ELECTRIC VEHICLE DEMAND: IMPLICATIONS ON COST AND EMISSIONS OF ELECTRICITY GENERATION IN APEC

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Overview

The Asia Pacific Economic Cooperation (APEC) consists of 21 economies which together accounted for almost 60% of global electricity generation in 2016. This paper focuses on two APEC economies that have policies to promote EVs, namely Indonesia and New Zealand, and presents model results to analyse the implications of increased demand from EV charging on the cost and emissions of electricity generation.

EV deployment theoretically has two contradictory effects. On one hand, it is expected to reduce air pollution by substituting for conventional vehicles, particularly in urban areas. On the other hand, there are concerns that the increase in emissions at power generating sources caused by transitioning to EVs will also be substantial.

This study investigates whether additional electricity demand from EV charging increases the cost and emissions of power generation by comparing the electricity generation mix, average cost of generation, and emissions in Business-as-Usual (BAU) and High EV share (HEV) scenarios. The BAU scenario is taken from the APEC Energy Outlook 7th Edition (APERC, 2019). The HEV scenario is based on the APEC Target Scenario of the same Outlook, and assumes a larger penetration of EVs (compared to the BAU, 107% larger for Indonesia and 86% for New Zealand).

Methods

The model and key assumptions for this study are based on the electricity model for the 7th Edition of the APEC Outlook. Additional enhancements such as increasing time slices to one hour to better represent EV demand profiles, and including non-CO_2 emissions as this study focuses on NO_x emissions, have also been made.

APERC's long-term electricity model calculates the optimal capacity and operation of power generation, including storage facilities, to satisfy demand as projected by a demand model. It is a bottom-up model formulated as a linear programming problem, designed to minimise the discounted total system cost over the projection period as shown below. The General Algebraic Modeling System (GAMS) is used to perform computation for the optimisation. One calendar year is divided into 288 time-slots to take seasonal and diurnal characteristics into account.

$$min.\, z = \sum_{y} \frac{1}{\gamma_y} (cc_y + fc_y + oc_y + ec_y)$$

Note: γ_y: discount rate, cc_y: total annualised capital costs for power generation and storage technologies in year y, fc_y: total fuel costs for power generation technologies in year y, oc_y: total O&M costs for power generation and storage technologies in year y, ec_y: total carbon taxes in year y (all costs in USD).

This study adopts the electricity charging pattern in Bedir et al. (2018) which comprehensively analysed electric charging patterns in the state of California. NO_x properties for each fuel category (i.e. coal, natural gas, oil and biomass) are derived from a report published by the IPCC which evaluates major non-CO_2 greenhouse gases from combustion processes (Amous, 2013). Daily load curve of electricity supply in Indonesia and New Zealand are obtained from PLN (2018) and Transpower (2019), respectively.

Results

In the HEV scenario in Indonesia, generation from power sources with higher ramp-up/ramp-down capabilities (e.g. natural gas, hydro, and biogas) increases, including EVs as storage. By 2050, gas generation increases 5,446 TWh (4.8%) and renewables increase 2,452 TWh (16%). In contrast, coal power plants, which have not been adjusted to allow rapid response to demand in Indonesia, decreases by 335 TWh (-3.4%), especially at peak hours.

In New Zealand, electricity generation is projected to be nearly 100% renewables in the BAU, mainly geothermal, hydro and wind power by 2050 (APERC 2019). Batteries and pumped hydro play important roles of storing excess electricity during early morning and daytime from wind power, to be discharged at night when demand peaks from residential electricity demand and EV charging. While electricity supply as a whole did not change drastically among scenarios, total supply contribution through energy storage increases 42% (21 TWh) in the HEV over the Outlook. By 2050, the increase of EVs in the HEV scenario reduces 7% of electricity supply curtailment from wind power compared with the BAU.

