**Adoption of electric vehicles in a laggard, car-dependent nation: investigating the potential influence of V2G and broader energy benefits on adoption**

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**Highlights**

* Investigates factors affecting EV adoption in a laggard market
* Vehicle-to-grid found to have a significant positive influence on EV preferences
* One-off electricity bill credits could also increase adoption
* Consumer awareness on EVs and V2G associated with higher likelihood of adoption

**Abstract**

*Increasing electrification of the global transport system is critical in the transition towards a net zero economy. While electric vehicle (EV) uptake is increasing in many countries, some nations – like Australia – are EV laggards. Here we analyse the stated preferences of a represenative sample of 500 Australian consumers by estimating a mixed logit model to understand preferences towards EVs in a laggard market and inform policymakers in similar markets on how potentially accelerate uptake. Additionally, the findings of this study are useful to EV manufacturers in exploring the specific vehicle features that are most attractive to consumers, and that are likely to be required to stimulate uptake in car-dependent markets, like Australia, with longer distances between urban areas.*

*The attributes examined in this study include purchase price, driving range, fast charging time, public fast charger availability, financial incentives and vehicle-to-grid (V2G) capabilities. As one of the first consumer preference studies to include V2G capabilities, this study also aims to understand how broader potential energy benefits stemming from EV ownership are perceived by consumers, and whether these features could further stimulate uptake. As expected, purchase price, driving range, fast charging time, public fast charger availability and financial incentives in the form of energy bill discounts were found to be significant factors affecting the choice to purchase an EV. Interestingly, the availability of V2G was found to have a significant impact on consumer choice, with consumers’ marginal willingness-to-pay for these features ranging from AUD 2,319 to AUD 5,346, depending on the technical details of its implementation. As identified in other studies, younger consumers were found to be more likely to purchase an EV, and higher levels of EV awareness also have a significant positive impact.*

**Keywords**

Battery electric vehicles, Vehicle-to-Grid, Willingness-to-pay, Australia, Discrete choice modelling, Consumers’ perception

1. **Introduction**

Transportation accounts for approximately 24 percent of carbon dioxide emissions globally (International Energy Agency, 2020). Electric Vehicles (EVs) have the potential to support transport decarbonisation as they can deliver lower lifecycle emissions compared to incumbent, internal combustion engine vehicles (ICEVs) (European Commission, 2020; Ma et al., 2019). Emission reductions can be maximised through the use of smart charging capabilities, to align charging with peak renewable energy generation periods, and potentially discharging, via vehicle to grid (V2G) at peak demand periods (Jochem et al., 2021) . EVs can also deliver other benefits, such as reduced air and noise pollution, higher energy efficiency and increased national fuel security (International Energy Agency, 2021).

To achieve net-zero emissions by 2050, it is expected that about 60 percent of new car sales will need to be EVs by 2030 (Bloomberg, 2021). However, EVs still account for only 4.6 percent of total car sales, and 1 percent of the global fleet as of the end of 2020 (International Energy Agency, 2021). While countries with high purchasing power are reported to have higher EV penetration rates (Rietmann & Lieven, 2019), it is notable that some wealthier countries, such as Australia and the US, are laggards. For instance, in 2020 EVs constituted 74 percent, 10.7 percent and 6.2 percent of the new vehicles sold in Norway, the UK and China respectively, while it was only 2.3 percent in the US and 0.8percent in Australia (Electric Vehicle Council, 2021). The state of California is a special case, with high EV adoption rates owing to pro-EV policies from an early stage in the development of this technology (Jenn et al., 2020). In car-dependent countries, with multiple cars per household, the purchase of at least one EV could drastically improve EV market share.

Increasing the number of EVs on roads also implies higher energy demand. Currently, EVs constitute about 0.3 percent of global energy demand. This is expected to go up to 2-4 percent by 2030 (International Energy Agency, 2021). This increase in electricity demand, while modest, should be planned for to minimise the potential risks to electricity grids. Smart charging techniques, such as V2G technology, offer a sustainable option whereby EV batteries could act as flexible, distributed energy sources during peak electricity demand periods enabling smoother integration of renewables with the grid, better voltage regulation and ancillary services. However, factors such as lack of awareness on V2G technology, higher desire for flexibility in car use, consumer perceptions of battery degradation due to increased charging cycles are identified as barriers to widespread adoption of V2G (Noel et al., 2019; Parsons et al., 2014). It has been reported that algorithms with a battery longevity maximization objective could extend battery life or at the least render the same longevity as normal charging without V2G (Amjad et al., 2018; Uddin et al., 2018).

There have been numerous studies, particularly Stated Preference (SP) studies, to elicit consumers’ preferences towards EVs and various authors have put forward reviews of the extant studies (Biresselioglu et al., 2018; Coffman et al., 2017; Greene et al., 2018; Hardman, 2019; Kumar & Alok, 2020; Liao et al., 2017; Rezvani et al., 2015). High purchase prices of EVs are found to have a significant negative impact on consumers’ preferences towards EVs (Beak et al., 2020; Bjerkan et al., 2016; Egbue & Long, 2012; Fluchs, 2020; Higgins et al., 2017). Driving range and charging time are two significant technical factors affecting consumer preferences towards EVs (Cecere et al., 2018; Ghasri et al., 2019; Noel et al., 2018; Rotaris et al., 2021). Charging infrastructure limitations, both in availability and technology, is a key barrier to EV penetration (Cherchi, 2017; Santos & Davies, 2020; Wolbertus et al., 2018). Although many studies have found policies to be generally effective, there is little consensus among researchers regarding the effectiveness of different policies (Cherchi, 2017; Mersky et al., 2016; Rietmann & Lieven, 2019; Wang et al., 2017; Whitehead et al., 2019; Wolbertus et al., 2018). Various other factors that have been found to influence EV adoption include socio-demographic factors, such as income, age, education, urbanization, employment, travel pattern (Fluchs, 2020; Gong et al., 2020; Rotaris et al., 2021), higher innovativeness and environmental factors (Bahamonde-Birke & Hanappi, 2016; Danielis et al., 2020; Langbroek et al., 2016; Smith et al., 2017). However, the results are inconclusive with mixed results. V2G being a relatively new technology, there are very few studies exploring the impact of V2G on EV adoption. Noel et al. (2019) investigated if V2G could boost EV adoption in five Nordic countries and found positive results for Norway and Finland, with consumers willing to pay € 5200 and € 4000 respectively, for EVs with V2G capability.

Despite vast literature on understanding consumers’ EV preferences, the majority focus on countries with comparatively high EV penetration rates such as Nordic or other European countries (Bjerkan et al., 2016; Fluchs, 2020; Hackbarth & Madlener, 2016; Santos & Davies, 2020; Taefi et al., 2016), California (Jenn et al., 2020; Nazari et al., 2019) or China (Li et al., 2020; Ma et al., 2019; Qian et al., 2019; Sovacool et al., 2019; Wang et al., 2017). There are very few studies focussed on markets with low EV adoption. There is limited literature exploring consumers’ perceptions on V2G technology and their willingness to participate in it. None of the extant literature analysing the Australian market (Ardeshiri & Rashidi, 2020; Ghasri et al., 2019; Gong et al., 2020; Smith et al., 2017) includes V2G as an attribute. This is the first study to do so in the Australian context.

