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ELECTRIC MOBILITY: MOTIVATIONS, APPROACHES AND THE CASES OF CANADA AND BRAZIL

Ronald Edward H.-B. de Amorim

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ABSTRACT

Transport electrification got into the political agenda of Governments around the world as a promising mean to achieve sustainable development goals, mainly through decarbonisation and improving efficiency of the transport sector. Electric vehicles come in many flavours. Whilst, the most appealing ones from the sustainability point-of-view are the so-called battery electric vehicles (BEVs), which run 100% on electricity.

From time to time, it´s necessary to plug BEVs to the electric grid to have their batteries recharged, what raises concerns from Electricity Regulators. Most concerns relate to the development of the necessary charging infrastructure, both private and public accessible. Questions such as: Who should pay for the new infrastructure? What kind of regulation is necessary? Should the charging business be considered a sale of electricity or a different business outside the electricity sector?

Depending on the answers to the above questions, different market structures may apply. A set of public policy incentives is also necessary since BEVs still lack some functionality to become perfect substitutes to conventional gasoline and diesel vehicles and have a significantly higher acquisition price.

Bearing these issues in mind, the experiences of the most advanced Canadian Provinces in transport electrification (Québec, British Columbina and Ontario) are analyzed, as well as the current situation in Brazil. Despite localized success initiatives, many challenges still hold to large-scale adoption of plug-in electric vehicles.

Keywords: Electric vehicles, charging infrastructure, transport electrification, electricity sector regulation, life-cycle analysis, energy efficiency, sustainable development.

RESUMO

A eletrificação do transporte entrou na agenda política de Governos pelo mundo como um meio promissor para se alcançar metas de desenvolvimento sustentável, principalmente por meio da descarbonização e do aumento da eficiência no setor de transporte. Existem veículos elétricos de vários tipos. Não obstante, os chamados veículos elétricos à bateria (VEBs), que rodam 100% a partir de eletricidade, são os mais promissores do ponto de vista da sustentabilidade.

O fato de os VEBs terem de ser conectados de tempos em tempos à rede elétrica para terem suas baterias recarregadas gera preocupações nas instituições reguladoras do setor elétrico. A maioria das preocupações está relacionada ao desenvolvimento da necessária infraestrutura de recarga, tanto de acesso privado quando público. Questões como: Quem deve pagar pela nova infraestrutura? Qual o tipo necessário de regulação? Deve o negócio de carga de veículos elétricos ser considerado venda de energia elétrica ou um negócio diferente fora do setor elétrico?

A depender das respostas às questões acima, podem ser aplicáveis diferentes formas de estruturar o mercado. Um conjunto de incentivos por meio de política pública é também necessário, uma vez que os VEBs ainda carecem de funcionalidade que os torne substitutos perfeitos para os veículos convencionais à gasolina e diesel, além de terem preço de aquisição significativamente mais alto.

Com esses aspectos em mente, as experiências das províncias canadense mais avançadas em termos de eletrificação do transporte (Québec, British Columbina and Ontario) são analisadas, assim como a situação atual no Brasil. Apesar de sucessos localizados, ainda existem muitos desafios para a adoção em larga-escala de veículos elétricos plug-in.

Palavras-chave: Veículos elétricos, infraestrutura de recarga, eletrificação do transporte, regulação do setor elétrico, análise de ciclo de vida, eficiência energética, desenvolvimento sustentável.

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1. INTRODUCTION

Around the world, there has been a renewed and growing interest in electric vehicles (EVs), mainly because of the higher efficiency of electric motors and their undeniable tailpipe zero emissions property. Nevertheless, at the present state of technology and charging infrastructure, EVs are not *perfect substitutes* for conventional gasoline and diesel vehicles in terms of functionality, in addition to having a significantly higher acquisition price. As consequence, government incentives and cooperation between different stakeholders are an imperative for those wishing to promote transport electrification.

The present work surveys relevant issues, from the Electricity Regulator perspective, around wide-scale adoption of plug-in electric vehicles, and focus on the aspects related to the public charging infrastructure. Canada´s and Brazil´s current situations are then presented and, to the extent possible, compared. The report ends with a few suggestions of points of attention.

2. ELECTRIC VEHICLE TECHNOLOGIES

A discussion around electric vehicle technologies is beyond the objectives of this work. Nonetheless, a general view of types of EV, modes of charging, and types of plug and sockets used is necessary to better understand issues related to the public charging infrastructure and consumers´ perceptions discussed later in this report.

2.1 TYPES OF ELECTRIC VEHICLES

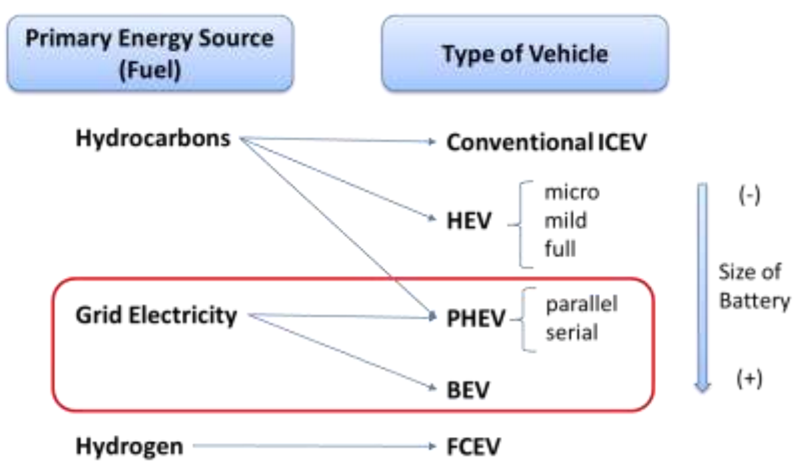
There are different types of electric vehicles and not all of them need to be connected to the electric grid from time to time for charging. The so-called *Hybrid Electric Vehicles (HEV)* use the electricity stored on an additional battery to reduce fuel consumption (i.e. to improve efficiency). The additional battery is recharged by transforming the mechanical energy generated by the movement of the car and/or the thermal energy generated by the brakes into electric energy. Therefore, HEV do not connect to the electric grid. The size of the batteries in HEV are smaller than in other types of EV and only provide a very limited autonomy for pure electric drive, if any. Examples of HEVs are the Toyota Prius and the Honda Accord hybrid.

Plug-in Hybrid Electric Vehicles (PHEV) carry bigger batteries than EV in order to enable a larger pure electric driving autonomy with no significant performance change. Because of the bigger battery capacity, it´s no longer possible to solely recharge the battery using energy generated by the movement of the car and/or by the brakes; there is a need to connect the PHEV to the electric grid from time to time to enable pure electric driving. PHEV may have a dual power train (i.e. internal combustion and electric), the so-called parallel PHEV, or a single electric power train, with the internal combustion engine being used only to recharge the battery, the so-called serial PHEV or Extended-Range Electric Vehicles (E-REV). Examples of PHEVs are the Chevy Volt and the Ford Fusion Energi.

Battery Electric Vehicles (BEV), on the other hand, only have an electric engine, and tend to use batteries with even bigger capacities. BEV are simpler, in technical terms, and because of fewer components, tend to be lighter, which favours autonomy and performance. Example of BEVs are the Nissan LEAF and Tesla Model S.

