast charging availability	0.55

An additional model availability parameter is calibrated using the share of BEV in sales by vehicle type, with an estimated coefficient of 0.7 applied to the log of model availability. When a model is unavailable for a given vehicle type, the utility becomes -∞ and the share of EV in sales is 0. When model availability is 100%, there is no penalty for BEVs for that vehicle type.

4. Reference scenario

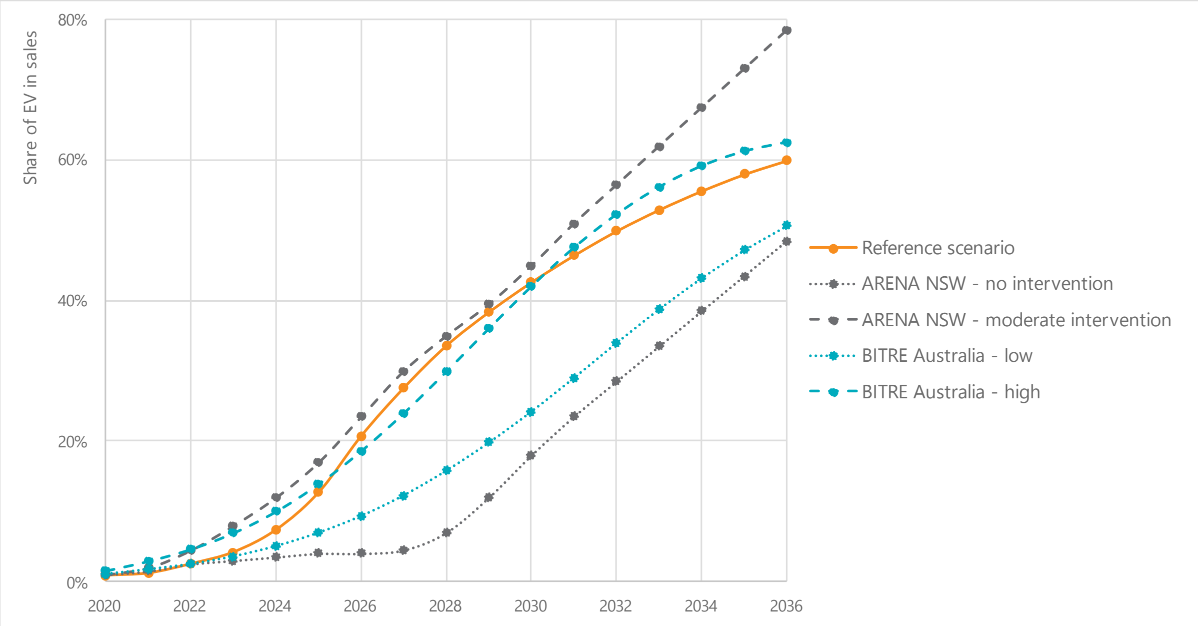
4.1. Uptake under the reference scenario

The uncertainty around the time path of future EV uptake is very large, as the EV market is in its very early stages, especially in Australia, and subject to decisions and events outside of the control of the governments of Australia (international car manufacturers, other countries' policies, technological breakthroughs, etc.).

This section introduces a reference scenario built around a few simple assumptions. This scenario does not constitute a baseline, but is merely one of the many possible futures that was used to assess the policies.

In this reference scenario, BEVs constitute close to 60% of sales by 2036. This reference forecast is in the mid-range of existing EV uptake forecasts. Compared to forecasts from ARENA (Energeia 2018), projected reference EV uptake in 2036 is between the *no intervention* scenario, which is a business-as-usual scenario based on the state of play in 2018, and the *moderate intervention* scenario, which assumes a large range of policy support at various government levels. By 2036, the reference projections for this report are also between the low and high forecasts produced by the Bureau of Infrastructure, Transport and Regional Economics (BITRE 2019).

Figure 3. Benchmark of reference scenario against ARENA and BITRE EV uptake projections



4.2. Reference uptake assumptions

The most critical assumptions behind the reference projections are:

Decline in vehicle prices - Price parity between BEV and ICE is reached around 2027. This largely aligns with price parity forecasts in Europe by the International Council for Clean Transportation (Lutsey and Nicholas 2019) and Bloomberg New Energy Finance (2021).