This paper aims to address the following research questions:

* How do different attributes, such as purchase price, driving range, fast charging time and public fast charger availability affect consumers’ preferences towards EVs?
* How do financial incentives, such as free parking, electricity bill credits and discounted toll roads, affect consumers’ preferences towards EVs?
* Could the availability of V2G capabilities affect consumers’ preferences towards EVs?
* How much are consumers willing to pay for different EV features in a laggard EV market?
* What policies and vehicle characteristics would be required to stimulate market adoption in laggard EV markets, such as Australia?

This paper aims to address a gap in the literature concerning EV preferences of consumers in countries with low EV adoption, investigating possibilities to increase EV adoption, with a focus on the effectiveness of V2G in shaping consumer preferences. This is achieved by means of a stated preference study in Australia. The chosen attributes are purchase price, driving range, fast charging time, public fast charger availability, financial incentives, and V2G capability.

This study focuses only on BEVs- referred to simply as EVs –since they have the absolute advantage of reduced emissions compared to all other EVs and the ability to be charged directly using renewable energy (Egnér & Trosvik, 2018; International Energy Agency, 2021).

This paper continues in Section 2 with an outline of the methodology and presents results in Section 3. It is followed by discussion of results in Section 4 and conclusion in Section 5.

1. **Methodology**
	1. **Experimental design / Survey**

In a discrete choice experiment, the model parameters are estimated using Stated Preference (SP) or Revealed Preference (RP) data. The relatively low number of EVs in some markets makes it difficult to obtain RP data from a representative sample. RP data would restrict the sample to early adopters and may not reflect the mass market. Nonetheless, employing SP technique was beneficial since it allowed incorporation of hypothetical, non-existing attributes, and levels such as different V2G options. Hence, like majority of the studies on EV preferences, this study also relies on SP data.

The attributes for the SP survey were chosen based on a comprehensive review of the literature and caution was exercised to primarily include factors that were previously found to be statistically significant. Additionally, V2G capability was included as an attribute to analyse the effects of the potential energy benefits of EVs. The untapped potential of EVs to store energy and act as so-called ‘batteries-on-wheels’ offers the potential for improved renewable energy integration, grid stability and lower energy costs. By including V2G as an attribute, this study explores if these benefits would persuade consumers to adopt EVs. The attributes included in the SP experiment were purchase price, driving range, fast charging time, public fast charger availability, financial incentives, and V2G capability.

The attribute levels were chosen to primarily resemble the current market and vehicle options that will be available in the near future. The global average EV price was around USD 40,000 (AUD 53,333)[[1]](#footnote-2) in 2020 (International Energy Agency, 2021). Assuming that EV prices will reduce in the coming years owing to economies of scale and technological improvements, price levels were chosen between A$ 30,000 and A$ 60,000. With the average driving range of EVs at 338 km in 2020 (International Energy Agency, 2021), four levels varying between 300 and 600 km were chosen. For both fast charging time and public fast charger availability, the different levels are set to represent the best, improved and average scenarios. The study includes only financial incentives as they have been reported to be more effective over non-financial incentives (Fluchs, 2020; Ghasri et al., 2019; Münzel et al., 2019; Sierzchula et al., 2014). 50 percent discount for on-street parking and toll roads were selected since they have been found significantly positive in some studies (Cherchi, 2017; Danielis et al., 2020; Wang et al., 2017). Electricity bill credits of AUD 1,000 and AUD 3,000 is a new policy approach, specifically considered for the Australian market as an alternative to a direct subsidy. Australian consumers reportedly have moderate to high price elasticity of demand for electricity, implying high consumer sensitivity to electricity costs (Chesser et al., 2018; Fan & Hyndman, 2011; Krishnamurthy & Kriström, 2015). As such, the aim is to explore if reduced electricity costs would persuade consumers to adopt EVs – beyond the already lower operating costs of these vehicles. The different levels for the V2G capability attribute were designed to capture consumers’ attitudes towards various energy exporting options. The six attributes and levels included in the survey are shown in Table 1.

|  |  |  |
| --- | --- | --- |
| Sl. No. | Attribute  |  Attribute levels |
| 1 | Purchase price  | AUD 30,000 (USD 22,500)AUD 35,000 (USD 26,250)AUD 40,000 (USD 30,000)AUD 45,000 (USD 33,750)AUD 50,000 (USD 37,500)AUD 55,000 (USD 41,250)AUD 60,000 (USD 45,000) |
| 2 | Driving range on a full charge | 300 km400 km500 km600 km |
| 3 | Fast charging time | 10 min20 min30 min40 min |
| 4 | Public fast charger availability | As common as petrol/diesel stationsEvery 50 kmEvery 100 kmEvery 150 km |
| 5 | Financial incentives | None50% discount for toll roads50% discount for on-street parkingAUD 1,000 one-off credit on your electricity billAUD 3,000 one-off credit on your electricity bill |
| 6 | Vehicle to grid (V-2-G) capabilities | NoneVehicle can only export to the electricity gridVehicle can only power your homeVehicle can power your home and/or export to the electricity grid |
| Conversion rate : 1 AUD = 0.75 USD |

Table 1. Survey attributes and levels in the SP survey

The stated preference survey was designed and conducted using Conjoint.ly, with the final models estimated in STATA. The SP tasks took the form of a fractional factorial choice experiment. The survey questionnaire comprised of four stages. In the first stage, participants were informed of the survey purpose, background and consent was requested. The second stage included questions aimed at understanding current car usage, location, and EV familiarity. Placing these questions prior to the choice sets helped to ensure that the participants were clear about their current needs and situation (Globisch et al., 2019). The third section included SP choice tasks. A two-minute explanatory video, customised for this survey, was shown at the beginning of this section to assist in informing participants about EV technology before completing the choice tasks. This video provided a high-level overview of EV technology, state of the market, types of vehicles available, and V2G capabilities. Each participant was then presented with eight blocks of choice sets, wherein they had to choose between two EV alternatives. Following each choice set, they were asked to confirm if they would buy the chosen EV over an identical ICEV. This two-stage approach was adopted to help improve the accuracy of estimations by encouraging participants to properly consider each choice (Hidrue et al., 2011; Noel et al., 2018; Parsons et al., 2014). An example of the choice task completed by participants is shown in Fig.1. The fourth part of the survey included questions about the socio-economic characteristics of participants. The survey was restricted to be concise, to minimise participant fatigue, with a median completion time of 10 minutes. Questions included in the second and fourth stages of the survey are shown in Appendix A.





Fig.1: Sample choice set faced by a participant

* 1. **Data**

A representative sample of 500 survey participants was obtained through panel provider Dynata in November 2020. A pilot survey was also conducted with 200 random participants and the final survey was modified based on this initial feedback.

