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Flexible, multi-modal electric vehicles in economic dispatch and capacity expansion models

K. Purnell[1,2], A. G. Bruce[1,2] and I. MacGill[2,3]

[1] School of Photovoltaics and Renewable Energy Engineering, University of New South Wales, Sydney, NSW 2052, Australia
[2] Centre for Energy and Environmental Markets, School of Electrical Engineering and Telecommunications, University of New South Wales, Sydney, NSW 2052, Australia
[3]School of Electrical Engineering and Telecommunications, University of New South Wales, Sydney, NSW 2052, Australia

Electric vehicles (EVs) have been promoted as a promising means to reduce greenhouse gas emissions from the transport sector and decreasing local air pollution while increasing national energy security. As many have noted, the electrification of the transport sector may increase peak demand and exacerbate ramping requirements for generators (AEMO, 2020). However, EVs also have the potential to alleviate these same issues to a certain extent by charging at opportune times from the grid's perspective via cost reflective tariffs (Ensslen et al., 2018), flexible smart charging via aggregation in VPPs (Deng et al., 2020) or utility controlled charging (Keller et al., 2019).

As the uptake of EVs across different transport modes increases globally, it is clear that long term planning for the electricity system will need to factor in their unique usage and charging characteristics. While economic dispatch and capacity expansion (EDCE) models increasingly have at least a simple representation of EV charging, the growing adoption of EVs across private, public and commercial sectors requires a more detailed representation to account for their impact as an uncontrolled load and their unique flexibility characteristics, such as potential automated smart charging and discharging via vehicle to grid (V2G).

To date, models incorporating EVs into EDCE models have largely focused on electric cars alone (Carrión et al., 2019; Gunkel et al., 2020; Koltsaklis and Dagoumas, 2018; Madzharov et al., 2014; Ramírez et al., 2016; Taibi et al., 2018). More recent models have included a wider range of vehicle modes, but often only cars are assumed able to participate in uni & bi-directional smart charging, (Keller et al., 2019; Lu et al., 2021; Taljegard, Maria et al., 2019). This includes, to the author's best knowledge, the integrated system plan (ISP) for the National Electricity Market (NEM) (AEMO, 2020). Therefore, this study aims to investigate how future electricity systems operate with multi-model EVs as flexible grid resources.

In this study, seven electric vehicle modes (private cars, light commercial vehicles, taxis and ride sharing vehicles, bicycles, public buses, public ferries and freight) are modelled from internal combustion engine (ICE) trip-data, capturing the diversity of each mode in terms of their connectivity to the grid and transport energy requirements throughout an average week, as well their passive uncontrolled charging profile.

We use the open-source EDCE model, openCEM (Zapata, J, 2020), created by ITP Analytics. OpenCEM currently accounts for distributed energy resources such as rooftop photovoltaics, household batteries and electric vehicles as part of the net load, from static input traces from the ISP, and are not flexible. We add the ability to model each EV mode in each planning zone[1] as a separate agent, aggregated and centrally controlled. We use the ISP 2020 Central scenario as a base and linearly project 100% electrification by 2050 for all vehicle modes considered.

In this study we first present the impacts of a 100% electrified and passive transport system in 2050 on the NEM compared to a future without EVs in terms of system costs, emissions and capacity expansion decisions. We then present the differences when allowing utility control of each

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[1] OpenCEM includes 16 planning zones across the NEM, loosely tied to the Renewable Energy Zones by AEMO.

EV mode under various smart charging pricing schemes. Lastly, we explore the patterns of what ‘optimal’ EV charging is for each vehicle mode across the various planning zones.

We find that the overall electricity system costs decrease with increasingly flexible EVs and that the types of generation installed, particularly battery storage, changes under differing levels of smart EV charging. The study highlights that vehicle modes other than private cars do have the potential to charge flexibility, particularly light commercial vehicles and public buses, and should be included in future EDCE models. This work can be used by researchers and electricity industry planners to investigate the impacts and opportunties of electrified transport fleets in the NEM.

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