MARKET MODEL FOR THE DEVELOPMENT OF RECHARGING INFRASTRUCTURE IN BRAZIL

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ABSTRACT

Brazil is lagging behind many countries when it comes to electric vehicles (EVs). Among the reasons to this poor performance, one can certainly argue that the absence of initiatives, public and private, to foster the deployment of public accessible Electric Vehicle Service Equipment (EVSE) infrastructure, a fundamental component to mitigate barriers such as the range anxiety of early adopters, is one of the main contributors. In this paper, we evaluate, from a distribution system operator (DSO) perspective, how market models alongside new and existing players can be orchestrated to stimulate a gradual deployment of public EVSEs in synch with forecasts for the evolution of Brazilian EV fleet. Our analysis shows that circumventing the impact of the high levels of CAPEX and OPEX in the early stages of the market and the low demand for charging might require some level of public investment. Our recommendation is the proposition of a hybrid market model, in which appropriated public policies applied in conjunction with private investment pave the way for the widespread deployment of the charging infrastructure.

INTRODUCTION

There is a strong belief that plug-in electric vehicles (PEVs) will fulfil an important role in reducing oil dependence, decreasing greenhouse gas emissions and improving urban air quality. However, there are many barriers to the mainstream adoption, such as technological limitations in battery technology, relative longer period to charge a depleted battery and restricted electric driving range. The latter refers to the fear of running out of charge, or *range anxiety*, and depends on the vehicle autonomy range, charging routines and driving patterns, being considered a key barrier to PEV diffusion [1].

In order to mitigate this barrier, many initiatives and regulatory frameworks have been discussed and put in place in different countries with the goal of making the recharging infrastructure widely available and, as a consequence, stimulate PEV adoption. In this regard, a range of issues have been raised by policy makers and stakeholders. For instance, the degree of regulation needed to form an efficient and competitive market is a challenging task since multiple interests need to be taken into account in order to achieve a cost effective deployment strategy and respond adequately to market needs.

A market model represents the requisites for the high-level interactions among the players, and is defined according to their roles under an economic and regulatory environment. Seeking to operationalize the analysis, [2] proposes a framework based on four market models (integrated, separated, independent, spot) which policy makers could use to analyse market and regulatory options by considering three main activities in the value chain: electricity distribution, charging station ownership and operation/retail of electricity as a whole. Extending that work, [3] proposes a generic market model for charging and e-mobility services and, while it does not express a definitive recommendation, it affirms that the choice should take into account the characteristics of local markets and mobility behaviours.

Building upon those studies, this paper seeks to answer which contours the market model for the recharging infrastructure in Brazil should exhibit in order to promote the growth of the future Brazilian EV fleet. It is also conceived to promote a competitive environment and be economically sustainable over time. The studies were developed as part of an ongoing electric mobility R&D project [4], developed by CPFL Energy, CPqD Foundation, Daimon and other technological partners.

The following sessions present the methodology applied in the work, the modelling of the charging infrastructure, the economic analysis, the design of the proposed market model and the conclusions.

METHODOLOGY

In this section, we present a high level view of the methodology employed in the work. More specific details are presented in the follow-on sections.

The methodology takes as a starting point the EV sales forecasts developed in other studies by CPFL and an economic viability analysis for a private operator offering recharging services in regions of the CPFL distribution concession area. These regions comprise 270 cities of the state of São Paulo. Due to their social and economic diversities, these cities could be considered as approximate representations of the Brazilian market.

In order to allow for a sensibility analysis, two scenarios are explored: a moderate penetration of PEVs and a more accelerated variant. It is also considered the offering of charging services to premium segments composed by cities exhibiting high development social levels. In this case, the propensity to PEV adoption would be above the average of the whole regions as a consequence of higher incomes.

As a premise, the deployed EVSE infrastructure is sized to support the demand for EV charging from the early stages of the market, when the coverage of urban area and the presence will be the priorities, thru its maturity, when the general availability of chargers and the quality of services will become more relevant aspects. The analysis covers a period of 15 years, extending from 2016 thru 2030.