The sample was restricted to residents of the state of Queensland, above 18 years of age, who currently own, lease or have access to a private car. These criteria were imposed to ensure the sample was representative of potential EV buyers. Best efforts were taken so that the sample closely represented the Queensland adult population in terms of demographics - namely age, gender, and income. Ninety percent of the sample were restricted to people who were willing to spend at least AUD 20,000 on their next car purchase, accounting for the reality that new EV prices are not going to fall below this level in the near future. This financial restriction led to a right- skew in the sample towards residents 35-55 years of age. This is likely due to younger respondents having less financial capacity to purchase a new vehicle above AUD 20,000. The demographic details of the survey participants has been included in Table 2. The other reported characteristics of participants is provided in Appendix B.

|  |  |  |
| --- | --- | --- |
| **Variable** | **Survey sample** | **Population statistics****(Adjusted to exclude under 18)** |
| ***Age*** Under 1818-2425-3435-4445-5455-6465 or more | 0%4%18%20%21%19%19% | 23% (0%)7% (12%)15% (19%)13% (17%)13% (17%)12% (15%)17% (20%) |
| ***Gender***FemaleMaleNon-binaryPrefer not to say | 48%52%0%0% | 51%49%-- |
| ***Location***Regional QLDSouth East QLD | 25%75% | 28%72% |
| ***Household weekly income before tax***A$ 0A$ 1-199 (A$ 1-10399 annually)A$ 200-299 (A$ 10,400-15,599 annually)A$ 300-399 (A$ 15,600-20,799 annually)A$ 400-599 (A$ 20,800-31,199 annually)A$ 600-799 (A$ 31,200-41,599 annually)A$ 800-999 (A$ 41,600-51,999 annually)A$ 1,000-1,249 (A$ 52,000-64,999 annually)A$ 1,250-1,499 (A$ 65,000-77,999 annually)A$ 1,500-1,999 (A$ 78,000-103,999 annually)A$ 2,000- 2,499 (A$ 104,000-129,999 annually)A$ 2,500-2,999 (A$ 130,000-155,999 annually)A$ 3,000-3,499 (A$ 156,000-181,999 annually)A$ 3,500-3,999 (A$ 182,000-207,999 annually)A$ 4,000 or more (A$ 208,000 or more annually)Prefer not to answer | 0%1%1%2%7%8%9%13%7%13%9%10%5%4%4%8% |  |
| ***Number of children under the age of 16****01234 or more*  | 63%20%12%3%2% |  |
| ***Number of registered cars in the household***01234 or more  | 58%33%7%2% |  |
| ***Type of dwelling***Free-standing houseTownhouse/VillaApartment | 73%15%13% |  |
| ***Current dwelling ownership***OwnRent | 71 %29% |  |

Table 2. Demographic statistics of survey participants

* 1. **Model**

A mixed logit (MXL) model was estimated using the stated preference survey data. MXL overcomes the limitations of multinomial logit (MNL) by allowing for random taste variation, unrestricted substitution patterns and correlation in unobserved factors over time (Train, 2009). Hence, many recent studies have preferred MXL over MNL to estimate consumers’ EV preferences (Danielis et al., 2020; Hoen & Koetse, 2014; Langbroek et al., 2016; Li et al., 2020; Noel et al., 2019; Qian et al., 2019; Wolbertus et al., 2018). According to the Random Utility model (McFadden, 1973; McFadden & Train, 2000; Train, 2009) decision maker’s utility from alternative j in choice situation t is expressed as

where represents the utility each respondent n associates to alternative j in the choice scenario, is the alternative specific constant, *βjx*is the vector of coefficients associated with vehicle specific attributes, *Xnjt*is the vector of all vehicle specific attributes, *βjy* is the vector of coefficients associated with individual specific attributes, Yn is the vector of individual specific attributes, *µ* represents error components with normal distribution, *εnjt*is independent and identically distributed value over individuals, choice situations and alternatives.

Considering the sequence of alternatives presented, the unconditional probability that an individual makes this sequence of choice is expressed as

where,

is the product of logit formulas. This integral is approximated through simulations. The logit formula is calculated repeatedly based on many draws of β from its distribution and the mean is taken as the approximate choice probability. The MXL model was estimated using 500 Halton draws. In the case of this study, the utility of choosing an electric vehicle was estimated relative to the base alternative of an equivalent ICEV. The variables driving range, fast charging time and  public fast charger availability were found to be correlated. The estimated model was specified to allow for this correlation between random variables. The random coefficients fast charging time, toll discounts, home grid and public fast charger availability were specified to follow a normal distribution, while driving range was specified to follow a lognormal distribution. Discrete choice models also allow for the estimation of willingness-to-pay (WTP). Since price is linear in the model, WTP is the ratio of the coefficient of interest to the coefficient of the price variable (Hess & Train, 2017) . In this study, the WTP estimates were calculated using the Delta method.

1. **Results**

**3.1 Parameter estimates**

The MXL model was estimated using STATA. Various models and model specifications were estimated using the collected data. The final model specification included: purchase price, driving range, fast charging time, public fast charger availability, 50 percent discount on toll roads, 50 percent discount for on-street parking, AUD 1,000 one-off credit on electricity bill, AUD 3,000 one-off credit on electricity bill, energy export from vehicle to home, energy export from vehicle to power grid and energy export from vehicle to both home and/or grid. Driving range, fast charging time, public fast charger availability, energy export to both home and/or grid and 50 percent discount on toll roads were specified to have random coefficients. As for the socio-demographic characteristics, attributes such as: gender, location (South East Queensland vs regional Queensland), number of cars, home ownership, income and several other attributes were included in the initial models estimated to explore if they had a significant effect on consumer choice. Ultimately these factors were not included in the final model as statistically significant estimates were not obtained . Although some previous studies have found one or more of these socio-demographic characteristics significant, the results of this study align more with Danielis et al. (2020) and Noel et al. (2019). Age, V2G awareness, non-familiarity with EV charger brands and EV experience were included in the final model specification in the form of dummy variables. Null responses were set as the reference level for V2G awareness, EV experience, and familiarity with least one EV charger brand as the reference for non-familiarity with EV charger brands. A dummy variable for participants under the age of 45 years was also included. Having driven and/or been a passenger in a EV was used to represent level of EV experience. V2G awareness was self-declared by the participants. The model estimates are provided in Table 3.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable  | β | Std. Error | p value  | 95 % CI |
| Alternative specific constant (EV) | 0.682 | 0.269 | 0.011 | 0.154 | 1.211 |
|   |   |   |   |   |   |
| **Vehicle characteristics and infrastructure facilities** |   |   |   |   |   |
| Purchase price (EV) [10,000 AUD] | -0.706 | 0.039 | 0.000 | -0.783 | -0.629 |
| Driving range (EV) [1000 km](logarithmic) | 0.560 | 0.173 | 0.001 | 0.221 | 0.899 |
| SD of driving range | 0.729 | 0.109 | 0.000 | 0.513 | 0.944 |
| Fast charging time (EV) [10 minutes] | -0.268 | 0.040 | 0.000 | -0.348 | -0.189 |
| SD of fast charging time | 0.343 | 0.047 | 0.000 | 0.249 | 0.436 |
| Public fast charger availability (EV) [100 km] | -0.393 | 0.088 | 0.000 | -0.566 | -0.219 |
| SD of public fast charger availability | 0.632 | 0.047 | 0.000 | 0.249 | 0.436 |
|   |   |   |   |   |   |
| **Financial incentives** |   |   |   |   |   |
| Electricity bill credit of AUD 3,000 | 0.599 | 0.111 | 0.000 | 0.381 | 0.817 |
| Electricity bill credit of AUD 1,000 | 0.524 | 0.111 | 0.000 | 0.307 | 0.741 |
| 50% discount for on-street parking | 0.209 | 0.112 | 0.063 | -0.011 | 0.429 |
| 50% discount for toll roads | 0.093 | 0.148 | 0.529 | -0.196 | 0.382 |
| SD of 50% discount on toll roads  | 0.716 | 0.205 | 0.000 | 0.313 | 1.118 |
|   |   |   |   |   |   |
| **V2G capabilities** |   |   |   |   |   |
| Export energy from vehicle only to home  | 0.267 | 0.095 | 0.005 | 0.081 | 0.453 |
| Export energy from vehicle only to grid | 0.164 | 0.098 | 0.096 | -0.029 | 0.357 |
| Export energy from vehicle to both home and/or grid | 0.378 | 0.119 | 0.001 | 0.145 | 0.611 |
| SD of Export energy from car to both home and/or grid | 0.719 | 0.151 | 0.000 | 0.423 | 1.016 |
|   |   |   |   |   |   |
| **Socio-economic variables** |   |   |   |   |   |
| Under 45 years old [dummy] | 0.634 | 0.153 | 0.000 | 0.333 | 0.934 |
| Previous BEV experience as driver and/or passenger [dummy] | 0.459 | 0.182 | 0.012 | 0.102 | 0.815 |
| Awareness of V2G technology [dummy] | 0.513 | 0.187 | 0.006 | 0.147 | 0.879 |
| Non-familiarity with EV charger brands [dummy] | -0.737 | 0.163 | 0.000 | -1.056 | -0.418 |
|   |   |   |   |   |   |
| **Model diagnostics** |   |   |   |   |   |
| Number of observations | 12,000 |   |   |   |   |
| Number of individuals | 500 |   |   |   |   |
| Log likelihood | -3,085.375 |   |   |   |   |
| Number of Halton draws | 500 |   |   |   |   |
| LR chi2(15) | 563.21 |   |   |   |   |
| Prob > chi2 | 0 |   |   |   |   |

