THE INCORPORATION OF ELECTRIC CARS IN LATIN AMERICA

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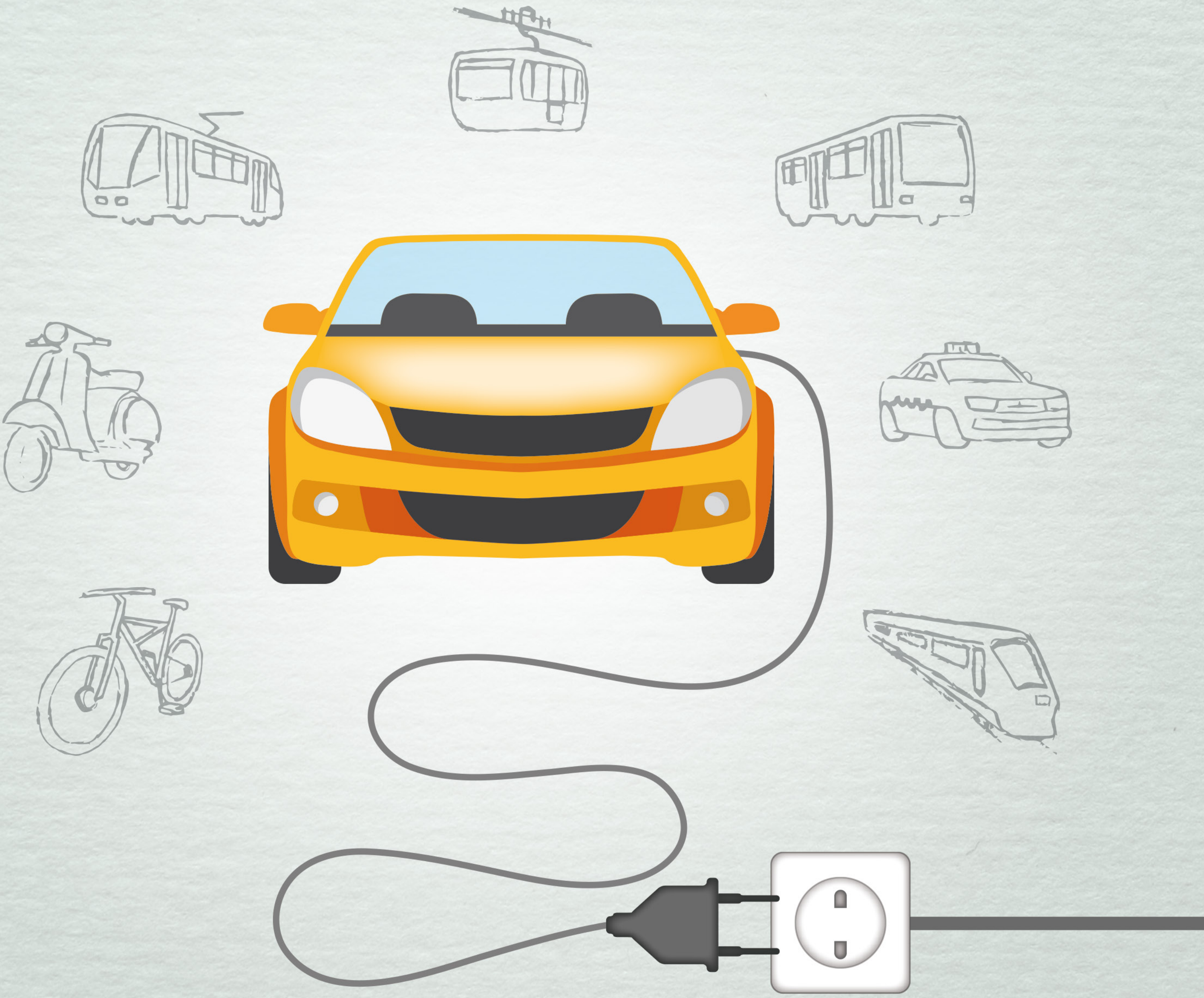

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1. INTRODUCTION

Electric vehicles (EVs) are widely regarded as a promising technology to reduce energy consumption, greenhouse gas (GHG) emissions and local air pollution from the transportation sector. Within the current sustainable mobility paradigm, EVs are among the actions that increase the technological efficiency of transportation systems (Banister, 2007). They complement other types of actions within this paradigm, which attempt to reduce the need to travel (less trips and shorter distances) or to cause a modal shift from private passenger vehicles to public transportation and active modes (cycling and walking).

The worldwide sales of electric passenger cars have increased exponentially in the last four years (Figure 1). From less than 20.000 units at the beginning of the current decade, the global stock has grown to about 700.000 by the end of 2014 (Frost & Sullivan, 2015)[1]. Approximately half of this stock belongs to the USA, one quarter to Europe and one quarter to Japan, China and the rest of the world. Latin America (LA) has contributed only marginally to this stock.