Then, an economic analysis taking into account the projected EV fleet, the required infrastructure for urban (normal) and road (fast) charging services, the associated investments (CAPEX) and operational costs (OPEX), and the projected revenues produces economic indicators such as payback, net present value (NPV) and operating margins over the course of the 15 years period.

The outcomes of the analysis will indicate two directions: should the business present itself as economically viable, private operators will be ready to launch services and no public policy will be required; otherwise, it follows an evaluation of the application of a selected public policy in order to verify if the operator business can be made economically viable, while guaranteeing that the economic impacts of the policy are manageable and likely to be acceptable by stakeholders.

For the evaluation of the public policies, we used the structure of CPFL distribution electricity tariff services. Since the project is sponsored by a DSO, this choice was straight forward due to the availability of data and thorough knowledge of the regulated tariff definition rules.

The final step comprises the construction of a comparison framework that takes into account Brazilian specificities to position the candidate market models in terms of pros and cons for the selection of the recommended model.

SIZING THE CHARGING INFRASTRUTURE

The initial focus of the infrastructure is on covering the urban area with enough EVSEs in order to mitigate the range anxiety of the first adopters. The aim is to build thrust by providing easy-to-reach publicly accessible charging alternatives to PEV users when away from their residences or work locations.

In this moment, the number of EVSEs is determined by mapping the urban area of municipalities into a 3X5 aspect ratio rectangle and distributing charging points uniformly throughout the mapped area. Working with geometric figures facilitates the handling of the cities located in the region of analysis and allows for standardization of the EVSE distribution process.

The coverage criteria consists in making sure that a PEV with 20% remaining battery charge level can reach a public charging point with a security margin of at least 10% of the total battery capacity. The reference car is a Renault Zoe equipped with a 22kWh battery and autonomy of 6.8 km/kWh. Since the actual rectangle dimensions depends on the actual area of the cities, the number of charging points will vary accordingly and can be taken as an approximate representation of what will be needed to provide coverage and alleviate *range anxiety*.

The second moment represents the transition to the maturity of the market and is characterized by a more accelerated growth of the EV fleet. The focus shifts towards *queue anxiety* rather than *range anxiety* and, consequently, the infrastructure has to be improved to provide service satisfaction levels equivalent to a referenced market, which in our study was established as the existing network of traditional liquid fuel stations.

In maturity, the sizing strategy takes into account the projected number of PEVs in the fleet, and assumes that coverage issues have already been solved in the initial moment. The estimation process treats gas/ethanol pumps as equipment similar to EVSEs and uses the average daily number of serviced gas/ethanol powered vehicles and PEVs to calculate the number of required charging points. This process also considers the fact that recharging a battery takes significantly longer time than filling up a gas tank, so the relation between these two operations is another parameter used in the estimation.

In both moments, the processes focus on urban located charging points, considered as normal power chargers (6.6-22 kW) falling in the medium power category defined in the classification scheme by Eurelectric [5]. The sizing also assumes that high power EVSE (>40 kW) will be deployed to allow for fast charging in long distance trips. In this case, the estimates are based on relations between recent medium and high-power EVSEs operation data in developed markets [6][7].

The number of urban EVSEs estimated by this process for the accelerated scenario is shown on Table 1, along with the projected number of PEVs on the road. Those estimates constituted the basis for calculating the annual CAPEX and OPEX required to acquire, deploy and operate the charging equipment network.

Table 1 – PEVs & EVSE annual estimates

Year	PEVs	EVSEs
2018	1.260	213
2020	5.840	373
2022	25.185	986

Year	PEVs	EVSEs
2025	169.780	14.535
2030	911.384	32.338
2034	1.788.890	63.444

ECONOMIC EVALUTION

This evaluation aimed at verifying the attractiveness of the charging business from a return of investments perspective under the economic conditions present in the areas where both the EV and the charging infrastructure markets will be developed. These conditions affect fundamentally the diffusion of electric mobility and, consequently, the demand for charging services.