Table 3. Mixed logit model estimates

All estimated coefficients have the expected signs. Additionally, all coefficients, except for 50 percent discount on toll roads, 50 percent discount for on-street parking and energy export from vehicle to power grid, are statistically significant.

In terms of vehicle attributes, purchase price and fast charging time have negative coefficients. This indicates, as expected, that consumers’ interest in EVs increases with a decrease in these attributes. Driving range has a positive coefficient implying that consumers are more likely to purchase an EV the higher its driving range. These are attributes that have been studied and found significant in majority of extant studies. Previous studies reported purchase price as an important attribute and in some cases, as the most significant attribute determining consumers’ preferences (Gong et al., 2020; Li et al., 2020; Rotaris et al., 2021; Wang et al., 2017). There are also similar findings for charging time (Ghasri et al., 2019; Guerra & Daziano, 2020; Hackbarth & Madlener, 2016) and driving range (Bahamonde-Birke & Hanappi, 2016; Dimitropoulos et al., 2013; Rotaris et al., 2021; Wang et al., 2017).

Regarding infrastructure facilities, the study identified a well-connected network of public fast charging stations as significant and positively affecting consumer adoption of EVs, consistent with majority of previous studies (Hackbarth & Madlener, 2016; Li et al., 2020; Qian et al., 2019; Santos & Davies, 2020). This finding, however, contradict Danielis et al. (2020) and (Rotaris et al., 2021), which reported maximum distance between fast charging stations non-significant for Italian consumers.

The results of this study suggest that financial incentives in the form of electricity bill credits, could have a significant, positive impact on EV adoption. These results are not directly comparable with literature owing to the novelty of this policy approach however, Ghasri et al. (2019) and Gong et al. (2020) reported energy bill discounts as a significant positive incentive promoting EV adoption. The results also support previous findings that financial incentives can play a significant role in EV adoption (Fluchs, 2020; Langbroek et al., 2016; Lieven, 2015; Mersky et al., 2016; Rietmann & Lieven, 2019; Taefi et al., 2016). In contrast, the 50 percent discount on toll roads and 50 percent discount for on-street parking were not found to have a significant impact on EV adoption. While many previous studies have identified full or partial discounts on parking fees to be effective (Cherchi, 2017; Gong et al., 2020; Langbroek et al., 2016; Rotaris et al., 2021; Wang et al., 2017; Wolbertus et al., 2018), the results of this study align with (Fluchs, 2020) which found it to be non-significant. Toll discounts have not been extensively studied like parking (Hardman, 2019). The findings of this study again align with that of (Fluchs, 2020) and Mersky et al. (2016) which found toll discounts to be non-significant, but contradicts Bjerkan et al. (2016) and Wang et al. (2017) which find toll discounts to be positively significant.

V2G capabilities were generally found to have a significantly positive effect on consumers’ preferences towards EVs. These results are similar to Noel et al. (2019) . This study is distinguished from the existing studies in offering consumers the option to choose between different energy export options, such as EV to grid only, EV to home only and EV to both home and/or grid. Energy export to home only and energy export to home and/or grid is clearly preferred over no V2G capability. The highest preference was for the option enabling energy export from vehicle to both home and/or grid. Energy export to grid only was not statistically significant.

As for socio-economic variables, both EV experience and V2G awareness were found to have a positive coefficient, in alignment with extant studies (Jensen et al., 2013; Kim et al., 2019; Noel et al., 2019; Sovacool et al., 2019). Non-familiarity with EV charger brands had a negative coefficient implying that people who are unaware of EV charger brands are less likely to adopt EVs. This is not directly comparable with literature as no studies have been identified with this attribute. Being under 45 years old had a positive coefficient. This confirms earlier findings that younger persons are more likely to adopt EVs (Noel et al., 2019; Sovacool et al., 2019) but contradicts Rotaris et al. (2021) , which reported that age did not influence the utility of buying an EV.

