BIGGER BATTERY CAPACITY OR MORE CHARGING STATIONS? A FRENCH TECHNO-ECONOMIC STUDY FOR ELECTRIC VEHICLES

HAIDAR Bassem, CentraleSupélec (Laboratoire Génie Industriel)-Groupe PSA, +33618882023, bassem.haidar@centralesupelec.fr
DA COSTA Pascal, CentraleSupélec (Laboratoire Génie Industriel), +33674526309, pascal.da-costa@centralesupelec.fr
LEPOUTRE Jan, ESSEC Business School, +33695596737, lepoutre@essec.edu
PEREZ Yannick, CentraleSupélec (Laboratoire Génie Industriel), +33631618728, yannick.perez@centralesupelec.fr

Overview

The IPCC called for GHG emissions reduction, especially in the energy and transportation sectors, which are currently heavily dependent on fossil fuels. During 2018, the transportation sector was responsible for 20% of global CO2 emissions, of which 72% are emitted by road transportation. Electric Vehicles, including Battery EVs (BEVs) and Plug-in Hybrid EVs (PHEVs), are considered one of most promising solutions for the replacement of ICEVs because of their limited GHG emissions, especially while driving. These types of vehicles have gained much recent attention because of their economic and environmental benefits (Amjad et al., 2018), compelling governments and environmentalists to promote EVs as a viable solution (Cao et al., 2020). However, although the number of EVs is growing fast, their diffusion is still relatively limited due to: the high purchasing cost and range anxiety. Eliminating these barriers, however, involves a trade-off: while bigger range can be provided with a larger battery, it comes with a higher cost. Besides the high price, the additional capacity will be only used for occasional long-distances trips (Funke et al., 2019). Alternatively, range anxiety can also be resolved with a high penetration of charging infrastructure, which is a trade-off between lower costs for the consumer, but higher costs for establishing recharging infrastructure. While most studies on EVs diffusion have focused on optimizing the location of charging stations based on different goals: minimizing the cost (Yang et al., 2017), minimizing the travelled distance (Sathaye and Kelley, 2013), maximizing the coverage area (Wang and Wang, 2010), etc. the trade-off between battery capacity and availability of charging points (CPs) has rarely been studied. Based on German real-world driving profiles, (Funke et al., 2019) concluded that the investments in only Fast Charging Infrastructure (50 and 150 kW chargers) are low compared to the investments in larger batteries due to the high price of 1 kWh (actually 350€/kWh). Due to the extravagant price of fast charging event in France (18€/100 km) compared to (3€/100 km on average) for normal chargers, a study on all-speed charging infrastructure is necessary to address all BEVs drivers. Therefore, we will apply (Funke et al., 2019)'s model on French driving data after upgrading it by adding a socket-BEV adaptability factor in order to label all BEVs types. Then, the French case will be compared with the German one in order to conclude with general requirements for BEV manufacturers.

Methods

In this paper, we conduct a techno-economic study in order to compare the investment in more available public infrastructure or in bigger batteries in BEVs. First, in order to determine the mileage-needs, we were based on two surveys done by The French National Institute of Statistics and Economic Studies: INSEE (2009) which indicates the travelled mileage during the weekends, and INSEE (2016) for home-work daily trips (approximately 627 km/month for Parisian drivers). Then, we applied these trips on real BEV models on the studied area in order to conclude with the energy demand, taking into consideration specific parameters of each BEV model such as: consumption [kWh/km], socket adaptability (AC, ChaDeMo, CCS,…), battery capacity [kWh], autonomy [km], etc. Second, the number of public charging points was deduced from the previous step, using a queuing model (the M/M/s model), and subjected to the following constraint: maximum waiting time is 5 minutes. The aim of this study is to identify where to invest: in bigger battery capacity or in more available-public charging stations taking into consideration different scenarios. Since, BEV, ICEV and charging infrastructure have different lifetimes and costs, the model used for this comparison is the Equivalent Annual Cost (EAC) developed in the followed equation derived from Funke… :

$$\boldsymbol{\Delta EAC_i = \left(EAC_{BEV,i} + \frac{1}{\#BEV_z} EAC_{CI}\right) - EAC_{ICEV,i}}$$

With:

- i: individual driving
- $\boldsymbol{\#BEV_z}$: $\begin{cases} BEV_{Type1}: Number\ of\ BEVs\ with\ c_{batt} \leq 30\ kWh\ that\ charge\ using\ a\ 22\ kW\ charger \\ BEV_{Type2}: Number\ of\ BEVs\ with\ 30\ kWh < c_{batt} \leq 50\ kWh\ that\ charge\ using\ a\ 50\ kW\ charger \\ BEV_{Type3}: Number\ of\ BEVs\ with\ c_{batt} \geq 50\ kWh\ that\ charge\ using\ a\ 120\ kW\ charger \end{cases}$
- $\boldsymbol{EAC_{BEV,i}}$ is the Equivalent Annual Cost of BEV detailed as:

$$\boldsymbol{EAC_{BEV,i} = \frac{(1+r)^T * r}{(1+r)^T - 1}(I_{veh} + c_{batt} * k_{batt}) + aVKT_i * (c_f * Cons_i + c_{O\&M})}$$