The adopted approach was a traditional business case analysis that provided as results the accumulated NPV curve, the moment of the break-even point (payback) and the operating margins over the 2016-2030 time-frame. The viability criterion was established as the achievement of a payback period prior to the lifetime of the EVSE equipment, considered in our case as ten years.

As to the service costs to PEV users, the analysis adopted a pricing model expressed in terms of the Brazilian national currency per the kWhs injected in the batteries (R$ / kWh), independently from the way the services would be offered to customers. The prices were set based on a comparison of charging offers in developed markets, mainly in the US west coast, and the relations between the gasoline and electricity driving costs per km, and the average charging cost in public accessible EVSEs and the average residential electricity tariffs in the referenced markets and in CPFL areas. The comparison pointed out a base line for the charging services as 2.8 times the current residential electricity tariff in CPFL area.

As to the estimation of the revenues, we considered that 90% of charging sessions would take place at residential or corporation locations, while the remaining 10% would occur in public EVSEs. Due to the absence of data about the Brazilian electric mobility behaviour, we adopted an average of usage patterns observed in developed markets[8][9].

The results are presented in a consolidated form in the graphic in Figure 2. It shows the accumulated NPV over the 15 years time-frame for an 8% interest rate (after tax and free of inflation), a value close to the asset remuneration rate (WACC) applied to the Brazilian electricity distribution sector, and the operating margin in the secondary axis. The market share for this analysis was established as in 30% of the total market. The double sided arrows indicate the variations in the results obtained by the sensibility analysis.

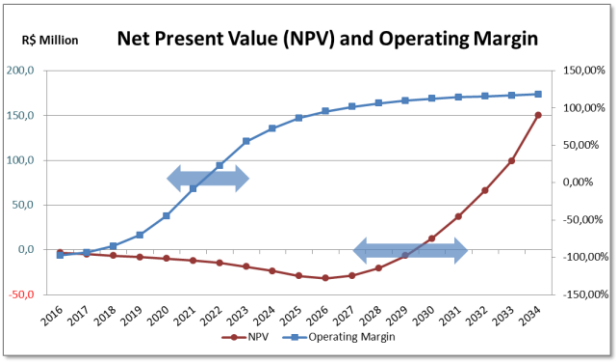

Figure 2 – NPV and Operating Margin

Based on the established criterion, the analysis showed that under the existing conditions, the charging business would not be considered economically viable to investors despite the fact that positive operational margins could be obtained after the fifth year, what could be interpreted as an indication of sustainable profitability over time.

The joint analysis of the NPV and operating margin curves also indicated that the main issue to be addressed is in the early stages of the market due to the association of high levels of investment and the low demand for public charging. In summary, investments in EVSE infrastructure and the operational costs in the early stages of the market tend to move the breakeven point beyond the ten years target, making the charging business not economically viable.

Similarly to what has happened in other countries [10], this classical chicken-egg problem can be mitigated by means of public policies applied at the moments when the number of PEVs on the road is too small to generate the charging demand that provides the economic return expected by investors. In this regard, it is fundamental to understand how the charging market could be organized from the early stages thru maturity in order to form a competitive and sustainable business environment and take advantage of public policies. In order to tackle this issue, we analyse in the next section possible alternatives for the market model and establish a comparison framework to base our recommendation.

THE PROPOSED MARKET MODEL

In order to get to the recommended market, we begin by defining a simplified value chain of the recharging business, encompassing the following activities: EVSE deployment, service operation and integration. While the former is predominantly CAPEX intensive, service operation concentrates the majority of the operational expenses. On the other hand, integration represents the highest level of market organization. It aims at enabling roaming services between charging operators and at providing facilities to the end users by promoting

partnerships among players. As premises, we consider that each of these activities can be realized as a complete *private* initiative, in a *stimulated* form which would count with the support of public funds or as a *regulated* service. In the latter case, the resources would come entirely from public policies. Jointly, the activities and the implementation approaches form the framework that will define the market model alternatives to be submitted to the *pros* and *cons* analysis.