**3.2. Willingness to Pay**

WTP estimates of various attributes were also estimated, which are provided in Table 4 below.

|  |  |  |
| --- | --- | --- |
| Variable  | WTP (AUD ) | Unit  |
|   |   |   |
| **Vehicle characteristics and infrastructure facilities** |   |   |
| Driving range  |  24.79 | AUD/km |
| Fast charging time  |  -380.73 | AUD/minute |
| Public fast charger availability  | -55.61 | AUD/km |
| **Financial incentives** |   |   |
| Electricity bill credit of AUD 3,000 | 8,475.58 | AUD/unit |
| Electricity bill credit of AUD 1,000 | 7,415.19 | AUD/unit |
| 50% discount for on-street parking | 2,957.60 | AUD/unit |
| 50% discount for toll roads | 1,314.75 | AUD/unit |
| **V2G capabilities** |   |   |
| Export energy from vehicle only to home  | 3,780.50 | AUD/unit |
| Export energy from vehicle only to grid | 2,319.41 | AUD/unit |
| Export energy from vehicle to both home and/or grid | 5,346.22 | AUD/unit |

Table 4. WTP estimates

The results demonstrate that consumers exhibit a high willingness to pay for improved EV attributes. Consumers had a WTP of AUD 24.79 (USD 18.59) for every 1 km increase in driving range. This aligns with the findings of Hackbarth and Madlener (2016) and Parsons et al. (2014) , the WTP values being USD 13-138/km and USD 18-37/km respectively- see review summary of WTP estimates from previous studies provided in Table 5. The WTP decreased by AUD 380.73 for each 1-minute increase in fast charging time. This aligns with the findings of Hackbarth and Madlener (2016); Hoen and Koetse (2014). For public fast charger availability, the WTP decreased by AUD 55.61 for every additional km of distance between charging stations. The highest WTP was observed at AUD 8,475.58 for the financial incentive of AUD 3,000 one-off credit on electricity bill. A similar high WTP at AUD 7415.19 was also observed for the financial incentive of AUD 1,000 one-off credit on electricity bill. These results suggest that the general prospect of ‘free electricity/fuel’ -irrespective of the precise value - could have a significant and positive impact on adoption, owing to Australian consumers’ high price elasticity of demand for electricity (Chesser et al., 2018; Fan & Hyndman, 2011; Krishnamurthy & Kriström, 2015). Consumers also had high WTP estimates for all V2G capabilities, with the highest WTP exhibited for energy export to both home and/or grid at AUD 5,346.22.

These estimates indicate that although Australia remains a laggard market for EV adoption, consumers are willing to make the switch to EVs, and are willing to pay significantly higher amounts for improved EV attributes, infrastructure facility, various financial incentives and V2G capability. This discrepancy between stated preferences towards EVs, and the reality of a laggard market, could suggest one of the primary barriers to uptake is in fact the supply of vehicles; and more specifically, the supply of fit-for-purpose vehicles which are perceived as equivalent in functionality to popular ICEVs.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Author** | **Country** | **Driving range**  | **Financial incentives** | **Charging time**  |  **Fuel availability**  | **V2G**  | **Fuel cost savings**  |
| Danielis et al., 2020 | Italy  | $ 32 /km | $ 1.98 per hour  | $ 95.7/ minute  |   |   | $ 330 for $ 1/100 km |
| Noel et al., 2019 | Norway, Finland, Sweden, Denmark, Iceland |  $100-363/ km |   | $ 103 / minute  |   | $ 4400 (Finland) $ 5720 (Norway) |  |
| Qian et al., 2019  | China  | $ 88 /km  | $ 15921 for free vehicle licensing  | $ 364 / minute  |   |   |  |
| Wang et al., 2017 | China  | $ 37.2 / km | $ 863 for road tolls full exemption$ 1566 for parking fee full exemption |   |   |   |  |
| Hackbarth & Madlener, 2016 | Germany  | $ 13-138/km | $ 7892 for vehicle tax exemption | $ 5.5 - 213 / minute | $ 66- 326 for increased fuel availability by 1 percent |   | $ 1162 for $1/ 100 km |
| Langbroek et al., 2016 | Sweden  | $ 70.2 /km  | $ 6306 for free parking$ 2390 for 50 percent discount on parking |   |   |   |  |
| Parsons et al., 2014 | USA | $ 18-37/ km |   |   |   |   |  |
| Hoen & Koetse, 2014  | Netherlands  | $ 57 /km  | $ 415 for free parking  | $ 26 / minute  | $ 129 to reduce additional detour to a charge location by a minute |   |  |
| Hidrue et al., 2011 | USA | $22-47/km |   |   | $ 7- 54 /minute |   |   |
| \*Conversion rates\* 1 AUD= 0.75 USD; 1 Euro= 1.10 USD; 1 CNY= 0.15 USD; 1 SEK =0.12 USD  |

Table 5. Comparison of WTP estimates (in USD)

1. **Discussion**

Through this study we investigated factors that could influence EV adoption rates in laggard markets. High purchase price has often been cited as a major barrier for increased EV adoption and this study confirms the same. EVs generally have higher purchase prices compared to Internal Combustion Engine Vehicles (ICEVs) owing primarily to battery costs, although prices, globally, have fallen in recent years. The weighted average cost of automotive batteries declined 13 percent in 2020 compared to 2019 and stands at USD 137/kWh (Danielis et al., 2020). With improving technology, manufacturing techniques and new cell chemistries, the prices are expected to fall further, below USD 100/kWh by 2024 and potentially reach $58/kWh by 2030 (Bloomberg, 2021). In addition to upfront cost, this study has found that there are other factors which are also deemed important by consumers in terms of choosing an EV.

Limited driving range is often considered a major reason for low EV uptake. Skippon et al. (2016) suggests driving range is the most significant factor affecting consumer preferences. While driving range anxiety - resulting from limited driving range - could easily appeal as an important factor, especially in countries with large geographical areas and/or longer distances between cities or suburbs, this may not be necessarily true. In a study including Italy and Slovenia, it was found that consumers in Italy with a larger geographical area had lower sensitivity towards driving range and fuel economy compared to Slovenia, a smaller country by area (Rotaris et al., 2021). With many existing studies identifying a decreased WTP at higher driving ranges (Hackbarth & Madlener, 2016; Noel et al., 2019), this could be an indication that consumers are starting to better understand their daily driving habits and range requirements, which could be well served by current EV driving range capabilities. The weighted average driving range of new EVs has increased from 211 km in 2015 to around 350 km in 2020, and appears to be starting to plateau around this level (International Energy Agency, 2021). This could suggest manufacturers are also identifying an increasing acceptance of EVs once this threshold is reached. It should be noted that people’s lifestyle and driving patterns are likely to significantly affect driving range preferences (Hoen & Koetse, 2014). The next pertinent question flowing from this is – are there ways to address range anxiety? The following results of this study provide insights on this.

As shown in Table 3, consumers are willing to pay AUD 7,439.10 for an increase in driving range from 300 to 600 km. However, it is notable that a decrease in fast charging time from 40 minutes to 10 minutes increased WTP by an even higher amount of AUD 11,421.90. Also, consumers’ average marginal WTP increased by AUD 7,507.35 if EV charging stations were perceived to be as common as petrol or diesel stations compared to being 150 km apart. These WTP values indicate that a well-connected public fast charging network is critical to promoting EV uptake in laggard markets (Li et al., 2020; Mersky et al., 2016; Qian et al., 2019) . It is worth noting that leading EV markets, such as Norway, Iceland and Sweden, had a significant share of EVs even when driving range was not as high as today. A common characteristic of these lead markets has been well-connected networks of public chargers, including fast chargers. China now leads in both slow and fast public charger availability and this has had great importance in the country’s adoption of EVs (International Energy Agency, 2021). Fast chargers are important for people travelling long distances and for EV owners/users with no home/office charging facilities. As such, it is likely that the lack of easily accessible, public fast-charging stations exacerbates range anxiety, delaying the uptake of EVs in laggard markets. As suggested by Dimitropoulos et al. (2013), raising consumers’ awareness about their driving range requirements and the availability of fast charging stations could be important in tackling range anxiety.