Fuel-Cell Electric Vehicles (FCEV) use a different concept, where the electricity used to move the car is generated in chemical reactions, most common from hydrogen. Large-scale adoption of FCEV will require a completely new "distribution" infrastructure, e.g., to make hydrogen available to FCEV drivers. Moreover, FCEV technology is not yet consolidated to market and it doesn´t require direct interaction with the electric grid. For these reasons, it´s beyond the scope of this study.

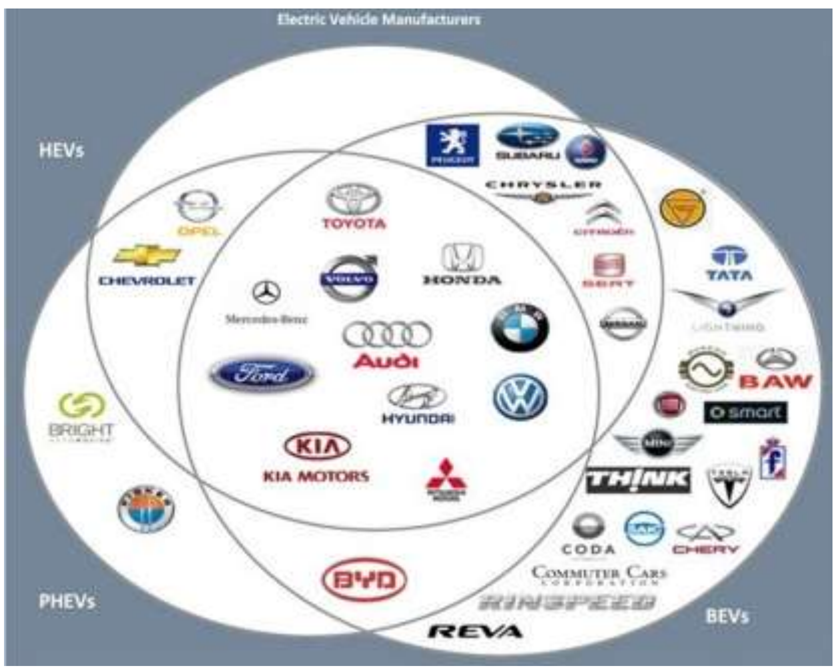
Figure 1: Types of Electric Vehicles



In terms of consumers´ acceptance, it is not clear yet whether PHEV or BEV will prevail. PHEV has the advantage to eliminate "range anxiety" (i.e. the fear to run-out of electricity in the middle of a journey after not finding a place to plug-in and charge), because it´s always possible to drive using the internal combustion engine. On the down side, by doing so, one won´t achieve the benefits of pure electric driving. PHEV are also more complex and demand two supply-chains. On the other hand, BEV have the potential to bring more benefits to society as a whole (as will be discussed in the next sections), are simpler to build and to maintain, and are already suitable to several uses, despite the smaller autonomy when compared to conventional gasoline and diesel vehicles. Moreover, as battery technology continues to improve, BEVs are expected to become more and more competitive.

Figure 2 depicts the offers of EV types from most automakers. Yet outdated, it´s interesting to illustrate the different strategic choices between most traditional ICE automakers and independent manufacturers. It is clear that, in late 2011, most established car companies were pursuing a multi-platform technology strategy, while most independent companies, with the exception of Fisker and Bright Automotive (the latter filed for bankruptcy in 2012), seemed to be focusing on BEVs. Possible reasons for that pointed out in (GTM Research 2011) are: (i) BEVs are simpler to engineer and build and so demand less expertise and capital to develop; and (ii) independent car manufacturers are less path-dependent than established conpanies and may find it easier to adapt their product strategy to market demand. However, whether or not consumers indeed prefer BEVs to PHEV or the other way around, still in 2015, remains to be seen.

Figure 2: Automakers EV Offers



Source: GTM Research (Hofstetter, D. 2011).

2.2 MODES OF OPERATION

The purpose of this section, in addition to presenting the modes of operation when charging EVs, is only to illustrate that a plug-in EV is actually not "like any other electric appliance". To achieve acceptable charging times and benefit from active battery management systems and smart charging capabilities it´s necessary to use a dedicated EV supply equipment (EVSE).

Accordingly to International Electrotechnical Comission´s standard IEC 62196, there are four modes of operation for conductive charging: modes 1 to 3 for alternate current (AC) charging and mode 4 for direct current (DC) charging.

Mode 1 is the mode of operation when using standard home or industrial plugs and sockets. In this case, the current demanded by the EV is limited to the maximum nominal current allowed by the standard (e.g. 10A for home standard outlets in Brazil). However, if adequate grounding is not present, this mode of operation presents safety risks. For this reason, some countries, as the United States, forbid mode 1.

Mode 2 enables connection between a standard home socket and an electric car car operating under Mode 3. This is accomplished by inserting a control box into the cable. With Mode 2, current only flows if earth is connected.

The “controlled” modes of charging (Modes 3 and 4) require special plugs and sockets since more connectors are need for the control signals. The use of special plugs and sockets also provides the necessary technical and safety conditions so that the vehicle can demand more power and thus, achieve shorter charging times.

In Mode 3, the EV controls the charging process by sending control signals to the charge point. In this case, power is not supplied unless a vehicle is connected and, second, the vehicle is immobilized while still connected. Typical operating values are 3.3-10/10-22 kW single/three phase, 230/440 V single/three phase, and 16-32 A.

In Mode 4, DC and even higher power demand and current (much higher than any electric home appliance!) are used to achieve the shortest charging times. Typical values are 50-120 kW, 300-500 V three phase and 100-350 A. For that reason, a new dedicated circuit and transformer in the electric grid is the rule for fast-charging stations. Mode 4 was conceived to take care of EV driver´s needs at public locations during longer journeys, and is popular known as “DC fast-charging”.

Charging up to 100 km of BEV range using normal AC Level 2 charging takes 3-8/1-3 h single/three phase, and 10-30 minutes using DC charging.

2.3 TYPES OF PLUGS AND SOCKETS

For informational purposes only, the following figure presents a panorama of conductive EV charging couplers used around the world. It was taken from a webinar (Bohn, T. 2012) organized by the Clean Cities national network of the U.S. Department of Energy (http://www1.eere.energy.gov/cleancities/index.html)

Figure 3: Conductive EV Charging Couplers

Source: Bohn, T. (2012)

The American (SAE J1772) and the European (IEC 62196-2) standards for AC charging have common control signal, eventhough the European standard also defines two additional types of plugs and sockets. IEC 62196-2 Type 2, commonly known as “Mennekes”, is the European Union standard of choice. IEC 62196-2 Type 3, commonly known as “Scame”, was developed by the EV Plug Alliance, has different shape but functionally similar to Type 2, and is mostly used in France and Italy.

These relatively new types plugs and sockets have been specifically designed for use with electric vehicles and are equipped with extra pilot and control pins (in addition to the usual 3 phase, neutral and ground pins) for the initialization of two-way communications with the plugged in cars.

To date, DC fast chargers still do not have a universal coupler. Therefore, no station model can charge all cars if not providing more than one type of coupler (at a higher unit cost, naturally). The most often found two type of connectors are DC Yazaki and SAE J1772 3-Phase Fast Charge Connector (DC COMBO).

Despite the overwhelming prevalence of conductive charging, there has also been some experimenting with alternative approaches to reduce the burden to provide EVs with the necessary electricity from an external source. Inductive charging is a technology that requires no cables attached to recharge a battery. Eventhough further developments are needed to achieve performance comparable to conductive charging, several manufacturers, like BMW, Volvo and Qualcomm, are working to make it a feasible alternative for the not to far future (http://inhabitat.com/index.php?s=wireless+inductive+technology).

