SHORTAGE OF RAW MATERIALS COULD CHOKE OUR ELECTRIC CAR FUTURE

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Overview

Even though pure battery electric vehicles (BEVs) offer great benefits, such as zero oil consumption and tailpipe emissions, their market penetration is still currently impeded by high battery prices. While the battery prices have been dropping rapidly in the past several years due to 'learning' as production volume increases, the prices will eventually stabilize as they get closer to the cost of the materials used to make them (e.g., lithium, nickel, and cobalt). We have recently projected future prices of NMC Li-ion batteries over the next 12 years recognizing the practical lower bounds set by the essential materials costs[1]; this practical limit would delay the occurrence of the transition to e-mobility at an attractive real cost, especially if the elemental price spiked resulted from a raw material shortage. China is selected as a market of particular interest owing to its leadership position in plug-in electric vehicles (PEVs, including BEVs and plug-in hybrid electric vehicles (PHEVs)) sales. The dual-credit scheme mandate announced recently is expected to compensate for the phase-out of the subsidy program. The incremental cost of PEVs over counterpart ICEVs will be posing a heavy economic burden throughout the society during the transition to widespread electrification. This paper is offered as a contribution towards assessing the true cost to society of the shift from ICEV to PEV. Since consumer decisions are mainly driven by the private cost instead of social cost, this paper also evaluates the lifetime cost to individual consumers by employing the total cost of ownership (TCO) method.

Method

The **total cost of ownership** (***TCO***) refers to the costs incurred during the car lifespan due to the vehicle ownership and use, which entails several different cost categories. The TCO calculation approach used in this study is shown in the following formula,

$$\boldsymbol{TCO = PC + \sum_{i=1}^{N} \frac{FC_i + O\&M_i}{(1+r)^N}} \tag{1}$$

Where ***PC*** is the vehicle purchase cost incurred in the present year; $\boldsymbol{FC_i}$ and $\boldsymbol{O\&M_i}$ are the fuel cost and non-fuel operation & maintenance cost (including insurance and maintenance costs) incurred during vehicle year ***i***; ***r*** is the discount rate and ***N*** is the vehicle lifespan. In this study, we assume ***r*** = 4% and ***N*** = 8 years.

The **transition cost to the society** in year ***n*** ($\boldsymbol{TrCS_n}$) of shifting from ICEVs to PEVs associated to the mandate and the present value in 2018 of the cumulative costs (***Cum. TrCS***) during 2021-2030 (or ***n*** = 0 to 9) are computed using Equation (2) and (3). The cost to society (***CS***) per vehicle is derived by excluding taxes and subsidies from ***TCO*** in Equation (1) since they are just a redistribution instead of a cost to society as a whole. Here we use the government targets for PEV penetration and our prior projection of the number of vehicles[2] to compute yearly PEV sales ($\boldsymbol{S_{PEV,n}}$) in China out to 2030; the sales amount ratio of PHEVs to BEVs in China is assumed to continue to be 1/4. Note that this does not count the societal value of avoided pollutant emissions, nor secondary costs related to importing petroleum.

$$\boldsymbol{TrCS_{mandate,n} = \frac{4}{5} S_{PEV,n}(CS_{BEV,n} - CS_{ICEV,n}) + \frac{1}{5} S_{PEV,n}(CS_{PHEV,n} - CS_{ICEV,n})} \tag{2}$$

$$\boldsymbol{Cum.TrCS_{mandate} = \sum_{n=0}^{(2030-2021)} \frac{TrCS_{mandate,n}}{(1+r)^{n+3}}} \tag{3}$$

Results

For simplicity's sake, all the cost components except for battery pack are assumed to remain the same through the timeline of interest. The projected price of the battery pack is given by a 2-stage battery learning curve model from our previous studies[1], shown in Figure 1(a). We proposed that the battery pack price should follow a 2-stage learning curve approaching a price floor dominated by the active materials costs, while the active materials costs themselves approach a price floor determined by the mineral/elemental costs. While NMC battery prices are dropping rapidly now, this process will slow in the medium-term (~10 years) as materials will make up an ever increasing fraction of the total battery price.

Cost to Society of the Transition from ICEV to PEV: The new mandate, which is expected to keep the growth momentum in local PEVs market, is computed to impose a substantial burden upon the whole society – cumulatively 2.54 trillion yuan over ten years to achieve 40% PEV market share by 2030, i.e., equivalent to about 3.3% of the 2017 GDP of China. This transition cost can be compared with the projected benefits (e.g., in lower healthcare costs and reduced risk of climate change). This investment will help drive the cost of producing batteries lower, making the cost differential between PEV and ICEV much smaller after 2030 than it is today. So the sizable societal investment over the next 12 years, which will help drive down battery costs, may lead to significant societal benefits in the long run due to reduced emissions leading to lower health costs and greenhouse gas emissions.