- EAC_{CI} is the Equivalent Annual Cost of Charging Infrastructure detailed as:

$$EAC_{CI} = \frac{(1+r)^{T} * r}{(1+r)^{T} - 1}(I_{CI}) + \#CP * \left(c_{O\&M,CI}\right) - \left[\left(c_{elec} - c_{elec,CI}\right) * YCE\right]$$

- And $EAC_{ICEV,i}$, the Equivalent Annual Cost of ICEV detailed as:

$$EAC_{ICEV,i} = \frac{(1+r)^{T} * r}{(1+r)^{T} - 1}(I_{veh}) + aVKT_{i} * \left(c_{fuel} * Cons_{i} + c_{O\&M}\right)$$

With the other variables (Table 1):

Variables		BEV	ICEV	CI
r	Interest rate [%]	5%	5%	5%
T	Lifetime [Years]	11.9	11.9	15
I_{veh}	Vehicle investment (w/o battery) [€]	Depends on the vehicle	Depends on the vehicle	--
c_{batt}	Battery capacity [kWh]	Depends on the vehicle	--	--
k_{batt}	Price of 1 kWh [€/kWh]	350 €/kWh 250 €/kWh (Medium term) 100 €/kWh (Long term)	--	--
$aVKT_{i}$	Annual Vehicle Km Travelled [km]	Depends on the vehicle	Depends on the vehicle	--
c_{f}	Electricity cost [€/kWh] Fuel cost [€/l]	0.25 €/kWh	1.509 €/l	--
$Cons_{i}$	Electricity consumption [kWh/km] Fuel consumption [l/km]	0.16 kWh/km	0.5 l/km	--
$c_{O\&M}$	Operation and Management cost [€/km]			3000 €/year
I_{CI}	Charging infrastructure investment [€]	--	--	Depends on the power
$\#CP$	Number of CPs [-]	--	--	To be identified
c_{elec}	Electricity cost [€/kWh]	--	--	0.25 €/kWh
$c_{elec,CI}$	Electricity cost for the CI [€/kWh]	--	--	0.18 €/kWh
YCE	Yearly Charged Energy [kWh/year]	--	--	

Table 1 List of variables

Results

Results are on going. They will be presented during the International IAEE 2020 conference.

Conclusions

This study apply an updated approach to compare the cost-efficiency of longer ranges with more available public all-speed charging infrastructure, for the French case, which will present a roadmap for electric vehicles manufacturers.

References

Amjad, M., Ahmad, A., Rehmani, M.H., Umer, T., 2018. A review of EVs charging: From the perspective of energy optimization, optimization approaches, and charging techniques. Transp. Res. Part Transp. Environ. 62, 386–417. https://doi.org/10.1016/j.trd.2018.03.006

Cao, Y., Huang, L., Li, Y., Jermsittiparsert, K., Ahmadi-Nezamabad, H., Nojavan, S., 2020. Optimal scheduling of electric vehicles aggregator under market price uncertainty using robust optimization technique. Int. J. Electr. Power Energy Syst. 117, 105628. https://doi.org/10.1016/j.ijepes.2019.105628

Funke, S.Á., Plötz, P., Wietschel, M., 2019. Invest in fast-charging infrastructure or in longer battery ranges? A cost-efficiency comparison for Germany. Appl. Energy 235, 888–899. https://doi.org/10.1016/j.apenergy.2018.10.134

Sathaye, N., Kelley, S., 2013. An approach for the optimal planning of electric vehicle infrastructure for highway corridors. Transp. Res. Part E Logist. Transp. Rev. 59, 15–33. https://doi.org/10.1016/j.tre.2013.08.003

Wang, Y.-W., Wang, C.-R., 2010. Locating passenger vehicle refueling stations. Transp. Res. Part E Logist. Transp. Rev. 46, 791–801. https://doi.org/10.1016/j.tre.2009.12.001

Yang, J., Dong, J., Hu, L., 2017. A data-driven optimization-based approach for siting and sizing of electric taxi charging stations. Transp. Res. Part C Emerg. Technol. 77, 462–477. https://doi.org/10.1016/j.trc.2017.02.014

Groupe PSA, in collaboration with CentraleSupélec and ESSEC Business School, fund this thesis under the CIFRE contract N2018/1162.