Exploration of the nexus between solar potential and electric vehicle uptake: Evidence from New Zealand

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Overview

Electric vehicles (EVs) are gaining momentum globally with the potential of emission reduction in the transportation sector by using renewable energy sources. New Zealand, as a country with committed climate change actions, encourages effective policy formulations to promote the uptake of EVs and other low-emission forms of transport (Ministry of Transport, 2021).

Increasing adoption levels of both EVs and PV solar panels will contribute greatly to carbon emission reduction by reducing fuel consumption and utilising renewable energy sources in the transportation sector and home buildings. Most research in EV uptake focuses on the electrical energy storage and charging facilities from an engineering feasibility point of view, such as the efficiency of the vehicle, charging infrastructure, and battery capacity (Goli and Shireen, 2014; Qian et al., 2011). Moreover, existing studies on the integration of EVs and solar PV use the simulation and scenarios analysis (van der Kam et al., 2015), the optimisation approach (Karan et al., 2016), heuristic methods (Zhang et al., 2012), or are more technology-focused (Savrun et a., 2022). There is a lack of econometric analysis on the relationships and interactions between the adoption of EV and solar PV by end users. EVs and PV have synergies, and consumers are playing an increasing role in sustainable technology uptake.

Promoting the adoption and use of sustainable technologies requires a co-adoption perspective that takes into account the integration of solar PV in the electricity network, as well as the spatial diffusion patterns (Rai et al., 2016; van der Kam et al., 2018). Geographically, most relevant studies are conducted in Northern America and the EU (Rai et al., 2016; Litjens et al., 2018; van der Kam et al., 2018), there is a lack of research in the Southern hemisphere. Our geographical context in Auckland offers new perspectives in the New Zealand context with detailed spatial data.

In this paper, we propose three hypotheses based on solar potential effects (H1), spatial autocorrelation (H2), and marginal effects (H3).

Hypothesis (H1): The availability of solar PV has a positive and significant impact on EV uptake in the community.

Hypothesis (H2): EV-charging infrastructure in the neighbouring areas has a positive and significant impact on EV uptake.

Hypothesis (H3): Early adoption has an overall positive effect on subsequent technology adoption.

This study aims to provide informative policy implications in accelerating the pace of EV uptake by providing a realistic signal given the great renewable energy potential from solar PV for a more sustainable mobility and energy system. To this end, we use a novel spatial analysis approach to explore the link between EV and residential solar PV adoption with detailed spatial modelling techniques. To test the above three hypotheses, we used spatial data matching in regression analysis to avoid biases compared to other non-spatial studies.

Methods

This paper employs negative binomial models with embedded spatial lagged variables to test three hypotheses based on potential solar effects, spatial autocorrelation, and marginal effects. The solar potential effects hypothesis is to test the availability of PV on EV uptake. The hypothesis on spatial autocorrelation is to test the "neighbourhood effect" of EV-charging infrastructure on EV uptake. And the hypothesis on marginal effects aims to examine if EV adoption by technology enthusiasts during the early-adopter phase could affect subsequent adoption once the technology becomes more widely spread.

Results

In this paper, we explicitly analysed how PV and EV integration is possible for higher EV uptake for energy efficiency. We found that a one-unit increase in the Solar PV installation raises the current EV uptake count by a factor of 1.021. Availability of PV panels has a positive impact on EV uptake. Solar has the potential to adopt EVs by providing sustainable charging solutions to EVs with solar PV-EV charging systems deployment. A one-unit increase in EV charger installation in the neighbouring areas would increase the current number of EV uptake by a factor of 41 under the inverse distance weight matrix 100 km, revealing that EV-charging infrastructure in the neighbouring areas positively impacts subsequent EV adoption. The EV uptake is increased by 1.047-1.049 in response to a one-unit increase in early EV adoption, indicating that the early-adopter phase also has a positive impact on subsequent EV uptake.

Conclusions

Our study highlights that solar PV and EV represent the way that sustainable technologies can be integrated into homes. The findings provide policy recommendations for increasing EV and solar PV uptakes. For example, incentive EV and PV programmes should be designed and implemented to encourage solar PV adoption and EV uptake. Smart metering technology in the residential charging systems provides data such as how much energy has been generated, used, and the cost of charging and charge history, enabling consumers to maximise the benefit of Solar PV and battery storage such as EVs. Hence, the electricity market regulator should support to roll-out of smart meters across the country. Moreover, a good public charging infrastructure provides confidence in using EVs, but requires a significant investment. A public-private partnership allows for building more chargers and accelerating EV uptake. Moreover, behaviour change programs are needed when combined with other forms of support for home efficiency improvements, such as, technology demonstration and related education programs among the young generation.

References

Karan, E., Asadi, S., & Ntaimo, L. (2016). A stochastic optimization approach to reduce greenhouse gas emissions from buildings and transportation. *Energy*, *106*, 367-377.Goli, P., & Shireen, W. (2014). PV powered smart charging station for PHEVs. *Renewable Energy*, *66*, 280–287. https://doi.org/10.1016/j.renene.2013.11.066

Litjens, G. B. M. A., Kausika, B. B., Worrell, E., & van Sark, W. G. J. H. M. (2018). A spatio-temporal city-scale assessment of residential photovoltaic power integration scenarios. *Solar Energy*, *174*, 1185–1197. https://doi.org/10.1016/j.solener.2018.09.055

Ministry of Transport. (2021). *Electric Vehicles Programme*. https://www.transport.govt.nz/area-of-interest/environment-and-climate-change/electric-vehicles-programme/

Qian, K., Zhou, C., Allan, M., & Yuan, Y. (2011). Modeling of load demand due to EV battery charging in distribution systems. *IEEE Transactions on Power Systems*, *26*(2), 802–810. https://doi.org/10.1109/TPWRS.2010.2057456

Rai, V., Reeves, D. C., & Margolis, R. (2016). Overcoming barriers and uncertainties in the adoption of residential solar PV. *Renewable Energy*, *89*, 498–505. https://doi.org/10.1016/j.renene.2015.11.080

Savrun, M. M., İnci, M., & Büyük, M. (2022). Design and analysis of a high energy efficient multi-port dc-dc converter interface for fuel cell/battery electric vehicle-to-home (V2H) system. *Journal of Energy Storage*, *45*, 103755.

van der Kam, M. J., & van Sark, W. (2015). Smart charging of electric vehicles with photovoltaic power and vehicle-to-grid technology in a microgrid; a case study. *Applied energy*, *152*, 20-30.

van der Kam, M. J., Meelen, A. A. H., van Sark, W. G. J. H. M., & Alkemade, F. (2018). Diffusion of solar photovoltaic systems and electric vehicles among Dutch consumers: Implications for the energy transition. *Energy Research & Social Science*, *46*, 68–85. https://doi.org/10.1016/j.erss.2018.06.003

Zhang, Q., Tezuka, T., Ishihara, K. N., & Mclellan, B. C. (2012). Integration of PV power into future low-carbon smart electricity systems with EV and HP in Kansai Area, Japan. *Renewable Energy*, *44*, 99-108.