Temporal TCO Projection in China: The current (2018) financial incentives for a BEV purchased in Beijing amount to 87,750 yuan reduction in lifetime consumer TCO, making it cost-competitive with conventional gasoline cars. Temporal TCO variations in China are computed, and the ratios of PEVs to ICEV are depicted in Figure 1 (b). Since the battery pack of a BEV is larger than a PHEV, the purchase cost reduction owing to a decrease in battery price is larger in a BEV. The delta in a consumer's TCO for BEV vs. ICEV is small during 2016-2020 owing to the strong government financial supports (e.g., subsidy and tax break). The substantial cuts in BEVs subsidy in 2017 and 2019 lead to the two rises in TCO ratio of BEV to ICEV, and the plan to entirely remove all the financial incentives at the end of 2020 causes a big jump in TCO ratio. It remains to be seen how the whole auto market will evolve over the next decade when the government is phasing out the subsidies but replacing it with the mandate. If the automakers keep the current business model and price structure, it is shown the cost parity in the absence of subsidies will no longer be reached by 2030. However, it is reasonable to expect that consumer-centric TCO (including subsidies, taxes, different automakers profits on different vehicles) for PEV and ICEV will still need to be at the similar level (i.e., TCO ratio close to 1 or even less than 1) for 40% of car purchasers to choose PEVs by 2030. Based on the experience in the USA with CAFE (Corporate Average Fuel Economy) standards, it is likely that car manufacturers will raise the price of ICEVs and lower the price of BEVs as needed to persuade consumers to purchase the required fraction of PEVs. This will shift much of the economic burden for electrification onto Chinese purchasers of ICEVs. However, it is expected that a significant fraction of the societal cost will continue to be borne by the government, in the form of reductions in gasoline tax revenues. Automakers may bear part of the societal cost in the form of reduced total profits during the transition period.

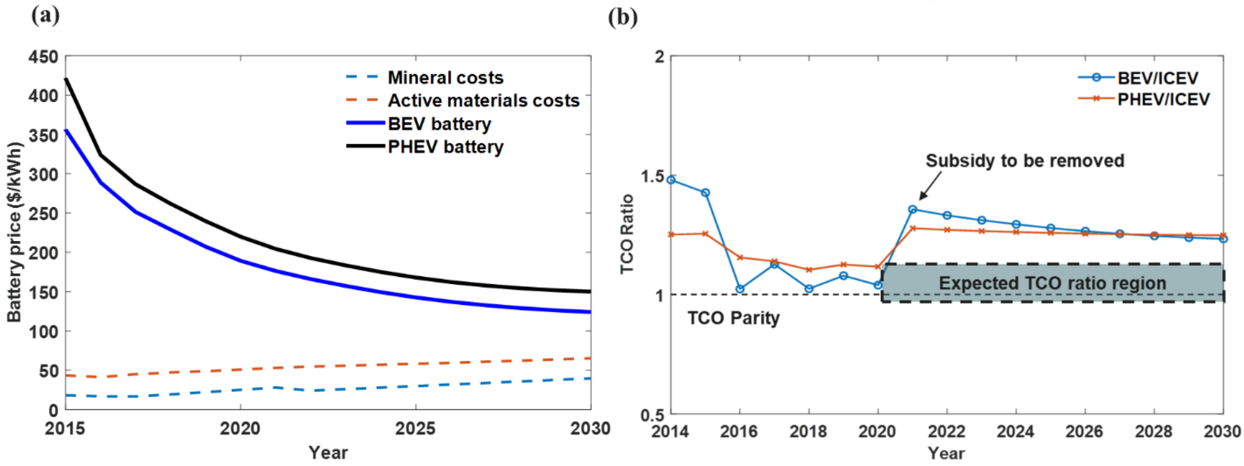

Figure 1. (a) Projected Battery Pack Price for BEVs and PHEVs from 2015 to 2030. (b) TCO trajectories of PEVs relative to ICEVs in China by 2030. Data up to 2017 are historical; 2018-2030 are projections.

Conclusions

China's ambitious dual-credit system mandate is expected to increase its local PEV adoption drastically, while ostensibly shifting the burden of filling in the cost gap between PEVs and ICEVs from the government to the automakers, though in practice to all car buyers. We compute the net transition societal cost to China of switching from ICEVs to PEVs; the value is significant, about 2.54 trillion yuan$_{2018}$ over the ten years from 2021 to 2030, which is approximately 3.3% of China's GDP value in 2017. Since consumer decisions are always determined by private cost instead of social cost, we also examine the cost attractiveness of PEVs by depicting their localized TCO trajectories relative to ICEVs out to 2030. Supported by the subsidy program, Beijing's BEVs are found to be nearly cost competitive with ICEVs during the period of 2016-2020; nevertheless, this TCO parity will no longer be reached beyond the abolishment of subsidy if the automakers keep the current business model and price structure. The mandate will force the automakers to adjust their pricing in order to achieve the required percentage of PEV sales. Based on the experience in the U.S. with CAFE standards, car makers are very likely to raise purchase prices of ICEVs and lower the PEVs prices to keep the TCO ratio of PEVs to ICEVs close to 1 or even less than 1 after the subsidies are phased out.

References

[1] Hsieh I-YL, Pan MS, Chiang Y-M, Green WH. Learning only buys you so much: practical limits on battery price reduction. Applied Energy (submitted, under review)

[2] Hsieh I-YL, Kishimoto PN, Green WH. Incorporating multiple uncertainties into projections of Chinese private car sales and stock. Transportation Research Record 2018.