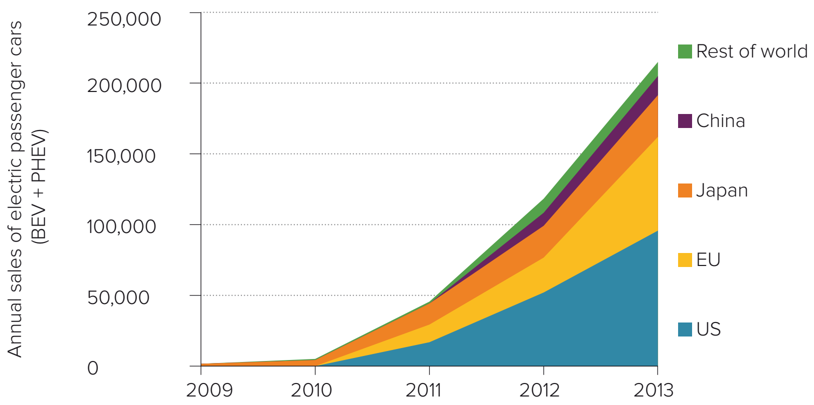


Figure 1.
Global sales of electric passenger cars, 2009-2013.
Source: Mock and Yang, 2014.

Even though annual sales worldwide have reached record numbers since the appearance of EVs more than a century ago, the current stock and market penetration still represent less than 1% of the total car market. It is then not clear yet whether the current wave of EVs constitutes the beginning of an inexorable transition from fuels to electricity as the source of energy for transportation. This is strengthened by the fact that the current wave of EVs has been driven largely by government support through strict fuel consumption and emissions regulations, research and development

1 These numbers include only Plug-in Electric Cars (pure Battery Electric Cars and Plug-in Hybrid Electric Cars). Hybrid Electric Cars are not included. The sales of Hybrid Electric Cars rose considerably earlier on, at the beginning of the current century. The current global stock of Hybrid Electric Cars is approximately 10 millions. These different types of EVs are described in section 2.2.

(R&D) financing, demand subsidies and other types of benefits for EV owners. Developed countries stimulate EV sales as an action that will help them achieve higher energy independence, decarbonize transportation and accomplish climate change goals. Although these are important objectives for developed countries, it is unlikely that major fiscal efforts to promote EVs can be maintained for a long period of time. If public incentives phase out in the future, EVs would have to prove superior to conventional internal combustion engine vehicles (ICEVs), overcoming long-standing barriers such as cost and driving range.

In this uncertain context, the outlook of the incorporation of EVs in LA is even fuzzier. LA and most developing countries have not implemented the public policies that many developed countries have employed to spur EV sales and, consequently, market penetration remains marginal. Additionally, it is not clear whether LA countries should emulate such policies and strongly support EV sales. First of all, it is not clear whether the benefits of EVs (which include effects difficult to monetize such as health impacts, GHG emissions and energy independence) would offset their incremental costs, related mainly to their higher manufacturing costs compared to ICEVs. Moreover, the promotion of EVs is probably not the most cost-effective approach for LA countries to achieve urban transportation sustainability. It has been argued that the most important challenge for LA cities in this respect is to increase the quality of public transportation and active modes in order to maintain or increase their current mode shares, defying the tendency of increasing car ownership and use levels dictated by raising income levels. Although EVs are clearly a complement to actions that attempt to prevent the modal shift towards cars, public resources are scarce and must be prioritized towards the most cost-effective initiatives. Finally, the promotion of EVs may even accelerate the motorization process in LA cities. This would exacerbate congestion problems, a phenomenon usually termed "clean congestion". For instance, a study in Norway (the leading country in terms of EV market penetration and promotion) showed that EV owners increased car use after buying the EV, moving away from public transportation (Rødseth, 2009; cited by Hjorthol, 2013).

The previous considerations do not imply that LA countries should not act with respect to the potential deployment of EVs in the region. There are several public policies that LA countries can implement to facilitate the introduction of EVs without accelerating the pace of motorization or spending significant public or private resources. These policies can prepare LA to take advantage of the benefits offered by EVs in the most favorable way, especially as the manufacturing cost of EVs decreases in the following decades.

In order to help clarify the outlook of the incorporation of EVs in LA, this article analyzes different characteristics of LA countries with respect to this potential incorporation and evaluates the available set of policies in this respect. Even though the electric technology may be applied to all types of vehicles, such as trucks, buses and motorcycles, this article focuses on passenger cars, which represent the majority of vehicles in most countries[2]. The introduction of EVs in the car market faces challenges that differ considerably from those found in other vehicle markets. However, many of the analyses presented here can be extended to other vehicle markets.