Increase in model availability – The constraint on model availability for EVs is included in the model via a model availability index describing the ratio between the number of EV models available and the number of ICE models available for each vehicle type. In our reference scenario, evolution of model availability mirrors the neutral scenario curve from Energeia (2018). However, all models reach an index of 1 by 2036, meaning that there are as many BEV models available as there are ICEs.

4.3. Spatial distribution of reference scenario uptake

BEV uptake in the short term is expected to concentrate in Greater Sydney, with BEVs representing over 16% of sales in 2025 there, compared to around 9% in regional NSW, as shown in Figure 4. List prices of BEVs are still at a premium compared to corresponding ICE models, which restricts uptake to higher-income households such as those in the inner suburbs or Sydney, as was already the case in 2020. By contrast, even within Greater Sydney, we do not expect a strong uptick for BEV sales in the Southwest by 2025, due to the lower average income in the area.

Already in 2025, EV uptake is projected to be higher in areas where households need to drive farther and hence would benefit more from reduced maintenance and running costs with EVs. This is visible in the strong expected uptake in the outer rings of Sydney. By 2036, this effect dominates, as EV list prices continue to decrease. Forecasts in the reference scenario predict that BEVs will represent at least 50% of sales in all regions of NSW by 2036, with shares of over 65% in Sydney’s outer urban fringe, Hunter and Illawarra regions, as shown in Figure 5.

