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Electrified Public Transit: A Global Estimation Tool on the Impact at the Small and Large Electricity Grid Scales

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Electric vehicles are a promising solution to transport emissions and urban air pollution. Electrifying public transit is a particularly interesting application as it provides an opportunity to reduce emissions while supporting supplementary aims such as reducing congestion on roads and supporting equitable travel options. For the electricity industry, large battery sizes and centralised control of the vehicles with a predictable schedule gives the potential of these fleets being used as distributed energy resources to aid in load shedding, peak filling and providing fast flexibility services.

Electrification of public transit however introduces the additional challenge of large, coincident demand in the low-voltage distribution network due to the high concentration of vehicles charging in centralized locations such as in bus depots. The additional electricity consumption from electrifying these fleets may also require new generation capacity to be built. Understanding how electrified public transit (EPT) charges at both detail levels is important for electricity planners to identify potential areas of future strain and work to mitigate its impact. Understanding how these vehicles move will also allow for estimations of their potential flexibility to offer.

There are three key gaps in the electrified public transit literature. Firstly, researchers use locally specific, privately obtained data sources which have different structures and information included. Some studies use empirical data from electric bus deployment (Kontou and Miles, 2015), (Miles and Potter, 2014), (Ding et al., 2015), but construction of charging profiles at the large scale still rely on probabilistic plug-in time assumptions (Zheng et al., 2020) and assumptions on the quantity of charge events per day per vehicle, or assumptions on the charging regime vehicles will use (Jian et al., 2018). When this data is not available, the electricity consumption and charging demand is often calculated from first principles, including the elevation, acceleration profiles and friction losses (Rogge et al., 2015), (Perrotta et al., 2014), (De Filippo et al., 2014), or use privately obtained transit schedules which is trip-chained with unique vehicle identifiers (Wei et al., 2018), information which is not generally released to the public due to privacy concerns.

Secondly, work is unable to retain detail at both the large and small geographic scales. Studies that investigate EPT at a large scale (state / country) are often dependant on generating time-series demand curves from a combination of average charging start time figures probabilistically distributed with an average daily electricity consumption figure (Su et al., 2019), (Colmenar-Santos et al., 2014), (He and Chen, 2013), (Wei et al., 2018) or assuming a flat charging profile (Taljegard et al., 2019). Using a bottom up approach, or scaling up small studies ignores the geographic variation in the usage and density of regions, whereas using a top-down approach does not highlight the impact at the low voltage substation level, the main concern of these vehicles.

Lastly, the temporal electricity requirements of passenger electric have not been explored, to the best of the author's knowledge. The electricity consumption and drive cycle of electric vehicle ferries has been investigated for vehicle ferries (Gagatsi et al., 2016), (Al-Falahi et al., 2018), (Al-Falahi et al., 2019) and for larger ships (Huang et al., 2020), but do not develop vehicle charging profiles or consider the impact on the electricity grid near the site, and have different requirements than passenger ferries.

This paper aims to address these gaps by presenting a tool that estimates the grid impacts of electrified public transit using public data that is available in over 150 cities / states globally. The tool applies a simple vehicle scheduling heuristic to existing public General Transit Feed Specification (GTFS) data structure (Google, n.d.) to generate estimates of total increased electricity consumption, fleet requirements, charging profiles, estimation of the fleet's capacity to act as a distributed energy resource (DER) as well as the impact on peak demand for both electric buses and ferries.

The tool is first applied to a case study of New South Wales, Australia, finding that electrifying public and private buses and ferries has a moderate increase on total state electricity annual consumption, the vast majority of which occurs within the Greater Sydney Metropolitan Area. The study considers the proportion of metropolitan and regional trips that can be electrified using current technology, suggesting that regional electrification is possible and should be considered along with its metropolitan counterpart.

Average weekly charging profiles across the entire state are presented, as well as at bus depots, ferry terminals and bus stops. Two common charging regimes by the transit authority are compared; an end-of-service (EOS) charging regime, where each vehicle is only permitted to charge at the depot, and a during-service (DS) charging regime, where vehicles can additionally charge at stops/terminals at the end of trips during dwell periods. The potential of the public transit fleet to act as a DER is discussed, considering the proportion of the entire state bus and ferry fleet which can be parked and connected, Figure 1, as well as the location of those vehicles and estimations of total capacity.

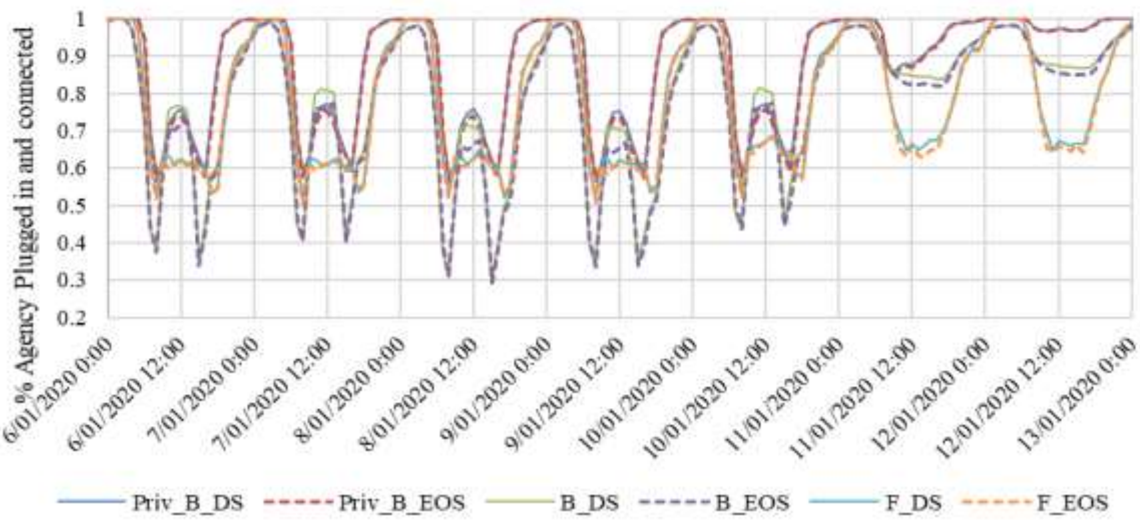

Figure 1. Vehicles Parked and Connected to the Grid for an Average NSW Transit Agency for Private buses (Priv_B), Public Buses (B) and Public Ferries (F) under During-Service (DS) and End-of-Service (EOS) Charging Regimes

To highlight the impact at the substation and individual transit agency level, the tool is applied to the peri-urban area of the Central Coast, north of Sydney. We consider the increase to demand at relevant 11/132kV Ausgrid substations, finding not only significant increases occurring at times of peak demand, but also increases during sunshine hours.

This bottom-up method can be used by researchers, public transit authorities and electricity industry planners to investigate the impact of 100% electrified public transit fleets in Australia and globally, without requiring private data agreements or specialised transit scheduling software. It can be scaled to look at a state / city / country level or specific geographic regions with minimal extra data required. Case study results for NSW and the Central Coast, NSW can be used to help investigate distribution network augmentation requirements, capacity expansion modelling and future flexibility resources.

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