2 The term "electric vehicles" (EVs) is used throughout the article to refer to electric passenger cars, unless noted differently.

The remaining of this article is organized in four sections. Section 2 summarizes the current state of the electric technology and its perspectives in the following decades. Section 3 analyzes the main market challenges for the introduction of EVs in LA. This section includes a total cost of ownership analysis, which compares the cost for private consumers of different vehicle technologies from a life-cycle perspective. Section 4 presents the results of a preliminary cost-benefit analysis of the introduction of EVs in several LA countries. Section 5 evaluates the policies available for LA countries to facilitate the future deployment of EVs. The last section summarizes the main recommendations for LA countries.

2. THE TECHNOLOGY AND ITS PERSPECTIVES

2.1 BRIEF HISTORY

The history of EVs dates back to the 19th century. The chemical storage of electric energy and the principles of electromagnetism, developed early in the century by Alessandro Volta and Michael Faraday, laid the main scientific foundations required for their conception. However, it was not until the end of the century, after several other innovations in electrochemistry and mechanics, that the first practical EVs were built. At about the same time, Karl Benz demonstrated the first conventional ICEVs. The first EVs were part of taxi fleets in major cities such as London, New York and Paris. Taxi fleets were clear candidates to start the application of EVs because taxi companies maintained the batteries in their common garages and the daily distances travelled by taxis were well within the battery range (Høyer, 2008).

EVs rapidly became a major player in the car market. They outsold steam-powered and gasoline ICEVs in USA in 1900, and their sells peaked in 1912 with approximately 30,000 units sold (Høyer, 2008). However, ICEVs had begun to achieve market dominance by this time, mainly with the Ford-T model. In spite of the expansion of electricity to houses, the establishment of public charging stations by electricity supply companies and innovations such as fast battery swapping systems, regenerative braking and hybrid vehicles, EVs lost ground to ICEVs because of concerns over cost, range, speed and time-consuming recharging. EVs had almost disappeared by the late 1920s.

With the exception of some governmental and commercial fleets, the interest in EVs did not return until the 1970s, due to concerns about air pollution and the oil crisis, and again in the 1990s, due additionally to concerns about climate change and sustainability.

Taking advantage of government support in the form of demand subsidies, R&D financing and fuel consumption and emissions regulations, Hybrid Electric Vehicles (vehicles that combine an electric motor and a combustion engine, see section 2.2 for a detailed description), started to enjoy commercial success by the turn of the century. Sales were initially concentrated in USA and Japan with models such as the Toyota Prius and the Honda Insight. Similarly, the first successful Plug-in Electric Vehicles (vehicles that can be plugged-in in order to take energy from the grid, see section 2.2 for a detailed description) appeared at the beginning of the current decade, with models such as the Mitsubishi i-MiEV and the Nissan Leaf. By the end of 2014, global cumulative sales of EVs had exceeded 9 million hybrids and 700.000 plug-ins, and over 20 EV models are offered in the market (Frost & Sullivan, 2015). LA has participated marginally in the EV market and most EV models are still not available for sale in the region. Public support to EVs in LA has been limited mainly to taxi fleet initiatives, but several legislative initiatives are currently being promoted to favor EVs over conventional ICEVs.

The current small-scale success of EVs, however, does not guarantee a long-term success. In the long term, public sector support in the form of demand subsidies and other benefits that imply high public expending is likely to phase out. Only public policies that favor EVs without significant public investment, such as pricing the environmental externalities of passenger cars, are likely to remain for longer periods of time. If the benefits to EVs phase out in the future, they would have to prove superior to ICEVs, overcoming long-standing barriers such as cost and range.

2.2 TYPES OF EVS

Four basic designs for electric driving can be distinguished: Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), pure Battery Electric Vehicles (BEVs) and Hydrogen Fuel Cell Electric Vehicles (FCEVs). Since only PHEVs and BEVs need to be plugged-in in order to charge, they are usually termed together as Plug-in Electric Vehicles (PEVs).

HEVs combine an electric system, battery and electric motor, with an internal combustion engine. This combination may prioritize the use of the electric system or the combustion engine, creating different levels of hybridization. In any case, the kinetic energy of the vehicle is converted into electricity in order to charge the battery, a process known as regenerative breaking or self-recharging. In other words, HEVs do not have to be plugged-in, they recharge automatically during the driving cycle. Driving range is not a concern for HEVs, because it is generally the same or even higher than that of an ICEV. Fuel efficiency and tailpipe emissions reduction gains from an HEV in comparison to an ICEV vary normally from 10% to 30%, depending on the level of hybridization and the battery's energy capacity, which is generally between 1 and 2 kWh. Since HEVs do not take energy from the electric system (i.e. they do not have to be plugged-in), they are sometimes excluded from the general category of EVs, being treated instead as a technology that helps ICEVs achieve lower fuel consumption.