Figure 4 BEV share of total car sales in the reference scenario, 2025

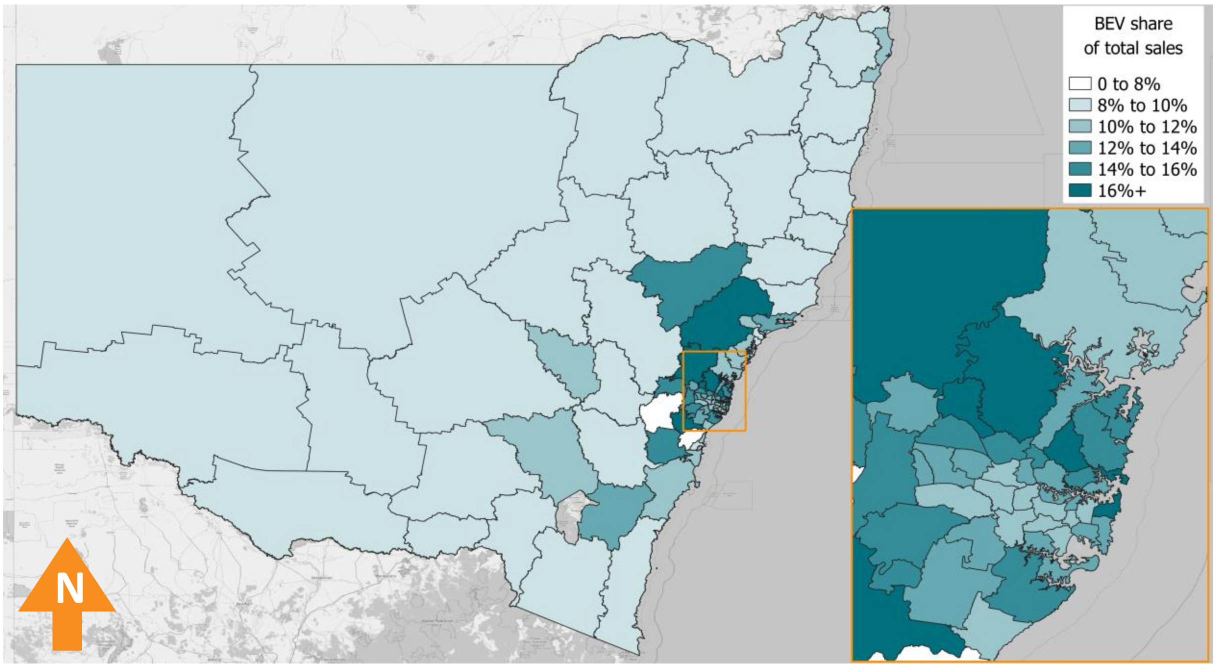
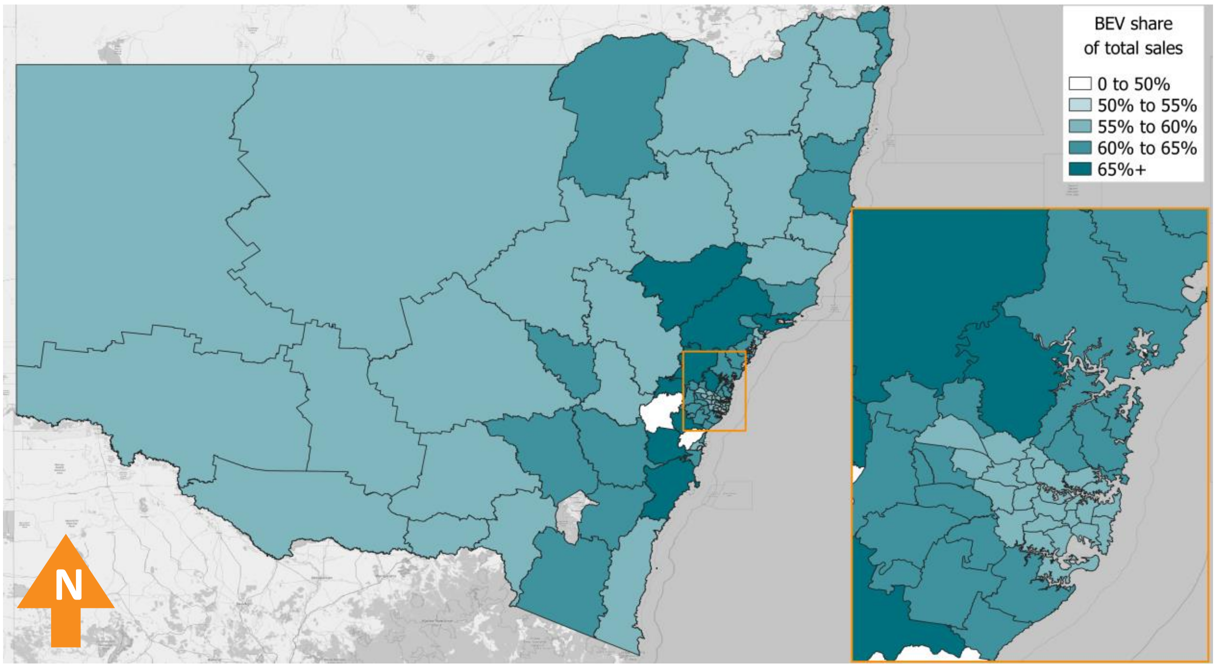


Figure 5 BEV share of total car sales in the reference scenario, 2036



5. Policy impacts

There are several policies to support EV uptake that have been considered across Australian state governments. For this paper, the potential impacts of a road-user charge, combined with transfer duty exemptions, were assessed as an example of how multiple policies can drive consumer preference for EV uptake while supporting the infrastructure required to sustain this.