As expected, consumers in laggard markets have high preferences for financial incentives. It is notable that electricity bill credits of AUD 3,000 and AUD 1,000 were estimated to increase consumers’ WTP by AUD 8,475.58 and AUD 7,415.19 respectively. Thus, regardless of the amount, an electricity bill reduction could significantly improve consumers’ willingness to adopt an EV. Considering the high price elasticity of demand for electricity in Australia, savings on energy costs could persuade consumers to switch to EVs, although it should be noted that energy costs for EVs are already significantly cheaper compared to ICEVs. Although not modelled in this study, it is worth noting that a similarly high WTP of AUD 10,522 (USD 7892)[[2]](#footnote-3) was estimated by Hackbarth and Madlener (2016) for ‘no vehicle tax’. Tax exemptions of varying amounts have been effective in promoting EVs in many countries – including Norway (Bjerkan et al., 2016) and China (Zhang et al., 2018).

Although all four financial incentives modelled in this study were found to have a positive impact, the relative impact varied across policies, and discounts on parking and toll roads were both not statistically significant. The impact of financial incentives could vary depending on demographics, timing, target consumers as well as consumer perception of policies (Ghasri et al., 2019; Gong et al., 2020; Jenn et al., 2020; Langbroek et al., 2016; Li et al., 2020). The lowest impact policy in this study was a toll road discount, which could be attributed to the fact that only 0.5 percent (240 km) of Australia’s motorways collect tolls compared to 3 percent in China and US, and 13 percent in Japan (Parliament of Australia).

Like many other new products in the market, consumers’ preferences towards EVs are also found to increase with higher levels of familiarity and use. Consumers’ previous EV experience had a positive impact on their willingness to purchase an EV. Similar results were obtained for charger brand familiarity and V2G awareness. This means that consumers are more willing to adopt EVs if they are better informed about EVs and aware of EV features. It is important to note that from the survey sample, 78 percent had no EV experience as either driver/passenger, 41 percent were not familiar with any EV charger brands, 45 percent had never seen an EV charging station and 81 percent had not heard of V2G prior to participating in the survey. Thus, general awareness is relatively low which presents an opportunity for further increases in EV uptake by strengthening awareness amongst consumers in Australia, and similar laggard markets.

The results from this study suggest that consumers in laggard markets are willing to adopt EVs, despite perceived notions of low demand in such markets. Model availability has often been reported as a major barrier to wide-spread EV adoption (Barisa et al., 2016; Berkeley et al., 2018; Haddadian et al., 2015). This low model availability, in part due to perceived low consumer demand, is in fact likely a major reason for low EV uptake, thus forming a vicious circle. Supportive government policy, market readiness and charging infrastructure are all important factors considered by car makers when deciding on vehicle allocation to a market. Major car makers, such as Volkswagen and BMW, have called out the lack of emissions regulation and inaction from the Australian government as hindering their ability to sell EVs in the country (Borys & Evans, 2021; Harris, 2020; Purtill, 2021). About 370 EV models were available globally in 2020 of which 235 were fully electric EV models i.e. BEVs. This is a 40 percent increase from 2019 (IEA,2021). However, only about 50 EV models were available in Australia as of 2021 (*Redbook*). As such, although consumers are willing to switch to EVs, supply side constraints are likely limiting the market. It is important that these issues be addressed by policy-makers, considering the economic, public health and environmental benefits that EVs can deliver.

* 1. **Impact of V2G on EV adoption**

A major finding of this study is the significant impact V2G could have on improving consumers’ willingness to adopt EVs. On average, consumers were estimated to be willing to pay an extra AUD 5,346.22 (USD 4,009.67) for an EV with V2G capabilities that would facilitate energy export to both the home and/or grid. This was the second highest WTP observed, next only to the incentive of AUD 3,000 credit on the consumer’s electricity bill. V2G offers the potential to deliver grid stability, smoother integration of renewables and overall lower emissions from both the transport and energy sectors. Noel et al. (2019) estimated WTP of USD 4,400 and USD 5,720 for V2G capability in Finland and Norway respectively. The estimates from this study are comparable but slightly lower. This could be probably due to allowing different options for consumers to choose from such as exporting to grid or home or both at their discretion. Australia also already has a relatively high penetration rate of rooftop solar, reflecting consumers’ desire to reduce dependency on the grid, reduce fossil fuel use, but importantly also reduce energy costs (Commonwealth Scientific and Industrial Research Organisation, 2021). The findings of this study suggest that V2G capabilities could be a key enabler of EV adoption, including in laggard markets. It comes at no surprise then to see that in 2021, Ford Motor Company has announced the fully electric version of its F-150 pickup truck with the built-in capability to provide up to 3 days’ worth of backup power to a home in the case of the power blackout (Ford Media Center, 2021).

Consumers exhibited relatively lower WTP at AUD 3,780.50 and AUD 2319.41 for energy export options to home only and grid only respectively. This implies higher preferences towards being able to use EVs to power the home, rather than simply for exporting energy to the grid. Interestingly, this also aligns with the marketing Ford has recently carried out for its electric pickup truck, focussed on using the vehicle to provide backup power to the home during grid blackouts. It could be assumed that although consumers have high WTP for V2G, their interests are not necessarily focussed on the grid benefits offered by V2G alone but extend beyond grid services and associated environmental benefits. This could be attributed to individual benefits such as energy independence and energy cost savings, especially for people with rooftop solar. That said, this survey did not include specific attributes related to how much consumers would be paid for exporting energy to the grid from their EVs. This will be explored in a future study of V2G deployment in the Australian market, and is likely to significantly impact an individual’s perception of the value of V2G capabilities that enable trading with the energy market.

Enabling V2G also requires the installation of V2G capable chargers, as well as the coordinated effort of government, energy utilities, and regulatory bodies to facilitate a distributed energy market which includes the use of EVs as “batteries-on-wheels”. The onus of installing infrastructure on private properties is expected to be the responsibility of EV owners. As such, policymakers will need to formulate policy that encourages the deployment of this infrastructure, if the associated benefits are to be captured on a wide-scale. In addition, effective contract options would also need to be introduced that align with consumers’ interests. In a study among Dutch EV owners, minimum guaranteed battery level and renumeration were found to have strong, positive impact on people’s willingness to sign up for V2G contracts while longer plug-in time and higher number of battery discharging cycles reduced their willingness (Huang et al., 2021). The study also reported that consumers had a higher preference for V2G participation in the context of a fast charging time of 5 minutes as compared to current charging time. Parsons et al. (2014) proposed alternate options such as cash payment in advance for V2G enabled EVs and ‘pay-as-you-go’ contracts at the EV driver’s convenience instead of strict V2G contracts. Short of achieving full V2G capabilities, smart charging infrastructure that enables management of the rate and time of charging to support the wider grid, should be supported in an approach that delivers an economic benefit to EV owners, while improving grid stability and supporting the uptake of renewable energy. Policies that could support the delivery of these benefits are explored in the following section.

