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100% Renewable Electricity and Electrified Land Transport in Australia

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The electrification of transport is an important step towards a decarbonised future. Greenhouse gas (GHG) emissions from the transport sector accounted for 17.3% of Australian emissions in 2017 [1] – with the bulk of emissions coming from the combustion of petrol and diesel. GHG emission from land transport, which includes all road transport and rail, comprise the majority of transport emissions (88%). These fuel emissions can be eliminated by replacing internal combustion engines with electric motors. Electricity used to power the vehicles can be sourced from on-board generators (fuel-cell vehicles and solar vehicles), on-board storage (battery electric vehicles), or through a direct connection to the grid, used for such applications as trolley buses and trams. However, solar vehicles are far from becoming commercially available due to limited power density, and high costs. The expansion of fuel-cell vehicles, is significantly limited by high fuel costs, and the lack of hydrogen infrastructure. Grid-connected transport require constant connection and complicated infrastructure modification for route changes. As a result of these issues, battery electric vehicles constitute the most promising technology for the electrification of the majority of land transport.

It is unlikely that batteries will solely be used to power freight and interstate passenger rail in the near future, due to high costs, and limited payload. Rather, the electrification of rail would be more likely through overhead wires.

Rapid development of battery technology has not only lowered the cost but also increased the range of electric vehicles. More and more car manufacturers have joined the market. In 2017, global electric vehicle sales reached 1.1 million [2], with over 150 models available for sale. Although Australia has had a slow uptake in electric vehicles, continued reductions in cost are expected to significantly increase the fleet in the near future, which could have three major impacts. Switching to electric vehicles could remove 15% of Australia's GHG emissions if this change is coupled with the decarbonisation of grid electricity. Total energy consumption would decrease due to the increased efficiency of battery electric vehicles compared to internal combustion engines. Thirdly, 100% electrification of land transport will also have a significant impact on the National Electricity Market (NEM) – resulting in an increase in electricity consumption of a third.

Charging can be a flexible load, providing opportunities to better balance the grid and lower the total cost of electricity. In this study, an hourly energy balance analysis is presented of the NEM in a 100% renewable electricity scenario with electrified land transport, which includes motorcycles, passenger vehicles, light commercial vehicles, articulated, rigid, and non-freight carrying trucks, diesel-powered rail, and buses. Other modes of transport, including aviation, shipping, etc., are excluded from the scope of this study.

The Household Travel Survey from the Greater Metropolitan Region of Sydney has been used to model the transport of passenger vehicles, LCVs and motorbikes, and data from RMS have been used for truck fleets. Public Transport Victoria (PTV) timetable and geographic information datasets in the General Transit Feed Specification (GTFS) format were used to model bus transport. Rail transport consumption is assumed to be flat, due to lack of publically available information for freight train movements, and enabled by constant connection to the power lines. The electricity generation mix is largely wind and photovoltaics (PV), which provide about 90% of the annual electricity demand and existing hydroelectricity and biomass provides the balance, and is supported by energy storage and strong interconnection between regions. Pumped hydro energy storage (PHES) constitutes 97% of worldwide electricity storage, and is adopted in this work [3]. Distribution of PV and wind over 10-100 million hectares, utilising high voltage transmission, accesses different weather systems and reduces storage requirements (and overall cost). A modified and extended version of the National Electricity Market Optimiser (NEMO) model [3-4] is used to identify solutions which meet the energy balance requirement.

A range of scenarios have been chosen to test the price effect EV charging has on NEM. Utilisation rates are currently much higher for all commercial vehicles, compared with passenger vehicles, and so charging profiles for these classes of vehicles are more difficult to control. Thus, charging regimes for passenger vehicles were tested. The scenarios modelled include a baseline scenario (unmanaged charging based on original datasets), a day-time charging scenario (better utilising PV-generated electricity during daytime) and a worst-case scenario (charging after work which coincides with the evening peak load). The worst-case scenario is developed to examine the upper-bound of the system cost. A plot of sample charging profiles is shown below. More scenarios have also been developed and modelled.

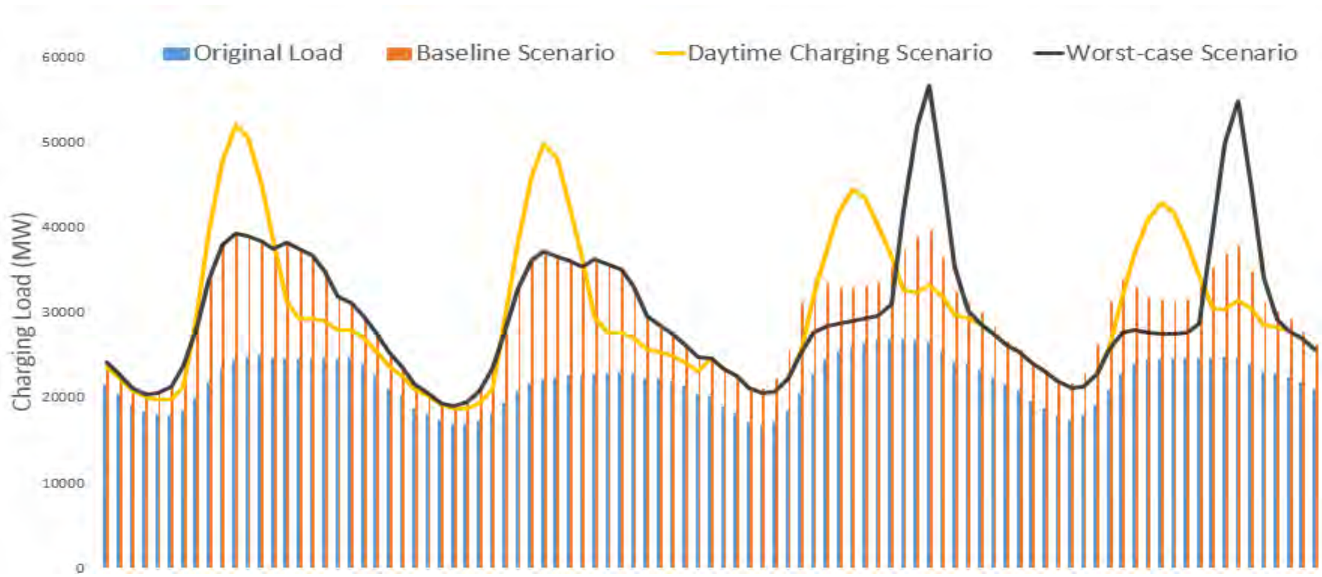

Figure 1. Plot of different charging regimes and original load over the first 4 days of the modelled period (01/01/2006 1am – 04/01/2006 11pm)

References

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