Battery swaping is another alternative approach that may help make EVs more convenient. However, simple in theory but difficult in practive, since EV batteries are not standardized. They come in different chemistries, power and energy densities, and form factors, making it very difficult to keep an inventory for multiple automakers. BetterPlace, an Israeli startup that build its business model around battery swapping for multiple automakers went backrupt in 2012. But Tesla Motors, a high-end EV manufacturer, thinks it can still play a role for particular driver´s needs (Inbar, M. 2015).

3. MOTIVATIONS

The electrification of transport got into the political agenda of Governments around the world for two main reasons: (i) the much higher efficiency of electric motors, when compared to internal combustion engines, especially as it relates to energy security; and (ii) the zero emissions property of electric motors (Govt. of Portugal 2010, Govt. of UK 2011, National Congress of Brazil 2012, Amsterdan Roundtables Foundation 2014). The transportation sector accounts for a significant share of energy consumption and greenhouse gases (GHG) emissions in most countries, especially in developed economies. As a result, the higher the use of electric motors for transportation, the higher the potential to increase the overall efficiency of energy consumption and to reduce emissions. This is the basic rationale for electric vehicles.

There are also several other reasons as well that, depending on the national, regional or local context, may contribute to a even stronger case for electric vehicles. For megacities, it´s worth mentioning the additional benefits of noise and pollution reduction. From an economics perspective, the savings resulting from a smaller cost per kilometer driven on electricity bring positive spillover effects. A study for California (Roland-Holst, D. 2012), because, on average, household demand is 16 times more job intensive than the fossil fuel supply chain, concluded that every dollar saved on the gas pump and spent on the other goods and services consumers want adds stimulus to state incomes, employment, and real wages. From a strategic point of view, a shift to electric transportation result in the development of a lead market that may favour the position of some country in international markets. A study (Bär, H. 2013) has compared the strategies pursued and the opportunities and threats for Germany and China concerning the development of a lead market for electric vehicles. Still, for some other countries the issue of security of supply may be crucial, due to limited natural resources and/or geopolitical aspects.

Nonetheless, several variables may affect the potential benefits resulting from transport electrification. The next sections deal with two of them that directly related to the cases of Canada and Brazil.

3.1 HIGHER EFFICIENCY

Despite the undeniable higher efficiency of electric motors, the improvement in overall energy consumption efficiency also depends on the relative efficiency of the supply-chain from the well to the gas station compared to the supply-chain from the electricity generation plant to the charging station. This kind of full lifecycle analysis (LCA) is know as "Well-To-Wheel Analysis", since it evaluates efficiency across the whole fuel production and consumption chain.

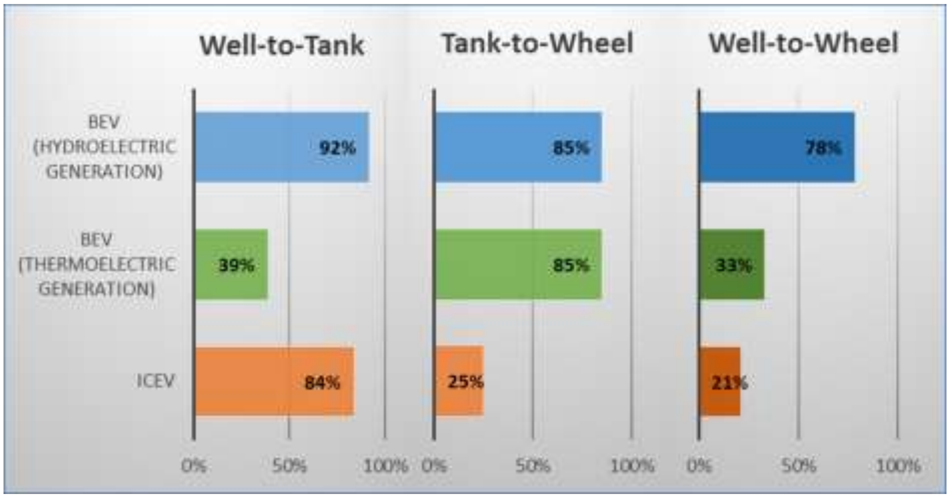
The type of fuel and the technology used in the car mainly determine the efficiency across the Tank-To-Wheel and, for this reason, is referred to as *direct fuel efficiency*. The efficiency across the Well/Power Plant-To-Tank/Battery, on the other hand, captures the efficiency in the fuel production and transportation processes and thus, is referred to as *indirect fuel efficiency*.

Due to the higher efficiency of electric motors, when compared to internal combustion motors/heat engines, BEV´s efficiency is around 85%, while ICV´s efficiency is around 25% (a bit higher for diesel; a bit lower for gasoline).

The following figure presents the comparison between indirect, direct and overall (WTW) efficiency of ICEVs and BEVs using two reference scenarios: pure hydroelectric and pure thermoelectric generation mix. The idea here is not to present exact numbers, but rather, to perform a sensitivity analysis. Examples of efficiency data and assumptions considered in LCA studies can be found on (Faria, R. et al. 2013), (Ma, H. et al. 2013) and (Itaipu Binacional 2014).

Based on Well-To-Wheel Analysis, depending on the actual power generation mix, the overall difference in efficiency between BEVs and ICEVs may be much smaller. The lower-end of WTW BEV efficiency, for instance, may be achieve by HVs, like the Toyota Prius.

Figure 4: Well-To-Wheel Efficiency Sensitivity Analysis – BEVs and ICEVs



Source: Prepared by the author using average values from several references and presentations.

3.2 REDUCED GREENHOUSE GASES EMISSIONS

The potential for reduction in GHG emissions is directly related to the quantity of total emissions from the transportation sector. However, from the policy setting point of view, the relative share of GHG emissions is also important, in order to justify the focus on transport sector emissions instead of the emissions from some other sector.

The following figure shows projected figures to 2030 from a study prepared by McKinsey & Co. for the Brazilian Government that clearly illustrates the differences between the Brazilian profile of GHG emissions and the agregate profile for the rest of the world.

Figure 5: Profile of GHG Emissions – Brazil and the rest of the World

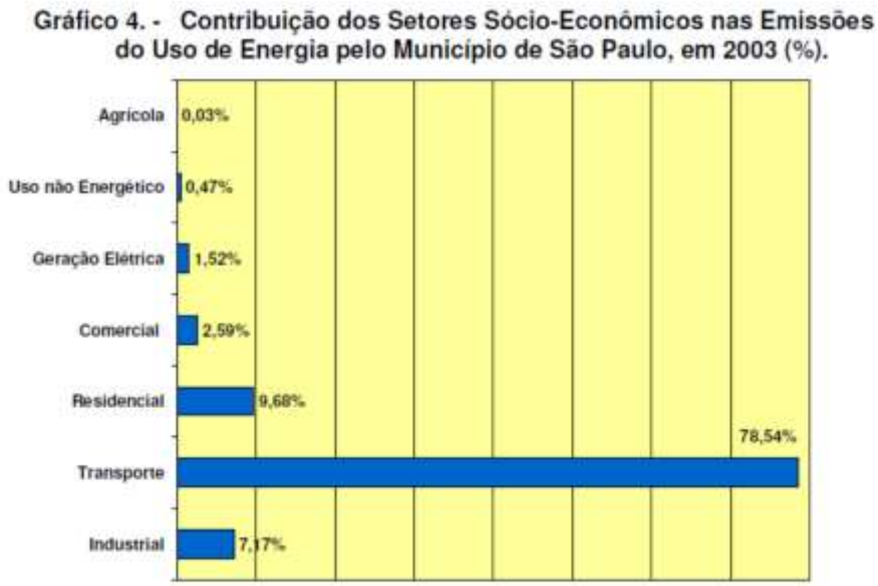
Source: McKinsey&Company (2009) – in Portuguese.