**4.2 Policy implications**

Similar to prior research, this study finds that purchase price is an important factor currently affecting EV uptake. The higher purchase price of EVs is primarily due to battery costs and economies-of-scale in general manufacturing. With continuing improvements in battery technology and expansion of the global EV market, costs are projected to continue to fall, and achieve unsubsidised price parity with ICEVs in the mid-to-late 2020’s (Bloomberg, 2021). However, given the need for immediate action to reduce emissions, and the slow transition of the global vehicle fleet, strong policy action is required now to accelerate EV uptake globally. In many leading EV markets, supportive policies have played an important role in accelerating EV adoption. For instance, Norwegian consumers have been offered strong incentives for EV adoption since the mid-90s (Bjerkan et al., 2016) and as of mid-2021, are approaching 80% of new vehicle sales being EVs (International Energy Agency, 2021; Klesty, 2021). Based on the results of this study, a number of policy recommendations to support the uptake of EVs in laggard markets are suggested.

*4.2.1 Energy bill credits*

This study identified energy bill credits as a potentially powerful financial incentive for persuading consumers to adopt EVs. This, at least in part, likely stems from the high price elasticity of demand for electricity. Thus, energy bill credits could be an effective policy measure. Moreover, we propose utilising energy bill credits in a more planned manner to incentivise people to participate in smart charging programs, including V2G.

Since V2G is not yet widely available, we recommend a two-staged approach to this policy mechanism, first for the short-term, and then in the medium-term.

Short-term

Electricity bill credits should be offered as an incentive for purchasing an EV, but in exchange for opting into a smart charging program where an energy utility/retailer/aggregator (depending on the energy market structure) could manage the time and rate of EV charging. Importantly, the EV owner could always override this management protocol – in cases where an urgent charge is required – and in those rare instances, consumers would pay a premium for the electricity consumed (assuming it is supplied from the grid, during a peak demand period). This could be seen as a first step towards enabling V2G; and in effect, puts in place a quid-pro-quo where EV owners get access to a financial incentive in return for opting into a smart charging scheme that can ensure EV charging is efficiently integrated into the electricity grid. The marketing of a scheme that provides several years of ‘free fuel’ when purchasing an EV is expected to have a significant and positive impact on adoption, as shown in this study. Additionally, if the electricity is being generated locally, the policy is simultaneously delivering a local economic benefit by investing in local energy production and jobs.

Medium-term

Eventually, as V2G capabilities become more prevalent in EV models, and the cost of V2G infrastructure falls, in addition to receiving a financial benefit for allowing management of charging rates and times, the export of energy (or energy services) to the grid could attract further financial compensation. As shown in this study, consumers tend to have a higher preference for using V2G capabilities to power their homes, rather than export energy to the grid, so it is clear that some form of financial incentive and/or compensation will be required to encourage participation in this new market. The cost of this compensation will need to be weighed up against the costs that such a program could help avoid such as investment in other forms of energy storage, electricity grid infrastructure reinforcements, etc.

*4.2.2 Charging infrastructure*

Consumers’ access to fast charging infrastructure depends heavily on technological change, government policy, city planning and energy utilities (Electric Vehicle Council, 2021). A well-connected national network of fast charging stations would reduce any looming range anxiety issues, especially when consumers take longer trips. The availability of public charging infrastructure has played a significant role in promoting EV uptake in Norway and China (Bjerkan et al., 2016; International Energy Agency, 2021). As shown in this study, the availability of charging infrastructure is unsurprisingly also a significant factor influencing consumers’ preferences towards EVs in a laggard market. Installing public fast charging stations every 50 km apart instead of at 100 km apart is equivalent to reducing EV price by AUD 5,561. As such, it is recommended that policymakers continue to invest in the deployment of public charging infrastructure, including facilities at shopping centres and workplaces that can take advantage of utilising renewable energy resources, such as solar generation during the day. Additionally, some of these facilities, where vehicles are parked for longer periods of time, particularly in the early hours of the evening, should consider the future provision of V2G charging infrastructure.

*4.2.3 Other financial incentives*

Although incentives, such as discounted parking and toll road discounts, were not statistically significant, bundling of an attractive package of incentives could be crucial for accelerating early adoption. For instance, (Lieven, 2015) reported that a combination of low cash grants and public charging infrastructure to be as effective as high cash grants. Incentive policies should ultimately be tailored to suit each market.

*4.2.4 Consumer awareness*

Raising consumer awareness of EV characteristics, and potential benefits, will be critical for accelerating uptake, especially so in laggard markets. Easy access to information on EVs should be made available to the general public. EV demonstration and test drive events would provide opportunities for consumers to become more familiar with the technology, and as shown in this study, higher EV awareness is associated with improved willingness to purchase an EV. Improving awareness of consumers travel needs, and how this aligns with EV capabilities will also be an important factor for addressing range anxiety, in addition to promoting greater awareness of the availability of public charging infrastructure as it continues to be expanded. Recall that 81 percent of the survey respondents in this study had not heard about V2G prior to participating in the survey. Hence, learning the potential benefits of V2G could further accelerate the adoption of EVs, as others have also suggested (Noel et al., 2019).

* 1. **Limitations and Future Research**

The primary limitation associated with this study pertains to the use of a survey, where hypothetical bias is always a challenge, and stated intentions could differ from actual behaviour (Beck et al., 2016). To minimise this potential bias, all respondents were presented with an information video and instructions prior to completely the SP tasks. The SP tasks were also carefully designed, and tested through a pilot survey sample, to ensure they were easy to understand. As more EV markets mature internationally, RP studies will become increasingly important in comparing actual behaviour to stated intentions. Given this study is based on a sample of participants from Australia, it also may not necessarily reflect the preferences of consumers in other markets internationally. That said, as reviewed in this paper, a number of the findings in this study are consistent with the extant literature. Some policy options and factors that have been considered internationally were also not included in this study. For instance, vehicle design and performance features such as class, model, size, acceleration (Kumar & Alok, 2020; Liao et al., 2017) were not included. Ultimately, a condensed list of policies and factors relevant to the Australian market were considered to ensure the survey was not overwhelming for respondents.

Further work is required to understand whether positive consumer preferences towards V2G capabilities would be similar in other laggard markets, such as the US. Other factors may warrant further investigation in future surveys of this laggard market, such as the influence of rooftop solar and/or home battery ownership on preferences towards EVs, and in turn, the impact of V2G capabilities on consumers’ WTP. Building on this analysis, the intention is to further investigate the details of smart charging programs, including V2G, that would be most attractive to consumers; the order of magnitude of financial incentives and/or compensation that EV owners would expect to receive to participate in these programs, and ultimately, how these costs compared to the broader economic benefits that could be delivered by utilising a national fleet of EVs as ‘batteries-on-wheels’ to deliver energy services.

1. **Conclusion**

In light of the recent concerns regarding adverse effects of climate change, many countries are now actively promoting the adoption of EVs, and car manufacturers are making commitments to produce a range of EVs, and in some cases, phase out ICEV manufacturing in the coming 10 to 15 years. Despite these promising signs, there are still a number of affluent, car-dependent countries, such as Australia, the US and Italy, that are laggard markets in terms of EV adoption. While the reasons for this are often speculated as centring around consumers being unwilling to make the switch to EVs, this paper attempts to identify which EV features are most important to consumers in a laggard market, using the case study of Australia. In turn, the policies that could accelerate EV adoption in these markets are also explored.