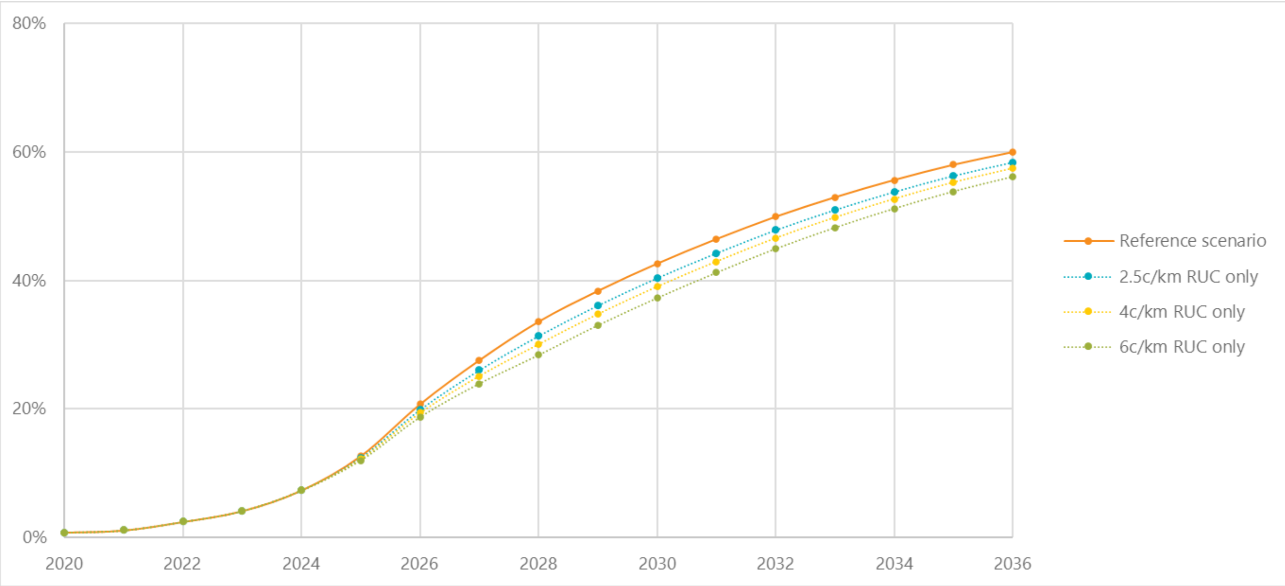
5.1. Road-user charge

To compensate for the loss of fuel excise, which BEVs do not pay, several Australian States have considered introducing a road-user charge (RUC). This consists in a kilometric fee that users of BEVs and PHEVs need to pay. This would be perceived as an additional running cost for EV users, which can impede EV uptake.

In this paper, the impact of three RUC amounts, implemented from 2027[2]: 2.5 cents/km, 4c/km and 6c/km, was assessed. The forecast EV uptake is shown in Figure 6.

By 2036, a 2.5c/km RUC is forecast to result in a 1.6% point drop in EV share of sales, while a 6c/km RUC results in a 3.8% point drop in EV share of sales. This represents between 94,000 (2.5c/km) and 224,000 (6c/km) fewer BEVs sold over the entire forecast period.

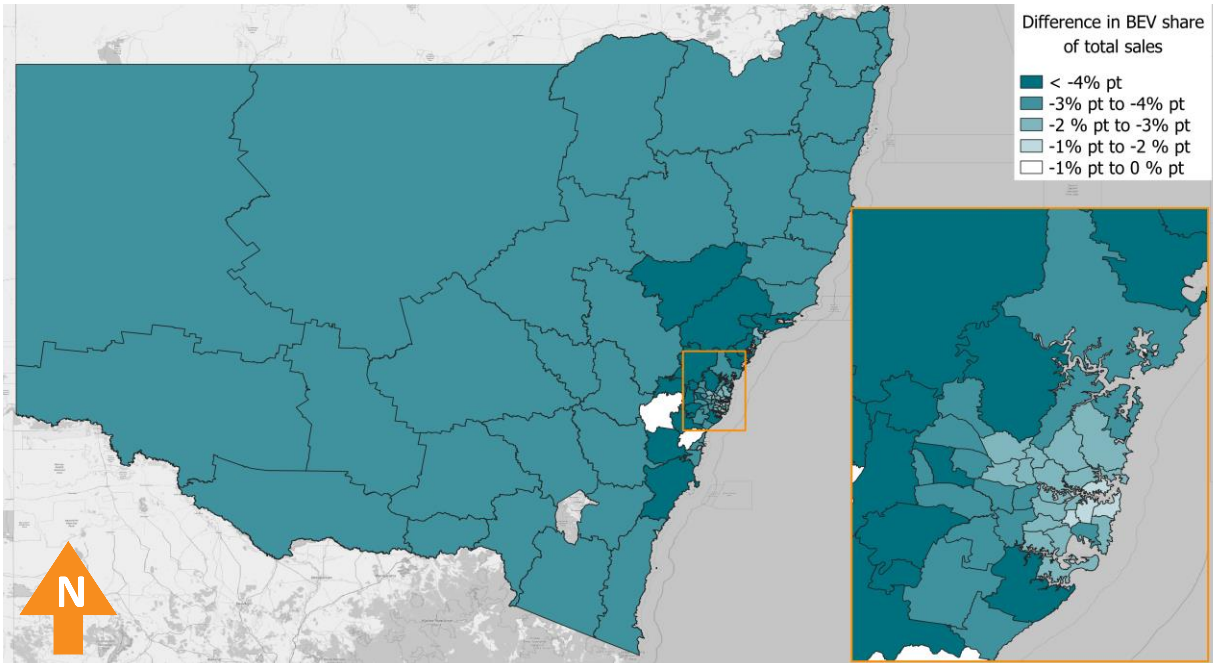
Figure 6 Road-user charge impact on BEV uptake