More than two-thirds of total Brazilian emissions in 2030 shall still come from the forest sector and the agricultural sector. Emissions form the forest sector are heavily related to the deforestation in the Amazon basin, driven by livestock production but also feedcrops. Emissions from the agriculture sector are basically generated by livestock production (50%) and agriculture practices (50%).

As the industrialization process continues, the share of the industry sector is going to increase. Projected Brazillian annual emissions per capita for 2030, excluding the forest sector, stand at 7tCO2, while the average at the time of the study for European countries was 10tCO2 and for the United States was 23tCO2 per capita per year.

Eventhough focusing on the GHG emissions from the transportation sector may not seem one of the top priorities in the Brazilian particular national context, the local situation of major cities is completely different. When one considers the local context of a densely populated urban area, the transportation sector kicks in as the major source of GHG emissions. The following graph shows the case of the city (municipality) of São Paulo, where a bit more than 11 million people live.

Figure 6: Profile of GHG Emissions – City of São Paulo



Source: COPPE (2005) – in Portuguese.

It´s important to note thar life-cycle GHG emissions will also depend heavily on the electricity generation mix. For countries where, for instance, most electricity comes from coal-fired power plants, the reduction in tailpipe emissions may be more than cancelled by the emissions resulting from the additional electricity generation needed (Faria, R. et al. 2013).

To sum up, to assess correctly the potential benefits from transport electrification, LCA studies for both energy consumption efficiency and GHG emissions must be carried out for each real-world context.

4. APPROACHES

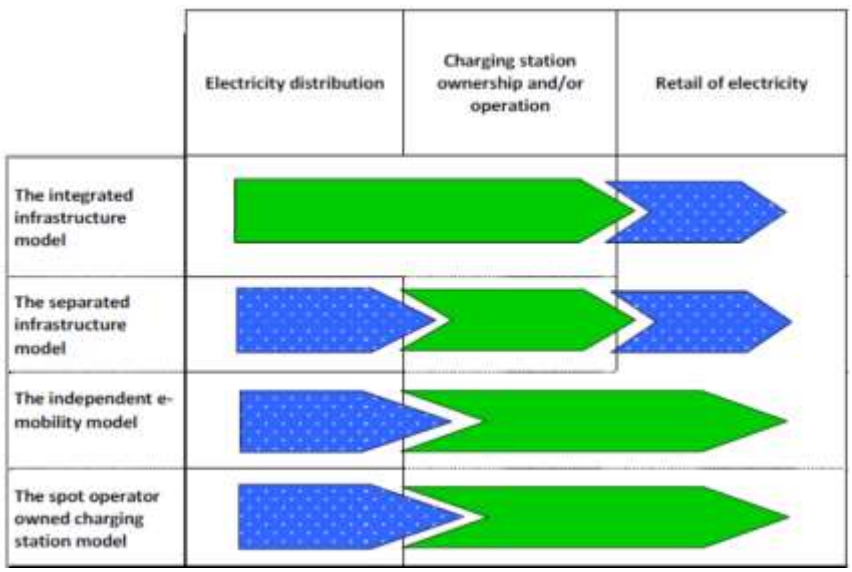
Two aspects are key to the success of any approach to transport electrification today: (i) the way to organize the market so that a public charging infrastructure may develop; and (ii) the range and extent of public incentives offered to EV owners and service providers (EVSP).

4.1 MARKET ORGANIZATION

EURELECTRIC, a pan-European industry organization that seeks, among other things, to promote the role of electricity in helping provide solutions to the challenges of sustainable development, identified four basic ways to organize the EV market concerning the retail of electricity for charging plug-in electric vehicles (EURELECTRIC 2010).

The intention of this section is not to fully describe each model, but rather to highlight key aspects of two models that are relevant to Canada´s and Brazil´s contexts. For the former purpose, the interested reader should refer to EURELECTRIC´s position papers (EURELECTRIC 2010, 2013).

Figure 7: EURELECTRIC Market Models



Source: EURELECTRIC (2010)

The proposed models refer to mass-market introduction of plug-in electric vehicles, meaning a market development stage where EVs are competitive with ICEV in certain segments and the number of electric vehicles already constitutes a significant demand for public charging. Public accessible areas can be either on public property (e.g. curbside) or on private property (e.g. shopping malls).

A basic assumption behind the identified market models is that investments have to be recuperated by some means. Free charging, in its strict sense, is not acceptable in the longer run, since there is no such thing as electricity at no cost. Moreover, free charging maybe have a detrimental effect on the use of EVs, as explained in (Nicolas, M. and Tal, G 2013).

Changes in color in the value chain mean the steps are unbundled and performed by different players. However, if the same color is used again later in the value chain, it doesn´t mean that the new step is performed by the same player for previous steps in the same color; it only means another separation occurred and a different player performs the roles from that point on.

It´s important to notice that there´s no one best model. In addition, different models may co-exist, as well as hybrid models may be conceived. Furthermore, as the electric mobility (e-mobility) market evolves, different models may be adopted. The next subsections present key aspects of the Integrated Infrastructure Model (Model 1) and the Spot Operator Owned Charging Station Model (Model 4).

Integrated Infrastructure Model (Model 1)

In the Integrated Infrastructure Model, the public charging infrastructure is fully integrated into the Distribution Service Operator´s (DSO´s) assets and thus, in the Regulatory Asset Base used to determine tariffs. Consequently, all electricity consumers pay for the EV public charging infrastructure; no ontly those who use it. As a result, there´s no need for changes in current tariff structures.

In principle, DSOs don´t participate directly in the EV retail market, since it´s assumed a competitive electricity retail market (open access infrastructure) open to all consumers. EV retailers can be existing electricity retailers or new players that only operate in the EV market. The contract relationship between EV retailers and EV users is equivalent to a normal electricity supply contract plus allowing mobility to the user.

EV users may have contracts with more than one EV retailer. Typically, users will receive a monthly bill from each retailer they have contracted from. Nevertheless, direct payment is also possible and the two approaches are not mutually exclusive.

Model 1 approach is particularly interesting in the case of on-street infrastructure for those without private domestic parking. It´s also a way to circumvent the “chicken-egg” problem during the early stages of market development (Caleno, F. and Coppola, G. 2013), when there is not enough demand for public charging in order to allow sustainable business models based on private investment.

Ireland and Italy, during the initial phase of market development, adopted the Integrated Infrastructure Model.

Spot Operator Owned Charging Station Model (Model 4).

The Spot Operator Owned Charging Station Model is a generalization of Model 3 that enables multiple low-scale market players. Any public parking spot owner or operator can perform the new role of *independent e-mobility provider* which provides the infrastructure and offers bundled services to EV users in a competitive e-mobility market, together with existing players like electricity retailers and DSOs (outside their regulated activities).

In Model 4 (as well as in models 2 and 3), only EV users pay for the public charging infrastructure.