While there are a number of existing studies that investigate consumers’ preferences towards EVs, these have primarily focussed on advanced EV markets. This study instead focusses on a laggard market, and in particular, attempts to understand how energy benefits and/or energy services could be delivered via EVs, and could in turn be used to improve consumer preferences towards EVs to accelerate adoption.

Similar to other studies, this study identified that lower upfront costs, a well-connected public fast charging network, improved driving range and fast charging time would all contribute towards an increased willingness amongst consumers in laggard markets to adopt EVs. Additionally, any form of financial incentive would have at least some level of positive impact on EV adoption, however, some forms of incentives may be more effective than others. Specifically, the financial incentive of an electricity bill credit of either AUD 3,000 or AUD 1,000, in both cases, is expected to have a significant impact on consumers’ average, marginal WTP for a new EV – well above the financial value of the credit. Similar impacts could be possible from tax exemptions of comparable monetary values, although would be more strongly linked to consumers’ perception of wanting to avoid paying taxes, as opposed to wanting to reduce electricity costs – two strong motivators for consumers in general.

While many jurisdictions have focussed on reducing upfront costs, here we argue that there may be a significant benefit in focussing on leveraging consumers’ sensitivity to electricity prices by marketing an incentive which provides ‘free fuel’ when you buy an EV, for a certain number of years. This policy could be combined with other financial incentives and should form a quid pro quo exchange for consumers opting-in to a smart charging program, to help manage the efficient integration of EV charging into the electricity grid. Additionally, by investing in local electricity generation, this policy could deliver wider economic benefits by redirecting imported fuel spending, into domestic energy generation, and in turn, supporting local jobs.

Beyond an initial focus on smart charging programs, this study also highlights consumers’ interest in vehicle-to-grid (V2G) capabilities, particularly the ability to power a home using the energy stored in an EV’s battery. The availability of V2G capabilities were found to significantly increase consumers’ willingness to purchase an EV – noting that this was amongst a consumer base with a relatively low awareness of the technology, and EVs in general. This potentially points again to consumers’ broader interest in reducing energy costs, and going further, being able to reduce their dependency on the electricity grid for meeting their household and/or business energy needs. While V2G capabilities are not yet widespread, this finding suggests that the availability of these capabilities – such as in the upcoming, 2022 Ford F-150 Lightning electric pickup truck – could significantly increase consumers’ willingness to switch to an EV. Importantly, however, policymakers will need to consider how to encourage consumers to not only use EVs as “batteries-on-wheels” to power their own homes, but to also potentially provide broader energy services to the grid. Further research is required to understand the design of V2G programs that would help to encourage consumer participation. This strategic approach to coupling the transport and energy sectors will not only be important for decarbonising the transport sector to meet climate targets, but may also prove crucial to the decarbonisation of the energy sector, through the matching of renewable energy generation with EV charging demand.

Finally, consumers in EV laggard markets do not appear to be well informed of EV characteristics and potential benefits. Through this study, increased awareness of EVs, and EV features, was found to have a significant, and positive impact on consumers’ willingness to purchase an EV. It is critical for policymakers, particularly in laggard EV markets, such as Australia, to deploy national campaigns to increase consumer awareness in order to accelerate uptake.

To achieve rapidly approaching global climate targets it is essential that the transport sector switches from fossil fuels to low-carbon alternatives as quickly as possible. Through this study we have highlighted that even in laggard markets, consumers are willing to make the switch to EVs, if the right policy settings are in place. We suggest policy-makers leverage the energy co-benefits of EVs – including V2G - to further increase their attractiveness to consumers, and accelerate adoption in a timeframe congruent with global climate targets.

**CRediT authorship contribution statement**

**Thara Philip: Methodology, Formal analysis, Investigation, Data Curation, Writing-Original draft**

**Jake Whitehead: Methodology, Formal analysis, Investigation, Data Curation, Resources, Writing-Review and Editing, Supervision, Funding acquisition**

**Carlo Prato: Methodology, Writing-Review and Editing, Supervision**

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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**Appendix A**

**Survey questionnaire**

This section includes survey questions.

 Questions- Part 2

* If you were to purchase a car in the next few years, approximately how much would you be willing to spend?
* How many registered cars are in your household?
* What is the brand and model of the car you use most often?
* What is the fuel type of the car you use most often?
* Was the car you use most often purchased brand new or second hand?
* What was the purchase price of the car you use most often?
* What is the average number of kilometres that the car you use most often is driven each year?
* Have you ever driven or been driven in a battery electric car?
* Have you ever seen an electric vehicle charging station?
* Are you familiar with any of the following electric vehicle charging networks or brands in Australia?
* Have you previously heard about Vehicle-to-Grid capabilities in relation to electric vehicles?

Questions- Part 4

* What is your age?
* What is your gender?
* Please enter your 4-digit home address postcode
* What type of home do you live in (majority of the time)?
* Do you own or rent this home?
* Besides yourself, who else lives in your home?
* How many children do you have under the age of 16?
* What is your household weekly income before tax?

**Appendix B**

**Other reported characteristics of survey participants**

|  |  |
| --- | --- |
| **Variable** | **Survey sample** |
| ***Household constitution***Live aloneWith partnerWith child/childrenHousemates/ flatmatesParentsSiblingsOther family membersOther  | 14%71%39%5%7%2%2%0% |
| ***Fuel type of the most often used car***PetrolDieselLPGHybrid (non-plug-in)Plug-in hybridBattery electric | 81%17%1%2%0%0% |
| ***Most often used car***Brand newSecond hand/Used | 65%35% |
| ***Purchase price of the most often used car***Less than A$ 20,000A$ 20,000- 29,999A$ 30,000-39,999A$ 40,000-49,999A$ 50,000-59,999A$ 60,000-69,999A$ 70,000-79,999A$ 80,000-89,999A$ 90000 or more | 26%25%20%11%9%4%2%1%2% |
| ***Annual average use of the most often used car*** Up to 5,000 kmUp to 8,000 kmUp to 10,000 kmUp to 12,000 kmUp to 15,000 kmUp to 17,500 kmUp to 20,000 kmUp to 25,000 kmUp to 30,000 kmOver 30,000 km | 15%14%25%10%14%2%7%5%3%4% |
| ***EV Experience***Driven a BEVPassenger in a BEVNo experienceUnsure  | 7%13%77%2% |
| ***Seen an EV charging station***YesNo | 53%47% |
| ***Familiarity with EV charging network brands***TritiumEvie NetworksChargefoxABBTeslaJetchargeNone  | 5%4%3%3%52%2%45% |
| ***Heard about V-2-G***YesNo | 19%81% |
| ***Amount willing to spend on next car***Less than A$ 20,000A$ 20,000-40,000A$ 40,000-60,000More than A$ 60,000 | 7%60%26%7% |

1. 1 AUD = 0.75 USD [↑](#footnote-ref-2)
2. 1 AUD = 0.75 USD [↑](#footnote-ref-3)