A RUC most significantly impacts households that drive farther on average. By 2036, EV uptake is expected to be over 4 percentage points lower in the outer rings of Greater Sydney, as shown in Figure 7.

[2] This is the year currently considered by NSW (NSW DPIE, 2021).

Figure 7 Impact of 6c/km road-user charge on BEV uptake by SA3, 2036

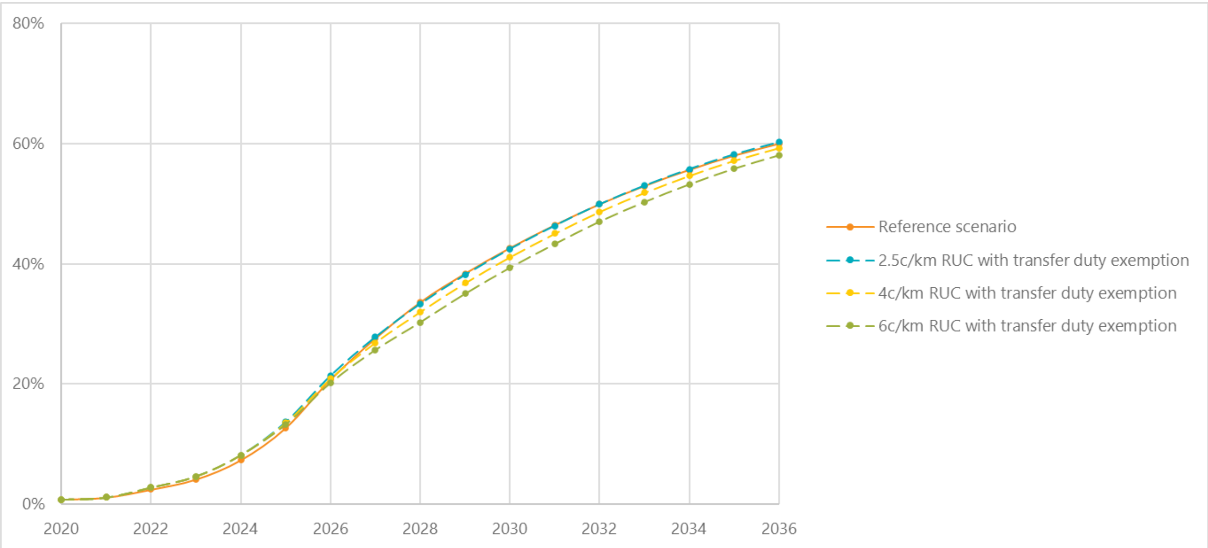


5.2. Transfer duty exemption

One of the potential financial incentives to reduce the barrier to entry resulting from the price gap between EVs and ICEs is an exemption from transfer duty. In NSW, transfer duty is paid when purchasing a vehicle, with rates between 3% and 5% depending on the vehicle price.

Transfer duty exemption for BEVs, implemented from 2022, has the potential to offset the disutility perceived from the RUC. In the first few years, it increases BEV uptake by a few percentage points and, by 2036, BEV uptake for a scenario with a road-user charge of 2.5c/km and transfer duty exemption is expected to be similar to the reference scenario, as shown in Figure 8. BEV uptake also improves in scenarios with a road-user charge of 4c/km and 6c/km, although uptake remains slightly lower than in the reference scenario.