The Spot Operator Owned Charging Station Model creates a new type of actor in the electricity sector consumers that may resell electricity to mobile customers. These lectricity consumers, under a normal power contract, may also charge their e-mobility customers for bundled products and use marketing metrics different from kWh.

Depending on national legislation, final consumers of electricity may or may not be allowed to resell electricity supplied at their installation to third parties. In Brazil, for instance, even transferring electricity at no cost to another final consumer may be viewed as a violation to present regulations.

This kind of market structure may allow the creation of “local monopolies”, similar to the current fuel distribution model, where EV customers cannot choose their spot operator freely. One network of EV public charging stations may or may not grant access to members of other networks, depending on B2B agreements. However, as market develops, roaming agreements shall proliferate to meet customers´ expectations.

Geographical development of charging infrastructure will be then driven by demand and private business decisions. Competition for high-potential spots and lack of interest for low-potential spots may require some sort of regulation and/or licensing mechanism.

Infrastructure operation and maintenance (O&M) companies may seize the opportunity to offer their services to multiple spot operators and benefit from larger scale.

Model 4 is expected to lead, as a rule, to a faster build-up of charging infrastructure. Because of that, has been the option of choice of most European countries. For example, Spain and France.

The aforementioned four market models were developed with the goal of large-scale deployment (mass market) of electric mobiity in mind.

During the introductory/market development phase, EVs can be charged at home or at private parking stations. BMW has a view that goes even further: that a public charging infrastructure is not necessary at all. This view may be behind BMW´s decision to start selling its electric models in Brazil, last September, before public charging stations are available (http://carros.uol.com.br/noticias/redacao/2014/09/10/eletrico-bmw-i3-chega-com-preco-de-9-populares-e-isencao-do-rodizio-em-sp.htm).

4.2 PUBLIC POLICY INCENTIVES

To discuss the role of public policy incentives, we´re going to take the case of BEVs because they represent a greater innovation than plug-in HEV and the characteristics of plug-in electric vehicles that most affect consumers´ choice and experience are exacerbated on BEVs.

The bigger the battery capacity in kilowatt-hour (kWh), the higher the cost. Reference cost estimates for Li-Ion batteries for BEVs range from $500 to $750 per kWh (MIT Technology Review 2011) (IEA 2013, 2015). That´s why BEVs, even being simpler and bearing less components than Plug-in HEVs, cost more. The additional cost for a larger battery more than offsets the savings from not having internal combustion components.The difference in the acquisition price when compared to conventional gasoline and diesel vehicles is even higher.

On the other hand, O&M costs, including fuel costs, are lower, and maintenance is required much less frequently. The average montly savings resulting from smaller O&M costs vary significantly with many variables, like the difference between the prices of gasoline and electricity and the number of driven kilometers. Estimates for the payback period of the higher initial investment for private, household use fall around 5 years.

As mentioned before, battery electric vehicles are not yet perfect substitutes to internal combustion engine vehicles. The lower suitability of BEV to consumers´driving needs result from shorter autonomy and limited public charging infrastructure.

Other characteristics of BEVs that affect consumers and are worth mentioning are the longer “fueling” time and uncertainties about the future of electric mobility. Sources of uncertainty are manifold: suppliers and repair parts; EVs resale values; availability and convenience of public charging infrastructure; battery life (that´s why some automakers have offerd the option to lease batteries) etc. Government incentives as well as public charging infrastructure are needed if for no other reason than to show long-term commitment to support e-mobility.

Public policy incentives fit in two categories: financial incentives and usage incentives. The most common (and effective) financial incentives are rebates for EV purchase and rebates for installation of chargers, both at home/private or at public accessible spots. Tax exemptions, reductions and/or credits at federal, state/provincial and municipal levels have also been extensively used in many countries, most commonly targeting Value-Added-Tax (VAT), annual tax on ownership/circulation and import tax. In Portugal is even possible to get a personal income tax reduction resulting from an EV purchase.

Usage incentives are usually structured as benefits for those driving a car with some sort of Green License plate. Examples include reserved parking spaces, access to express lanes, no road toll and even free public charging. Depending on excess capacity, several usage incentives have no direct economic cost.

As electric vehicles’ competitiveness improves and market matures, incentives need to be phased out. To do so in a way not to generate negative impacts on the market requires active monitoring and reliable data.

5. THE CASE OF CANADA

The electricity market structure in Canada is defined at the province level, not at the national level (CEA 2014). Similarly, each province has separately decided how to organize the EV market. Moreover, a few provinces are quite advanced in transport electrification while others are in the very early stages, if adopting any consistent approach to transport electrification at all.

The present work focus on the electric mobility approaches of Ontario, Québec and British Columbia, which have been the most active provinces in this field. One evidence of this fact is that the Canadian Electricity Association´s 2015 Leading Battery Electric Vehicle (BEV) Dealership Award and Leading Plug-in Hybrid Electric Vehicle (PHEV) Dealership Award are restricted to dealers in these three provinces.

The Canadian plug-in EV fleet, as of January 2015, was around 10,938 (Green Car Report´s estimate, available at www.tinyurl.com/CanadaEVSales), with Québec accounting for almost 50% of the national fleet (5,186 PEVs, Hydro-Quebec´s estimate).

In terms of electric mobility market organization, all three provinces chose the Spot Operator Owned Charging Station Model (Model 4). Remember that, Model 4 is expected to lead, as a rule, to a faster build-up of charging infrastructure. Nonetheless, the development of public charging infrastructure wasn´t totally relegated to be driven by demand and private business decisions. All three provincial governments also teamed up several stakeholders in programs to accelerate the deployment of public chargers.

The Québécois *Electric Circuit* (http://www.lecircuitelectrique.com/index.en.html), created on March 30, 2013, was the first public charging network in Canada. A initiative of Hydro-Québec (HQ), the vertically integrated distribution crown corporation company that servers nearly 100% of Québec´s electricity market and four founding partners: Agence Métropolitaine de Transport (AMT), the transportation agency for Montréal, RONA hardware stores, Metro grocery stores, and St-Hubert Rôtisseries, encompasses 368 charging stations in QC (8 DC fast-charging) and 96 private and institutional partners. HQ plans to have 50 fast-charging stations installed over the next two years.

Charges using AC Level 2 chargers cost $2.50 per event, no matter the duration. Fast-charging service costs more: $10 per hour and is billed by the minute. The bill is calculated based on the total time connected to the station, not only the duration of the charge or energy transfer. Typical times to reach 80% of battery capacity using DC fast charging are, in summer, 20-30 minutes and, in winter, 40-50 minutes.

The Electric Circuit adopted the SAE J1772 standard, to seek interoperability throughout North America. HQ´s managed network has 3,800 members, out of 5,186 plug-in electric vehicles registred in Québec.

The public charging network in British Columbia, *PluginBC* (http://pluginbc.ca/), resulted from broad collaboration between the Province of BC, BC Hydro, the Fraser Basin Council, several academic institutions, regional governments, and over 100 communities and businesses.

PluginBc encompasses 558 charging stations in BC (8 DC fast-charging). The plan is to add 5 more fast-charging stations by March 2015 and 17 more by March 2016.

The Province of BC's Clean Energy Vehicle (CEV) program, with contributions from the various charging station spot owners or operators, also supported the deployment of chargers at 306 home units through a LiveSmart residential rebate, and 142 multi-unit buildings around BC.

