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Modelling of Integration of Electric Vehicles and Heat Pumps in the Australian National Electricity Market

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In Australia, energy sectors including electricity, stationary energy (excluding electricity) and transport contributed 82% of the total greenhouse gas (GHG) emissions in 2017 [1]. Electrifications of land transport via electric vehicles and low-temperature heating via heat pumps, together with 100% renewable electricity, can facilitate a 75% reduction of the energy-related GHG emissions in Australia (equivalent to 60% of the total emissions) or even further, due to the accordingly decreased energy consumptions in fossil fuels-related exploitation, transportation and distribution activities. Significantly, electric vehicles with built-in batteries and heat pumps coupled with low-temperature thermal energy storage such as hot water tanks provide substantial demand flexibility to electricity systems, which enables balancing of renewable energy systems at low marginal costs (levelised cost of balancing, LCOB).

Preliminary work at the Australian National University[1] has demonstrated that integration of electric vehicles including passenger cars, light commercial vehicles, articulated trucks, buses, motorcycles and rail, will not significantly increase the levelised costs of electricity (LCOE) for 100% renewable electricity. This is despite adding 35% to the original demand of the National Electricity Market (NEM). Following the preliminary research, this study focuses on the development of active load management models to simulate active load shifting and shedding in response to energy deficiency or surplus in renewable energy systems. A novel modelling approach is adopted where load shedding is modelled as a flexible energy source like existing hydropower and bioenergy while load shifting is scheduled similar to energy storage facilities though it is actually a "discharge-charge" cycle instead of "charge-discharge". Least-cost solutions of 100% renewable electricity in the NEM are decided through a synergy of flexible renewable energy sources (e.g. hydropower and bioenergy), enhanced interstate high-voltage direct-/alternating-current (HVDC/AC) links, demand flexibility from electric vehicles and heat pumps and lastly, large-scale energy storage including pumped hydro energy storage and batteries. Electricity generation, storage and transmission technologies included in the modelling are all existing mature energy technologies which have already been deployed on a large scale, namely photovoltaics (PV), wind, pumped hydro energy storage, batteries, existing hydropower and bioenergy and HVDC/AC transmission.

Initial results from the modelling show that by integration of electric vehicles and heat pumps in the NEM, the requirements for large-scale energy storage and interstate HVDC/AC transmission are considerably reduced (Figure 1), which indicates a low figure of the LCOE/LCOB for 100% renewable electricity (LCOB $15-20/MWh) compared with the scenarios (LCOB $25-30/MWh) without integration of electric vehicles [2, 3]. Moreover, electric vehicles and heat pumps are capable of providing ancillary services such as fast frequency response through rapid increase or decrease of energy consumptions, which helps to stabilise renewable electricity systems with high penetrations of intermittent PV and wind energy.

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[1] A separate submission to the APSRC 2018 by Anna Nadolny and Cheng Cheng.

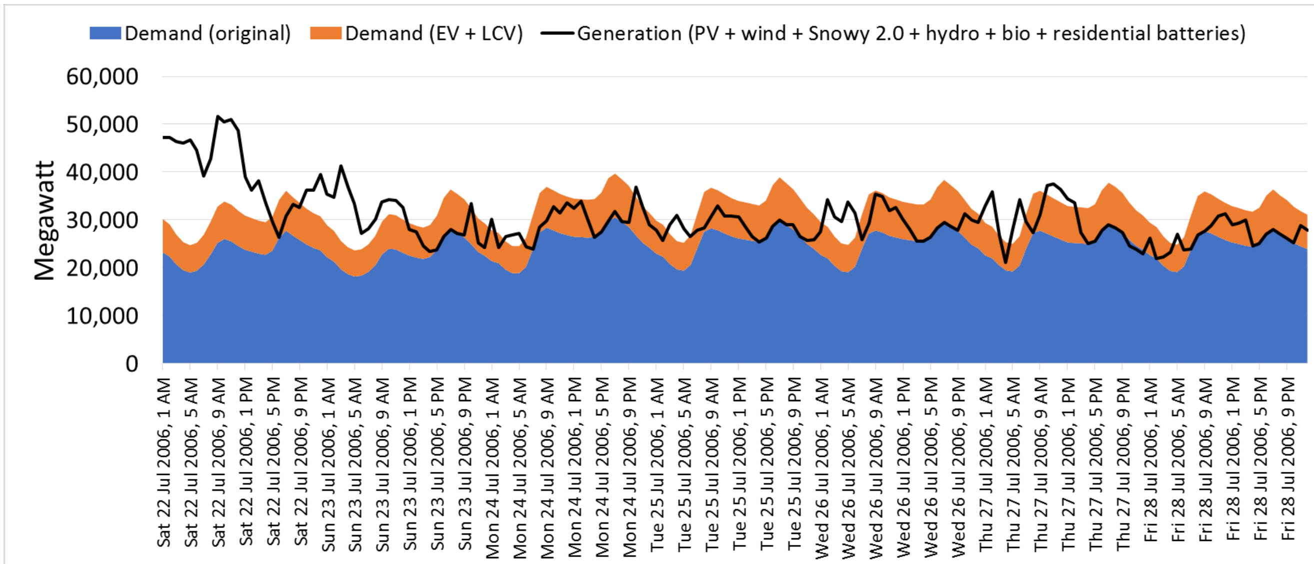

Figure 1. Load profiles and generation mix during the most difficult week (modified with electric vehicles demand and magnified PV and wind energy supply).

References

[1] Australian Department of the Environment and Energy. Quarterly Update of Australia's National Greenhouse Gas Inventory: December 2017. 2018.

[2] Blakers A, Lu B, Stocks M. 100% renewable electricity in Australia. Energy. 2017;133:471-82.

[3] Lu B, Blakers A, Stocks M. 90-100% renewable electricity for the South West Interconnected System of Western Australia. Energy. 2017;122:663-74.