Figure 8 Road-user charge and transfer duty exemption, combined impact on BEV uptake



Although transfer duty exemption offsets some of the negative impact of the RUC in aggregate, the effects differ by geography. If the RUC amount is lower than the fuel excise that would be paid using an ICE vehicle, residents of outer suburbs would see the largest decrease in the kilometric tax that they pay. Inner-city households are likely to pay little RUC in total as they do not drive long distances. They would also receive the largest discounts from the transfer duty exemption as they purchase expensive vehicles, except if there is a limit on the sale price of eligible vehicles, as is the case in the NSW policy for instance.

6. Conclusion

The results presented in this paper demonstrate the need to go beyond aggregate impact measurements and to instead look at the distributive effect of policies. The VLC model can be used in aggregate form to understand the uptake and budget impacts of any set of policies. It can also inform on the spatial disparity of the effects, observed in relation to differences in income and mobility needs depending on the area.

Across NSW, transfer duty exemptions offset the disincentive to EV uptake caused by RUC, with varying effect across the state. The availability of suitable EV vehicles also varies geographically. In both cases, EV policies which do not take equity into consideration could favour wealthier inner-city dwellers but a careful choice of the RUC amount, along with price eligibility caps on purchase incentives, can successfully mitigate these effects.

.

7. References

Australian Energy Market Operator (AEMO) 2017, *Retail electricity price history and projected trends*, viewed 5 July 2021,

https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Demand-Forecasts/EFI/Jacobs-Retail-electricity-price-history-and-projections_Final-Public-Report-June-2017.pdf

Bloomberg New Energy Finance 2021, *Hitting the EV inflection point*, viewed 5 July 2021,

https://www.transportenvironment.org/sites/te/files/publications/2021_05_05_Electric_vehicle_price_parity_and_adoption_in_Europe_Final.pdf

Bureau of Infrastructure, Transport and Regional Economics (BITRE) 2019, *Research report 151, Electric vehicle uptake: Modelling a global phenomenon*, viewed 5 July 2021,

https://www.bitre.gov.au/sites/default/files/bitre-report-151.pdf

Energeia 2018, *Australian electric vehicle market study*, p. 81, viewed 5 July 2021, https://arena.gov.au/assets/2018/06/australian-ev-market-study-report.pdf

International Energy Agency (IEA) 2021, *Global EV Outlook 2021*.

https://www.iea.org/reports/global-ev-outlook-2021/trends-and-developments-in-electric-vehicle-markets

Lutsey, N and Nicholas, M 2019, *The International Council on Clean Transportation (ICCT), Update on electric vehicle costs in the United States through 2030*, viewed 5 July 2021,

https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf

NSW Government 2019, *NSW electric and hybrid vehicle plan*, viewed 5 July 2021, https://future.transport.nsw.gov.au/sites/default/files/media/documents/2019/Future%20Transport%20NSW%20Electric%20%26%20Hybrid%20vehicle%20plan.pdf

NSW Government 2021, *NSW electric vehicle strategy*, viewed 5 July 2021, https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Climate-change/nsw-electric-vehicle-strategy-210225.pdf

Royal Automotive Club of Queensland (RACQ) 2019, *Private vehicle expenses*, viewed 3 March 2020, https://www.racq.com.au/cars-and-driving/cars/owning-and-maintaining-a-car/car-running-costs

Sovacool, B., Kester, J., Noel, L. and Zaruzua de Rubens, G. 2018, 'The demographics of decarbonizing transport: The influence of gender, education, occupation, age, and household size on electric mobility preferences in the Nordic region', *Global Environmental Change*, vol. 52, pp 86-100, viewed 16 July 2021, https://www.sciencedirect.com/science/article/pii/S095937801830030X

Sovacool, B., Kester, J., Noel, L. and Zaruzua de Rubens, G. 2019, 'Income, political affiliation, urbanism and geography in stated preferences for electric vehicles (EVs) and vehicle-to-grid (V2G) technologies in Northern Europe', *Journal of Transport Geography*, vol. 78, pp 214-229, viewed 16 July 2021, https://www.sciencedirect.com/science/article/pii/S0966692318302928