The majority of AC Level 2 (240V) public charging stations are free in BC (http://pluginbc.ca/charging-stations/public-charging/). The usage fee during pilot DC fast charging project is $0.35/kWh with a minimum $2.00 bill per charge session. The minimum payment is necessary to cover fixed cost. For instance, the $ 0.91 payment transaction fee.

Examples of private-owned networks operating in more than one province are the VERnetwork and the Sun Country Highway. The *VERnetwork* (http://www.reseauver.com/index.en.html) is owned and operated by AddÉnergie, which is the supplier of chargers for the Electric Circuit so far. It has 600+ charging stations in

Canada, including BC, ON and QC. Each spot owner determines the price on an hourly and/or session base. A usual fare is $1 per parking hour.

The *Sun Country Highway* network (http://www.suncountryhighway.ca/) has around 1,000 charging stations in Canada, mostly along Trans-Canada Highway. Roughly, 90% of them are free. It has an ambitious plan to double the network, adding more 1,000 stations by the end of 2015 (https://suncountryhighway.ca/news-media/2014/12/sun-country-highway-announces-massive-infrastructure-rollout/).

Canada´s EV market is also attracting investments from international networks. Tesla Motors, an independent manufacturer of highend BEVs, is developing worldwide its own network dedicated to Tesla cars owners. Tesla´s network only uses fast charges: 1,968 only in North America (few of them in Canada), spread over 366 Supercharger stations. A probable reason behind the superchargers is that Tesla cars carry high capacity batteries (>50kWh), twice the size of a Nissan Leaf battery, the BEV leader in sales worldwide.

Charge Point (http://www.chargepoint.com/), the world´s largest network (20,500+ locations) is also operating in Canada and has at least 20 charging stations in BC and another 20 in QC (figures drawn from visual inspections of charging stations´ locations maps available on the website). Charge Point has several automakers partners: BMW, Nissan, Chevrolet, Cadillac and Volkswagen.

In terms of public policy incentives, Bristih Columbia adopted the most comprehensive approach concerning public policy incentives, eventhough most them are no longer effective. The Clean Energy Vehicle (CEV) Program provided the following incentives:

1) Incentives for Installing Electric Vehicle Charging Stations in Multi-Unit Residential Buildings. Until Feb 8, 2013, with installation by Aug 15, 2013;
2) CEVforBC™ Point-of-Sale Incentives: up to $5,000 per eligible clean energy vehicle. From Dec 1, 2011 to Mar 31, 2014;
3) Residential Rebates for Purchase of Qualifying Electric Vehicle Charging Equipment: up to $500 per eligible electric vehicle charging station (EVCS). From Dec 1, 2011 to Mar 31, 2014;
4) Plug-in BC Community Charging Infrastructure (CCI) Deployment Fund: target of 570 Level 2 and 30 DC fast EVCS by Mar 31, 2013; and
5) Building Owners and Managers Association (BOMA) Clean Connect Program, in partnership with the Province of BC. Targeting multi-unit residential buildings, ended in Mar 31, 2014.

British Columbina also has the Scrap-It Program (https://scrapit.ca/), where the incentive values are based on the greenhouse gas reduction that occurs when an old vehicle is scrapped and an incentive is used as a replacement. Incentives are offered to support the purchase of a low emission vehicle (up to $ 3,000 for a BEV), transit passes, and credit with a car-sharing organisation or a new bicycle.

Ontario was the only province, amongst the three studied, to adopt some sort of usage incentive. The province of Ontario provides the following incentives.

1) EV incentive program: up to $8,500, for individuals, businesses, non-profit organizations, and municipalities (launched Jul 1, 2010);
2) EV charging incentive program: up to $1,000 per eligible EVCS; and
3) Green Licence Plates: until Jun 30, 2015, EVs with green plates are granted access to High Occupancy Vehicle (HOV) lanes, even if there is only one person in the car.

The value of the rebate for the purchase of a new electric vehicle is based on the vehicle's battery capacity. To receive a rebate, the vehicle must remain plated, registered and insured in Ontario in the name of the requester for at least 12 months. To be able to receive the rebate, one need to apply within six months from the date he/she bought or leased an EV.

As of October 3, 2014, Ontario had issued 2,932 Green licence plates, awarded 2,404 EV Rebates and 447 EV Charging Rebates.

The province of Québec has a more limited range of incentives but with significant extent and depth, both in terms of amounts and duration. Within the Drive Electric Program, which started in Jan 1, 2012 and will run until Dec 31, 2016, exist two types of rebates:

1) Purchase/lease rebate: up to $8,000, for individuals, businesses, non-profit organizations, and Québec municipalities.

2) Charging station rebate: up to $1,000 per eligible EVCS

Eligible vehicles, in addition to all-electrics (BEVs) and plug-in hybrids (PHEVs), include hybrids (up to $500) and low-speed electric vehicle (up to $1,000).

Building on international experience and results so far in Canada, we have identified a few issues to look into to continue the roll out of transport electrification:

- ✓ *How to implement a seamless public charging infrastructure across all Canadian regions and also the United States?*
- ✓ *Try to extract lessons from the bankruptcies of two US proprietary networks.*
- ✓ *Usage data is key to decide about public infrastructure growth and new investments*.
- ✓ *Be careful about the timing and pace to phase out public policy incentives.*

Customers want a seamless public charging infrastructure that enables troubleless journeys with their electric vehicles. There is still a long way to go before Canada reaches a seamless public charging infrastructure acros al Canadian regions, and also the United States. To achieve that, trade-offs between the different pricing models and the interests of multiple public and private distribution utilities will be necessary, as well as a wider range of payment methods, when compared to the somewhat limited options of the present moment.

As a rule, membership cards are required to grant access and unlock the charging station, even when the service is free. Payment options like using credit cards facilitates the access to non-members. But, when available, are cumbersome in most Canadian networks.

Analysts have argued making it difficult to non-members to access chargers may have been one of the reasons for the bankruptcies of two US proprietary networks: Better Place and Blink (Hausser, B. 2013).

Another lesson learned, not only in the US but also in Europe, is that proprietary networks may lead to *vendor lock-in*. Proprietary communication protocols make it impossible for charging stations to be controlled by new back-end software, and retrofitting is uneconomical in many cases.

In Canada, BC has embraced open communications standards, which improves interoperability. That means the back-end software network may be changed without the need to buy and install new charging stations. It´s a way to avoid vendor lock-in. An example of an open-standards protocol is the Open Charge Point Protocol (OCPP), now mandatory in several European countries (e.g. Netherlands and Ireland).

Independent growth planning (i.e. by each network owner) tend to be inefficient, sub-optimal in the Economics sense. The usage of public chargers must be monitored and assessed so that informed decisions about new investments and the public infrastructure growth can be made. In these terms, multiple proprietary networks represent an additional challenge.

BC has pioneered in this aspect, with the evCloud Project (https://www.fleetcarma.com/evCloud). The media has anticipated a few findings of the evCloud Project for Sep 2013 (Klippenstein, M. 2014). Charging events, for instance, varied from a number of stations with zero up to 175 (equivalent to an average of 6 times a day). The average considering all stations located in BC has been 16.3 times per month or once every two days.

As explained before, public policy incentives play a major role in reducing barriers to adoption and making electric vehicles competitive with conventional vehicles, at least in some segments. The negative impacts brought by the end of British Columbia Clean Energy Vehicle (CEV) Program in early 2014 raised concerns amongst EV advocates. The drop in the share of plug-in car sales was so significant that returning with incentives has been proposed during Budget 2015 consultations (Electric Mobility Canada 2014).

