ELECTRIC VEHICLES CHARGING IMPACT ON ELECTRICITY LOAD CURVES IN APEC REGION: CASE STUDY OF CANADA, INDONESIA, AND JAPAN

Mr. Alexey Kabalinskiy, Researcher, Asia-Pacific Energy Research Centre, +81-3-5144-8560, alexey.kabalinskiy@aperc.ieej.or.jp
Dr. Gigih Atmo, Researcher, Asia-Pacific Energy Research Centre, +81-3-5144-8554, gigih.atmo@aperc.ieej.or.jp
Mr. Takashi Otsuki, Researcher, Asia-Pacific Energy Research Centre, +81-3-6863-9700, takashi.otsuki@aperc.ieej.or.jp

Overview

Electric vehicles (EV) are becoming more popular in Asia-Pacific region, and their stock has grown significantly because of government financial support, restrictions on vehicle pollution in urban areas and early technology adopters (IEA, 2018). The stock is expected to keep growing even with long-term subsidy uncertainty, and supported by improving economics of electric propultion thanks to decreasing battery costs and increasing competition.

Charging demand with high EV ownership rates could lead to significant shifts in daily electricity load curves. Charging patterns will be mainly driven by infrastructure availability, electricity tariffs and travel demand. There have been a few studies to investigate the potential impacts of EV charging on daily electricity loads such as Croziera et al (2018) that investigates consequences of anytime charging, and considers practical ways to mitigate the impact, and Jiana et al (2018) that conducts a survey of charging behaviors and evaluates the capacity potential and cost of EV smart charging.

The objective of this research is to estimate electricity loads from road EVs, and to discuss charging practices to mitigate potential impacts. This study covers three APEC economies with varying shares of private and public transportation, at varying stages of economic development.

Methods

A multi-region demand-driven set of bottom-up and top-down models developed by APERC is used to project the fuels demand and supply of APEC economies in the period 2016-50. The deterministic transport model is applied to analyze the long-term development of the transport sector. The model has an Excel-based user interface and is written in General Algebraic Modeling System (GAMS) programming language. A transportation multi-modal approach allows to investigate mode shift for passenger and freight transport, and road transport is modeled with a stock turnover sub-model and new vehicle choice algorithm allowing for investigation of the speed of technology change (Figure 1).

Grid electricity is consumed by five types of vehicles (2-wheelers, light vehicles, light trucks, buses and heavy vehicles) and two powertrain technologies (Battery EV and Plug-in Hybrid EV). After annual road electricity demand is determined, a probabilistic algorithm is utilised to estimate charging load curves for six characteristic days: two types of days (workday and holiday) in three seasons (summer, intermediate and winter). The charging options are: (i) slow-charging at home (Level 1), (ii) slow-charging (Level 2) and (iii) fast DC charging at public stations.

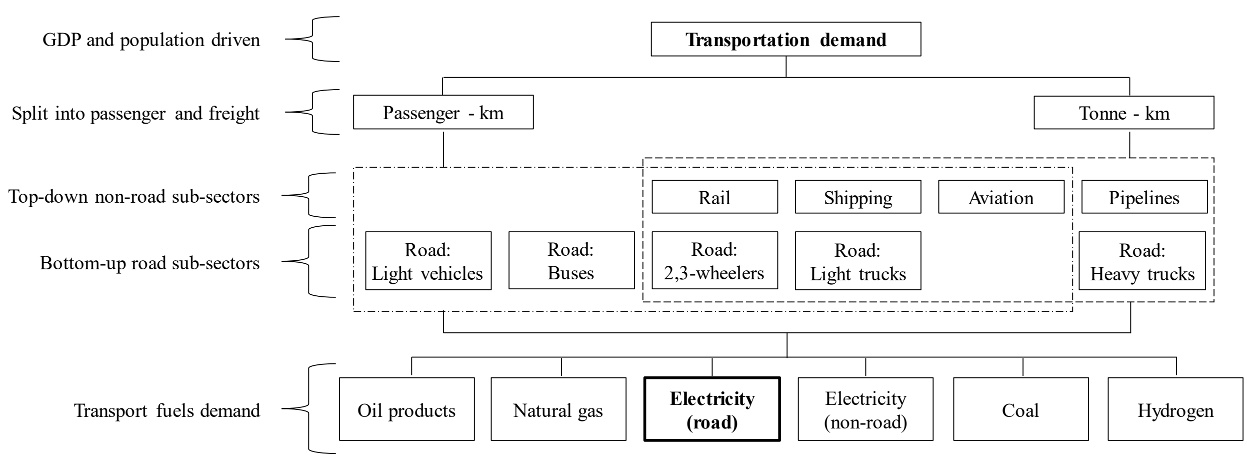

Figure 1: APEC Transport model structure

Three scenarios are defined: Busines-as-usual (BAU, historical trends and currently implemented policy), APEC Target scenario (TGT, economies work towards APEC aspirational energy intensity and renewable goals), and Two Degree Celcius scenario (2DC, low carbon emission scenario).