In the HEV scenario, the average cost of generation increases in both economies. In the case of Indonesia, the average cost in 5.2% higher than the BAU. This is mainly driven by a higher consumption of natural gas for electricity generation and additional investment in solar PV and biogas to provide higher output flexibility. In New Zealand, the average cost of generation increases only marginally in the HEV. Additional power capacity is not required to meet EV demand, however, investment in battery storage (875 MW in total) is needed so that enough batteries can be charged in the daytime to meet EV charging demand at night. Accordingly, the average cost of generation increases 1.1% in the HEV. Figure 1 shows electricity demand and supply curves in Indonesia and New Zealand in 2030.

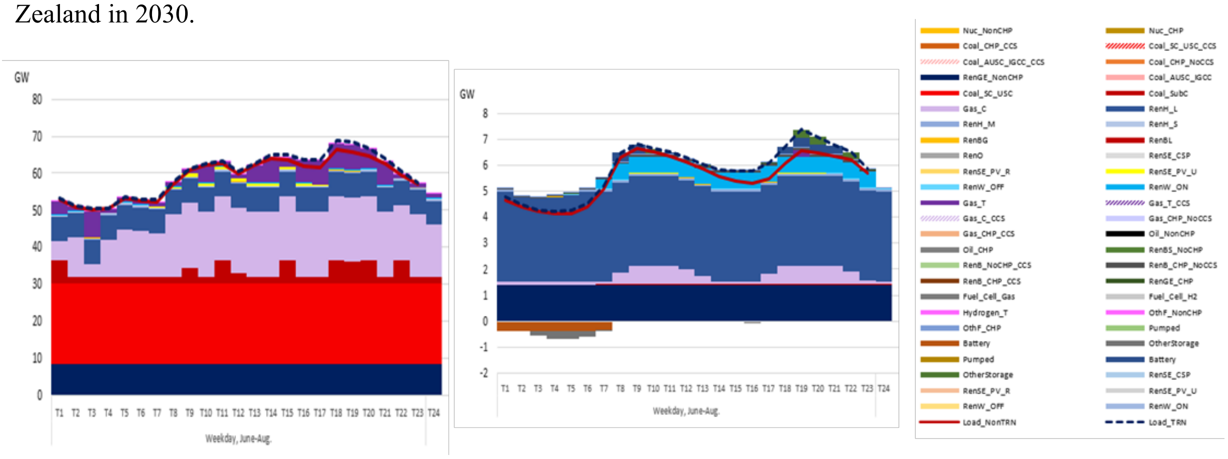

Figure 1: Electricity supply in Indonesia and New Zealand, 2030

In the HEV scenario, NO_x emissions are reduced in Indonesia but briefly rise in New Zealand (Table 1), although average annual NO_x emissions in New Zealand are already very low as they are a developed economy. Average emissions in Indonesia decreased 4.1% from 2031 to 2050, mainly because of the reduction in coal generation.

Table 1: NO_x emissions from electricity generation, BAU and HEV scenarios

NO_x emissions	**Indonesia**		**New Zealand**	
Period	2016 – 2030	2031 – 2050	2016 – 2030	2031 – 2050
Average emissions (g/kWh) in the BAU scenario	1.83	1.57	0.146	0.026
Average emissions (g/kWh) in the HEV scenario	1.83	1.51	0.149	0.025
Change (+/-)	0.0%	-4.1%	2.0%	-3.3%

Conclusions

Electricity generation from flexible power generation increases. In the case of Indonesia, gas increases as other flexible power sources are not sufficient to supply peak demand from EVs in the HEV scenario at night. For New Zealand, the added demand from EVs reduces wind power curtailment although it requires additional storage capacity. Meanwhile, introducing EVs without promoting demand peak cuts or peak shifts increases the average cost of generation, because EV demand is only met through power sources with rapid ramp-up/ramp-down capabilities. This effect is more significant for Indonesia. NO_x emissions are also generally reduced in the HEV, with an especially notable change in Indonesia due to the transition from coal generation to more nimble sources like gas and renewables.

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