Secondly, we defined three market model candidates by combining selected realizations options with the activities of the value chain. These candidates are the *Open*, *Hybrid* and *Regulated* models, as shown in Figure 2. The driver was to cover the spectrum from a complete liberalized market to a regulated one.

Model	EVSE Deployment	Recharging Service Operation	Service Integration
Open	*Private*	*Private*	*Private*
Hybrid	*Stimulated* / *Private*	*Stimulated* / *Private*	*Private*
Regulated	*Regulated*	*Regulated*	*Private*

Adapted from Eurelectric Framework [3]

Figure 2 – Possible Market Models

Although the economic analysis has shown that complete private initiatives are not likely to succeed, the *Open* model is included in the framework in order to guarantee a comprehensive comparison analysis. This model assumes that all required investments are made by private entities.

On the other hand, The *Hybrid* model considers that the most intensive capital investments activities, deployment and operation, are partially funded by public policies, which could complement private investments in the moments when the charging demand does not yet provide adequate returns to investors. As to the service integration activity in the value chain, it was treated as entirely private since it is typically associated to the maturity of the market when there are multiple operators in the field.

Finally, the *Regulated* model considers that the deployment and operation activities are funded by public policies. Consequently, they are submitted to operation rules established by designated regulation authorities. Similarly to the *Hybrid* model, service integration is treated completely as a private initiative.

The Comparison Framework

The following step consisted in establishing the comprehensive criteria for a qualitative *pros* and *cons* evaluation of each model. In this regard, we took into account aspects such as the availability of the EVSE infrastructure from the early stages thru maturity, the quality of services provided to the users, the stimulus to competition, the non-exclusively reliance on public support and the creation of competitive ecosystem that would bring the most perennial contributions to electric mobility. These aspects were mapped into five dimensions which were then evaluated by the project team and specialists, allowing for the construction of an evaluation table filled with the perceived contribution of the models applied to each of the defined dimensions, as depicted in Figure 3.

Dimension	EVSE density at beginning	EVSE denisty at maturity	Service quality at maturity	Competitive stimulus	Overall contribution
Focus	Addresses range anxiety	Addresses queue anxiety	Quality of the services	Competitive environment	Long term contributions
Open Model	◔	◑	◑	●	◔
Hybrid Model	◑	◕	◑	◕	◕
Regulated Model	●	◕	◑	◔	◑

Legend: Less Contribution ◔ → ● More Contribution

Figure 3 – Evaluation of the candidate models

The Selection of the Recommended Model

In order to get to a recommendation, it is necessary a thoroughly analysis of the evaluation framework described previously.

As expected, the *Open Model* is the one that could provide the biggest contribution for the creation of a competitive environment. However, as demonstrated in the economic analysis, the slow penetration rate observed in the early stages of the market makes complete private initiatives vulnerable and likely to fail over time.

At another extreme, *The Regulated Model* seems to be the best option to alleviate range anxiety of the first adopters due to the guarantee of the return of the investments via regulated tariffs and/or assured revenues. This model would probably take the form of public funded concessions, which, in principle, do not foster a competitive environment in the long run due the reliance on public funding and the intrinsic characteristics of regulated services.

When analyzing the average ratings of the *Hybrid Model*, we can clearly identify that this option provides well balanced contributions across the various dimensions, due mainly to the potential synergies between public and private investments that can be explored over the development of the market. This point was the main fundament for recommending the *Hybrid Model*. Other aspects also taken into account are listed below:

- Assurance of the minimal infrastructure for

urban service in the early stages of the market;

- Gradual evolution of the infrastructure and the availability of public accessible EVSEs.
- Openness to private investor from the very beginning fosters a healthy business environment.