Figure 8: Evolution of the share of plug-in car sales in BC, ON and QC

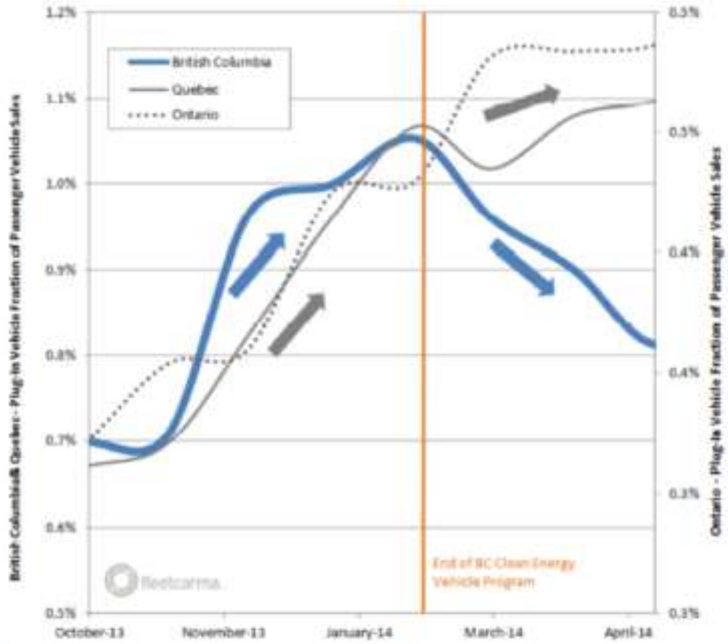


Figure 2 : Fraction of Passenger Vehicle Sales that re plug-in for the provinces of Quebec, Ontario and BC

Source : FleetCarma, September 2014, fraction of plug-in car sales, using three month trailing averages to eliminate seasonal sales variations.

Source: Electric Mobility Canada (2014)

The three provinces examined used the development of a public charging infrastructure as a “pulling mechanism” to increase public awareness and foster EV adoption. Buy a “pulling mechanism” it´s meant the infrastructure was put in place to estimulate the demand for EVs and show strong government commitment to electric mobility, rather than to simple respond to a growing market demand. This bet may have a cost not all countries can afford or want to pay.

6. THE CASE OF BRAZIL

In Brazil, the structure and the regulation of the electricity sector is a federal government responsibility defined in the Constitution. Accordingly to the institutional framework in place, the National Congress and the National Council for Policies on Energy (CNPE, from its name in Portuguese: Conselho Nacional de Política Energética) set the policies and directives for the electricity sector. ANEEL´s major responsibilities are the regulation and oversight of the electricity sector, in addition to implementing the applicable national policies and directives. Policy formulation is beyond ANEEL´s responsibilities. Yet, the Agency may contribute to a better informed and evidence based due process.

Figure 9: Brazilian Electricity Sector Institutional Framework

Source: ANEEL

If there is no public policy to support electric mobility in Brazil, why then is ANEEL studying electric mobility? A number of Country specific practical reasons and general reasons exist. The first country specific reason are two bills at the National Congress that, if approved, will require immediate action from ANEEL. Second, several local governments (states and municipalities) are very much interested in electric mobility and have given incentives to it within their scopes of competencies. Last, major Brazilian cities have demonstration projects underway. ANEEL must position itself whether the ideas and models being experimented are indeed positive and acceptable considering the electricity sector regulatory framework.

In addition to the Country specific pratical reasons, there are more general yet relevant reasons the electricity regulator should be ready to actively participate in any discussion about electric mobility. Many countries, including developing countries, are making massive investments to promote EVs and the necessary charging infrastructure. Electric vehicles are undeniable attractive for specific uses and customers´ profiles, in addition to being more environment friendly. Large-scale introduction of EVs requires public charging infrastructure which, in turn, needs to be regulated or, a least, a clear understanding that it doesn´t fit in the electricity sector and, thus, won´t be subject to its regulation. Last, there are concerns about the potential impact on the distribution grid that need to be taken in consideration and, when confirmed, mitigated.

It´s worth examining two of the bills related to electric vehicles at the National Congress in greater detail. Bill (*Projeto de Lei* in Portuguese) PL 4751/2012 proposes that distribution companies are obliged by law to install charging spots at all parking spaces reserved to EVs in public parking lots. It delegates to ANEEL the decisions about conditions of supply, tariffs and eventually necessary amendments to concession contracts. It also allows existing distribution companies to act as e-mobility retailers and proposes that e-mobility retailers may generate the electricity they need.

Once it explicity delegates to ANEEL decisions about tariffs and amendments to concession contracts, our understanding is that public charging is considered an electricity sector regulated activity and that the distribution company will own the charging equipment. It also suggests regulated prices for e-mobility customers, by using the term “tariff”, whilst the Regulator may decide not to establish tariffs at all. In general terms, it resembles Model 1 (Integrated Infrastructure), eventhough this model doesn´t allow the distribution company to directly participate in electric retail for charging electric vehicles.

In our opinion, PL-4751/2012 deals with only part of the issues related to public charging. For instance, it says nothing about charging spots in private ownership areas of public access. Moreover, a significant share of the public charging infrastructure will be driven by the availability of public parking spaces reserved to EVs. However, it´s not clear which areas will be considered “public parking lots”. Only paid, closed public parking lots will be considered, since there are many open spaces under the control of municipality-authorized caretakers in Brazilian big cities? The criteria adopted by different municipalities may differ. This fact may bring conflicts between federal and local legislation objectives.

Bill PL-3895/2012 follows a diferente path. It creates a new class of electricity retailers dedicated to electric mobility and establishes that authorizations shall be granted by ANEEL. Our understanding is that public charging, in this case, is considered a separated business from the electricity distribution business. In that sense, it would resemble Model 4 (Spot Operator Owned Charging Station). In line with PL-4751/2012 proposal, e-mobility retailers would be allowed to generate the electricity they need.

Futhermore, it also allows existing distribution companies to act as e-mobility retailers. But our understanding is that, in this case, it wouldn´t be part of the regulated distribution business. To participate in the e-mobility retailing activity, the distribution would have to establish a different legal entity to be granted the specific authorization, as it is the case in Brazil when the utilities want to sell electricity to consumers outside the regulated market (the so-called “free consumers”).

By not having any references to tariff set by ANEEL, it suggests, in our view, market prices for e-mobility customers. In terms of assets’ ownership, it is not clear whether charging assets owned by distribution companies will be or not part of the regulated asset base. And once no guidelines for granting authorizations are included (e.g. regional monopolies vs. open competition; bidding process for high-interest public locations), it looks like private business investment decisions would drive public charging network growth..

The aforementioned bills show there is no common understanding amongst Brazilian legislators about how to organize the electric mobility market, particularty the public charging infrastructure. Some stakeholder fear the lack of a “comprehensive” proposal may lead to incomplete and conflicting regulation, what may be worst than no regulation at all.

Last November, ANEEL invited the Brazilian distributors most active in the electric mobility for a one-day seminar. Many of these companies belong to international groups with headquarters in countries that are well more advanced in electric mobility than Brazil (Endesa/Enel – Spain/Italy, Iberdrola – Spain, AES – US and EDP – Portugal) and several demonstration projects aim to build on successful international experiences.