Appendix – Supplementary tables and figures

Table 2. Vehicle types and representative models: 8 vehicle types, 5 of which with prestige version

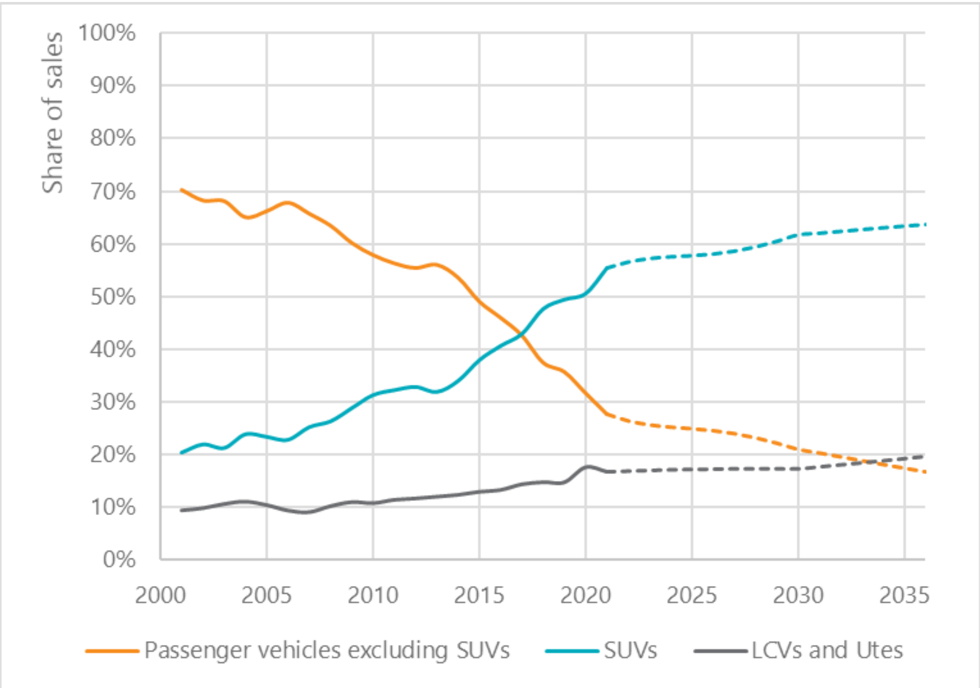
Modelled vehicle type	Representative model ICE	Representative model ICE prestige	Representative model EV	Representative model EV prestige
Micro / light	Toyota Yaris	Audi A1	Renault Zoe	N/A
Small	Toyota Corolla	BMW 1	Nissan Leaf	BMW i3
Medium / large	Ford Mondeo	BMW 5	Volvo S60	Tesla Model S
Light / Small SUV	Mitsubishi ASX	Audi Q3	Hyundai Kona	N/A
Medium / Large SUV	Volkswagen Tiguan	BMW X3	N/A	Audi e-tron
People mover	Kia Carnival		Mercedes-Benz EQC	
Ute	Toyota Hilux	Not modelled	(Rivian R1T/N/A)	Not modelled
Van	Toyota Hi-Ace		Renault Kangoo	

Note: Some vehicle types are currently not available in an EV version.

Table 3. Model coefficient for the number of cars per household in an SA2

Parameter	Households with 0 cars	Households with 1 car	Households with 2+ cars	Interpretation
Intercept	0	1.03	-0.92	
Median total household income (weekly)	0	0.00035	0.00077	Low income remains a barrier to car ownership, especially to the ownership of 2+ cars.
Population density	0	-0.00013	-0.00031	Households own less cars in dense areas, in particular because of parking constraints.
Proportion of population under 15 years	0	1.25	1.62	Large households tend to own 2+ cars.
Average household size	0	-0.21	0.31	
Car / Public transport accessibility ratio	0	0.77	1.44	Car ownership is especially high when public transport accessibility (to jobs and services) is low compared to the accessibility offered by cars.

Figure 9. Distribution of sales between passenger vehicles (excluding SUVs), SUVs and LCVs and utes. Historical data in solid lines, projections in dashed lines



Source: TfNSW new registration data, Retrieved from website on 1 July 2021.