Three economies out of 21 were selected for this research, namely:

- Canada – a developed economy with a high share of personal transportation, especially light trucks;
- Indonesia – the largest developing economy in south-east Asia, with fast increasing light vehicles stock, and high penetration of 2-wheelers; and
- Japan – a developed economy and a notable EV manufacturer with one of the highest fuel economy standards and strong government support for alternative fuel vehicles.

Results

Modelling results show that:

- in Canada, EVs could reach 12% to 48% (low estimations are for the BAU and high for the 2DC scenario) of vehicle stock by 2050, and EV charging could represent 3.0% to 7.8% of total electricity demand, given potentially higher penetration of domestic chargers, high evening weekday peak loads could be anticipated. However, if EV charging loads are shifted to night time for private and daytime for public charging (to utilize the solar PV outputs), load becomes more manageable (Figure 2);
- in Indonesia, EVs could reach 8% to 51% of fleet by 2050, and 1.4% to 8.8% of electricity demand;
- in Japan, EVs could reach 19% to 61% of fleet by 2050, and 1.6% to 4.9% of electricity demand.

Uncontrolled EV charging demands occur largely in evening peak time (roughly 6pm to 10pm), and increase the system ramp-up and ramp-down requirement, while reducing the operational capacity factor. In addition, this behaviour does not utilise the nighttime charging, as most of vehicle batteries are fully charged by midnight. This is mainly caused by slow residential on-demand charging in the evening.

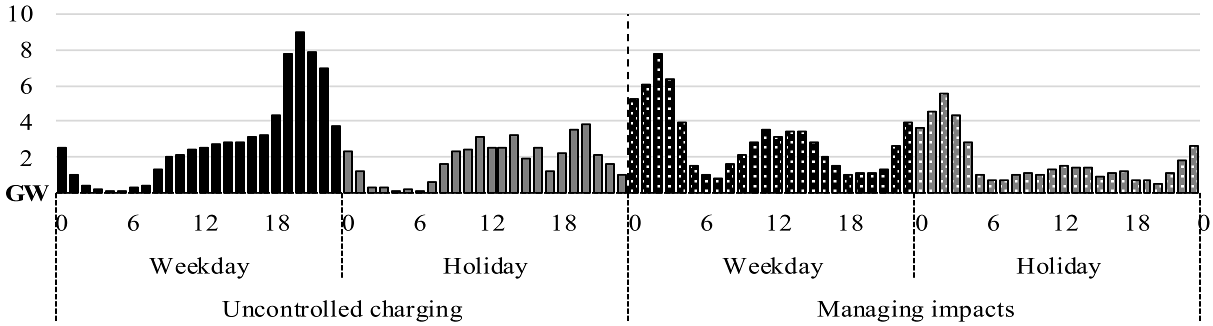

Figure 2: Indonesia, EV charging load curves: low EV penetration, uncontrolled and managed charging in 2050

Through regulatory work, pricing and infrastructure control, EV charging could be shifted to less expensive and more manageable times for a grid operator. Regulations are needed to ensure that charging units could be remotely control to avoid system overloads, and utilize cheaper off-peak electricity. Electricity pricing provides economic incentive for EV owners to optimize their charging behaviour. And grid operator control is needed to ensure staged-charging and optimized use of electricity grid capacity.

Conclusions

EV charging loads could account for up to 14% of electricity demand in the above three APEC economies, and if time of charging is not controlled significant loads coincide with evening peak loads, while nighttime load is minimal. However, these impacts could be managed by shifting loads away from morning and evening peaks to mid-day and nighttime. This could be achieved with staged-charging, remote control of charging infrastructure and time-of-use electricity tariffs.

References

1. IEA, “Global EV Outlook 2018”, https://webstore.iea.org/global-ev-outlook-2018, accessed on 17 December 2018, 2018.
2. C.Croziera, D.Apostolopouloub, M.McCullocha, “Mitigating the impact of personal vehicle electrification: A power generation perspective”, Energy Policy, vol.118, pp.474-481, 2018.
3. L.Jiana, Z.Yongqianga, K.Hyoungmib, “The potential and economics of EV smart charging: A case study in Shanghai”, Energy Policy, vol.119, pp.206-214, 2018.