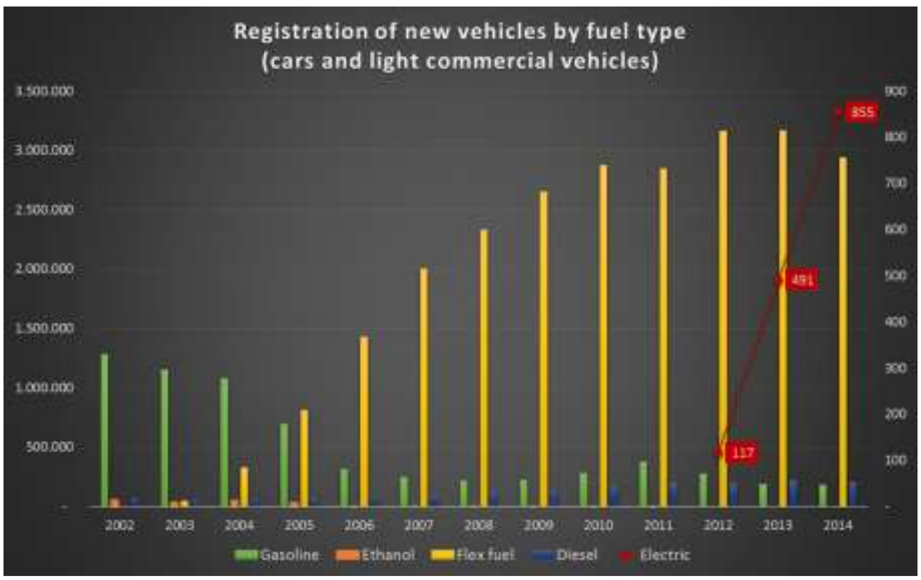
The initial findings, based on the participants’ feedback, can be summarized as follows:

- EV running costs are very competitive for the Brazilian reality as well. The high acquisition cost is what needs to be addressed by public policy;
- Distribution companies that participated in the seminar don´t see obstacles, either technical or financial, to cope with the additional demand from e-mobility during the early stages of market development
- In addition, none of them stated any special interest in owning the assets that will constitute the public charging infrastructure;

- Concerns about the potential negative impacts from regulating the e-mobility market too early popped up. The same kind of concern exists around the previously mentioned bills at National Congress and the different paths proposed by each of them;
- Some participants suggested that not to consider recharging services as electricity retail may be an effective alternative proposition to avoid excessive regulation and thus favor a faster build up of the necessary infrastructure;
- Yet, most participants also think public infrastructure is not mandatory in the early stages of market development.

There is no official public available data on the number of registred plug-in electric vehicles in Brazil, but the total amount of electric cars and light commercial vehicles reached 855 vehicles at the end of 2014, HEV being the most common type. Best estimates account for no more than a few hundreds plug-in EVs in the whole Country.

Figure 10: Registration of new vehicles by fuel type in Brazil



Flex fuel: Gasoline/Ethanol
Electric: includes external source, electric internal source, hybrid versions (liquid fuels + electric)

Source: Anfavea (2015). In Portuguese and English. Data compiled by the author.

7. CONCLUSIONS

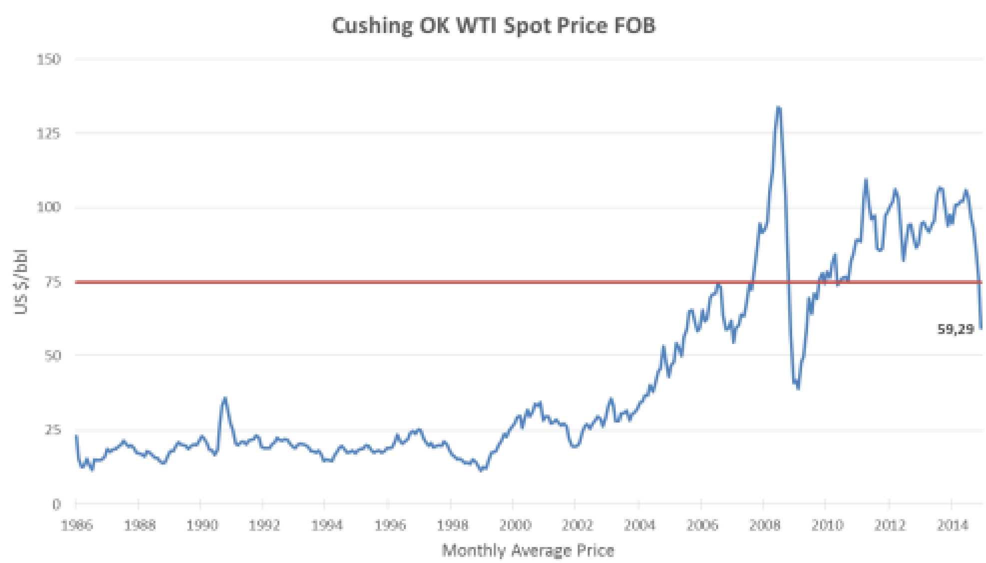
Decision makers must avoid overregulation as not to stall the necessary investments. Do not consider recharging services as electricity retail may be an effective alternative proposition to facilitate the build up and the development of the necessary public charging infrastructure. This has been the alternative of choice of Québec and several US states (ECOtality North America 2013b).

Nonetheless, interoperability is an issue regulators should not overlook. The bankruptcy of two US proprietary charging networks, Better Place and Blink, as well as experiences in European countries like the Netherlands and Ireland, have showed spot owners may end up with stranded assets resulting from the use of proprietary technology. The adoption of open-standard communication protocols improves interoperability and thus, reduces the risks for potential investors. With reduced risks, the number of those willing to embrace electric mobility tend to increase.

Coordination between multiple stakeholders, with sometimes-conflicting interests, has proven to be key to accelerate the adoption of electric mobility. This is particularly true for the fast-charging public infrastructure where the higher necessary investment combined with a short parking time make it hard for spot operators to build a sustainable business model. This is the case why Hydro-Québec, for instance, has followed a different approach for fast-charging stations within the Electric Circuit. Accordingly to the basic business model, partners pay for the costs of charging stations, installation and related services (telecommunications, management, warranties etc), while Hydro-Québec handles expertise for selecting technology, coordination of rollout CAA-provided 24/7 helpline, and visibility and advertising (Lampron, F. 2014). For the 50 DC fast chargers HQ plans to have installed over the next two years, it will pay up to 50% of the cost of buying and installing the DC fast charger, limited to a maximum equal to the price of the charging station.

Macroecomic conjunctural issues may also pose threats to further development of electric mobility. Historical low international oil prices in early 2015 triggered debates about the future of EVs. Once the average montly savings resulting from EV´s smaller fuelling costs is directly related to the difference between the prices of gasoline and electricity: the smaller the difference, the less likely consumers will choose to buy an electric vehicle.

Figure 11: International Crude Oil Prices



Source: Prepared by the author using US Energy Information Association (EIA) data.

Criticism from specific groups of tax payers and stakeholders is “part of the game”, and something that must be dealt with whilst public resources are involved and considering the Freedom of Information Act, in Canada, and the Access to Information Law (*Lei de Acesso à Informação*), in Brazil.

Battery technology is expected to continue to improve in the light of the massive investments in research. At some point in time, capacity may reach such levels public charging will become a less important issue, maybe only relevant to intercity driving. But this can take several years to happen. Meanwhile, public charging infrastructure remains a relevant issue to any large-scale transport electrification strategy.

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