The challenges of vehicles electrification for road infrastructure

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The transport sector has been evolving with the introduction of electricity powered vehicles, with associated requirements in terms of electric vehicle supply equipment (EVSE). Even if the deployment of EVSE started with less technological solutions mainly focused on urban environment, it has lately been expanding to long-distance trips with the deployment of a growing fast-charging EVSE network. This brings new opportunities for road infrastructure, namely highways, which must be adapted to accompany these trends of new vehicle technologies.

The transport sector has been rapidly facing a new paradigm, mostly related to how the user interacts with different mobility products and with the need to mitigate their externalities. One of these options has been diversification of vehicle technologies and of energy sources by the steady electrification of vehicles' powertrains. If this electrification started with hybrid electric vehicles in the 1990s, without requiring a recharging procedure with associated electric vehicle supply equipment (EVSE), the last 5 years has seen a wider adoption of battery electric vehicles (BEVs) and of plug-in hybrid electric vehicles (PHEVs), increasing the need for a complimentary EVSE network. In more detail, the European BEV and PHEV has increased significantly, approximately 180 thousand vehicle sales in 2017, having surpassed the 1% share of sales in 2015 [1][2].

The initial adoption of BEV and even PHEV was focused on urban use. It is in urban context that the potential for local pollutant mitigation and noise reduction is more significant, so the promotion of electric mobility has been pursued mostly focused on this environment. Furthermore, the majority of vehicles available in the market regard the B-segment, more directed to a quotidian, commuting use. In fact, contradicting the general belief that vehicle range would be insufficient for BEV use, several studies show that electric mobility is highly feasible for weekday urban trips [1,3,4], while weekend trips, due to their higher average distance, are less suitable to be performed by EVs. A study for the city of Lisbon, Portugal, showed that the percentage of eligible real-world trips for BEV was found to be equal to or higher than 94% and 88% on weekdays and weekend days, respectively. The same study showed that lower electric mobility feasibility would be associated with considering only daytime charging, while if considering night charging, electric mobility eligibility would improve significantly [3].

All these facts have justified that the first investments in EVSE have been centered in cities, directed at a daily use of vehicles, mostly to the home-work-home commute. Also, vehicle users have shown a clear preference for home and workplace recharging, namely stated in surveys for Nordic countries, stating that a large majority of EV owners perform their charging routine daily or weekly at home [5]. Consequently, in the last decade, around 60 thousand EVSE have been deployed in Europe with countries such as France, Germany, the United Kingdom, and Norway being leaders in the implementation of this infrastructure [1]. This deployment was accompanied by complimentary studies regarding the optimal location for the EVSE, with different approaches regarding home, work, or street charging [6][7].

Additionally, the deployed EVSE started with less technological solutions that within time have evolved into more integrated and robust solutions. Even if a simple socket can be used for recharging a BEV or PHEV, matters of safety and of current limitation (resulting in higher recharging times) have justified more developed options. The most significant barrier to the wider deployment of EVSE has been its cost, justifying economic feasibility studies for quantifying the tradeoff between economic and energy/environmental impacts for deployment of EV parking spaces. One example focused on urban context by comparing cities such as Lisbon, Madrid, Minneapolis, and Manhattan concluded that the maximization of the parking premium and the minimization of the equipment cost lead to higher net present value results [8].

Currently, urban centers have reached a point that already have some offer of standard EVSE and where an opportunity arises for solving the range anxiety problem associated with electric mobility. If on a daily basis, the current battery capacities are proving to be enough for most of home-work-home commuting mobility patterns, the occasional long-distance trips are on the verge of being possible with the deployment of a growing fast-charging EVSE network.

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The recharging types and modes differ significantly, according to the level of control and protection, as well as the voltages and current involved. These different levels can be found in both the infrastructure and vehicle, identified by three main characteristics, which include level (the range of the power output of the EVSE outlet), type (the type of socket and connector used for recharging), and mode (the type of communication protocol used between the vehicle and the EVSE). In the European context, slow charging is typically dominated by modes 2 and 3 (wall socket and wall box, respectively) and type 3 connector (the standard connector in recent BEV vehicles manufactured in Europe). This configuration can handle 3 to 22 kW, if charging from a socket or a wall box, respectively [9]. Therefore, if charging occurs in public parking, the occupancy rate of parking places with charging infrastructure is high, and rotation is low.

Fast charging mainly uses CCS Combo and CHAdeMO plugs, ranging from 43 kW AC to 120 kW DC [9]. This is a potential solution to overcome the high occupancy and low rotation of parking places. It is also the best solution to deploy a roadmap towards the battery range limitations on long-distance trips. The choice has been to deploy fast EVSE in the most important highway corridors, enabling a 20- to 30-minute stop to reach the 85% state-of-charge required to continue the trip.

Due to the importance of deploying EVSE along the major road networks to enable the long-distance driving of BEV and PHEV, the main markets have ramped up their goals for EVSE along highways. This ambition is reflected in the targets for number of EVSE (set at 800 for China, around 600 for the EU, and 900 for the USA), and in the target distance between EVSE in these corridors (45 km for China, 60 km for the EU and 115 km for the USA) [1]. These are ambitious values for which emerging market opportunities arise, possibly requiring regulatory and fiscal policies that support this EVSE expansion.

Moreover, the expansion of the EVSE network is also highly dependent on local market circumstances, resulting in national policy frameworks that influence the regulatory framework and the mobilization for funding for direct investment and for other types of financial support. The existence of such conditions, at least in some markets, is triggering private sector stakeholders, including vehicle manufactures, and utility companies as well as oil companies, to more actively begin entering the EVSE market, which in a longer term will be a positive sign for more competitive products and prices associated to recharging.

Additionally, the rapid technological development observed in recent decades may also rapidly change the paradigm in the recharging of electric vehicles. Aftermarket suppliers and OEMs have tested inductive recharging as a seamless solution regarding the interaction of vehicle and road. This solution has been tested on parking places (eliminating plugs), but most interestingly on roads. In this case, the road is not only a base to provide vehicle adherence and traction, comfort and roughness, but also an energy vector that provides continuous energy supply, changing the current paradigm of a discrete "fill-the-tank" system [10].

Inductive charging allows for overcoming the BEV barrier around charging compared with conventional vehicle refueling. This recharging alternative must be suited for low-ground-clearance sport cars, as well as high-ride SUVs and be comprised of a primary coil installed on the pavement and a secondary coil installed on the vehicle, which is connected to the vehicle battery charging control. SAE J2954 standard has already introduced practices regarding automated wireless charging up to 11 kW, underlining the importance of this system in the near future, particularly for long-range trips or shared mobility vehicles or taxis, where low stoppage rate is usually required [11].

Connected to this possibility is the fact that most vehicle manufacturers are planning and making considerable R&D investments in fully autonomous transportation. In the possibility of vehicle automation, inductive recharging may be complementary because if a vehicle is able to drive itself, it must be able recharge itself.

To sum up, the challenges associated with electric mobility are being transformed in opportunities, namely regarding the supporting highway infrastructure, which must be designed to accompany the trends in new vehicle technologies on the road.

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