Estimating the Impacts of the Public Policies

Using public funds to incentive private business raises questions that need to be addressed when designing the required policies. Among them, we can cite: How much public funding is necessary? Which stakeholders (car buyer, DSO, DSO customers, citizen, government) should pay such costs? How the monetary impact of the funding can be properly evaluated? How long should the incentives last? Answering all these questions is certainly a challenging task and requires active interactions of several interested parties. So, in this section, we will limit ourselves to provide answers to the two last questions by considering the charging operation as an extension of the traditional electricity distribution business and applying customer base market data, asset information and operational costs provided by CPFL to a hypothetical tariff impact analysis.

The analysis consisted in running a hypothetical tariff calculation by taking the CAPEX, OPEX and the projected revenues of the charging business for estimating the average impact on the regulated electricity rates applied to the consumers. The analysis considered a scenario where 100% of the expenses would be subsidized during the first years of the PEV market development, characterized by low penetration rates. This period ran from 2017 thru 2023. Under these conditions, the overall impact of the basic scenario on rate payers was estimated as approximately 0.2% in 2023 and significantly lower in the previous years due to the smaller number of PEVs on the road. As to for how long the incentives should last, we recommended a continuous monitoring of the evolution of PEV market and the associated demand for charging services in order to gradually remove the support of the public funds as the business gets to maturity .

These results showed that, although the tariff impacts were not negligible, subsidizing the infrastructure via electricity rate-payers is a viable option for the realization of the *Hybrid Model* in the early stages of the market.

CONCLUSIONS

Along this paper, we presented a methodology to evaluate the development of public charging services for electric vehicles and subsidize the selection of a market model for the operation of commercial charging business operators in Brazil through a multi-dimension *pros* and *cons* comparison analysis framework.

The results showed that handling the operation of the service as an activity independent from the deployment of the EVSEs allowed the conception of a *Hybrid Model*, which could be commercially explored by private entities and stimulated by public investments when the economic viability of the business were at risk. This model was our recommendation due to its well-balanced set of attributes in the comparison analysis, its capability of fostering a sustainable business environment and the manageable economic impact of the public funds.

As many countries will be searching approaches to foster EVSE diffusion in the coming years, we believe that the presented methodology can also be applied in other markets, along with the fundaments and analysis concerning the *Hybrid Model*. Further enhancements to this work will focus on expanding the analysis to other public policy alternatives and encompassing other relevant economic markets in Brazil.

REFERENCES

[1] National Research Council, 2015, "Overcoming barriers to deployment of plug-in electric vehicles", In National Academy of Science, chapter 2, 37-64.

[2] Eurelectric, 2010, "Market Models for the Roll-Out of Electric Vehicle Public Charging Infrastructure", available at: www.eurelectric.org.

[3] Eurelectric, 2013, "Deploying publicly accessible charging infrastructure for electric vehicles: how to organise the market?", available at: www.eurelectric.org.

[4] Emotive R&D Project Description, available at: http://www.cpfl.com.br/energias-sustentaveis/inovacao/projetos/Paginas/pa0060-mobilidade-eletrica.aspx

[5] Eurelectric 2011, "European electricity views on charging Electrict views, available at www.eurelectric.org.

[6] European Alternative Fuel Observatory, on line data, http://www.eafo.eu/ (October 2016).

[7] Alternative Fuels - US DOE, on line data, http://www.afdc.energy.gov/data/categories/afvs-and-hevs (October 2016).

[8] Danish Technical University, 2010, "Travel behaviour of potential Electric Vehicle drivers. The need for charging".

[9] Amsterdam Roundtables Foundation and McKinsey & Company, 2014, "Evolution Electric vehicles in Europe: gearing up for a new phase?".

[10] van Deventer, P., van der Steen, M., van Schelven, R., Rubin, B., & Kotter, R., 2015. Large-Scale Deployment of Public Charging Infrastructure: Identifying Possible Next Steps Forward. In *E-Mobility in Europe* (pp. 107-124). Springer International Publishing.