PHEVs are a type of hybrid in which the battery can be charged from an ordinary household electric outlet or charging station. PHEVs can run only on electricity for several miles. Once the electric range is exhausted, the combustion engine operates in a hybrid mode, offering a more ample range. The electric range commonly varies between 15 and 70 km, depending on the energy capacity of the battery, which varies from 4 to 20 kWh (National Research Council, 2013). Fuel efficiency and tailpipe emissions reduction gains in PHEVs depend largely on the driving cycle. PHEVs may be charged frequently and the electric range may be sufficient for daily urban driving. In this case, tailpipe emissions and fuel consumption approach zero. On the other extreme, if there are no charging points available, PHEVs may run mainly on fuel, resembling the environmental performance of HEVs. Due to their flexible source of energy, PHEVs are considered a practical technology for the transition between ICEVs and BEVs.

BEVs do not have a combustion engine. Their propulsion is purely electric. Their driving range varies amply between 80 and 250 km, depending again on the energy capacity of the battery, which generally varies between 20 and 55 kWh. As an example, the Nissan Leaf, the most sold BEV worldwide with over 120.000 units to date, has a battery capacity of 24 kWh and a driving range of 135 km[3]. BEVs are currently the main contending technology to achieve zero tailpipe emissions from passenger vehicles.

Hydrogen FCEVs offer also zero tailpipe emissions. They are similar to a BEV, but create electricity using a fuel cell system with on-board hydrogen storage. Several major car manufacturers have announced plans to introduce FCEVs commercially in 2015. The main market challenges for FCEVs will be the manufacturing cost, which is driven by the cost of the fuel cell stack, the availability of hydrogen fueling infra-

3 www.fueleconomy.gov The official U.S. government source for fuel economy information.

structure and the clean and low-cost production and distribution of hydrogen. In comparison to BEVs, FCEVs have two major advantages: their driving range and refueling time are expected to be similar to that of an ICEV (450 km and less than 5 minutes; National Research Council, 2013).

This article focuses mainly on PEVs (PHEVs and BEVs) as a technology that has already achieved significant sales numbers worldwide and whose deployment faces important barriers because of their use of the electric system. Nevertheless, it is important to have in mind that there are other electric technologies that may become the most viable option in the future, depending on research progress. In general, policy design to promote EVs or other alternative vehicles and fuels should not attempt to pick a winning technology, but to facilitate the emergence of new technologies (Ahman, 2006).

2.3 BATTERIES AND CHARGING METHODS

The battery is the most important factor influencing the performance and cost of PEVs. In BEVs, the battery constitutes approximately one third of the sale price. There are several types of batteries available for use in passenger cars. However, over 90% of car manufacturers currently use lithium-ion batteries because of their superior performance in energy density, lifespan, charging cycles and reliability. Lithium-ion batteries are also expected to be the main type of batteries in the foreseeable future (National Research Council, 2013). The current cost of lithium-ion batteries for BEVs is approximately USD 400 per kWh and cost projections point to USD 200 to 250 by 2030 and USD 150 to 160 by 2050. The battery cost for PHEVs is likely to be USD 60 to 70 per kWh higher than for BEVs (National Research Council, 2013). The expected reduction in the manufacturing cost of batteries would significantly lower the sale price of PEVs.

There are three basic charging methods for PEVs, which according to the terminology used in USA are known as Level 1, Level 2 and Direct Current (DC) charging[4]. Level 1 charging refers to plugging the car directly to an ordinary 120-volt household or workplace electric outlet. PEVs commonly come with the charging cord set that is required for this type of charging. It costs between USD 800 and 1.000 and does not require any installation procedures, as long as the outlet is close enough to the parking place. Level 1 charging is the slowest way of charging a PEV. It adds approximately 4 to 8 km of range per hour of charging. This means that charging a BEV with a driving range of 135 km, such as the Nissan Leaf, from empty to full takes at least 17 hours. This long time makes Level 1 charging suitable only for residential or workplace charging, where cars generally spend several hours parked.

Level 2 charging uses 240-volt outlets, which may also be found at households and workplaces. It requires a charging station (box and cord), which must be installed by a certified electrician. The cost of a Level 2 charging station varies between USD 1.500 and 2.000. The installation cost varies between USD 300 and 4.000, depending on the location of the outlet and possible obstacles (Axsen and Kurani, 2012). Level 2 charging allows for a wide range of charging speeds, up to 100 km of range per hour of charging. However,

4 The terminology used in Europe refers to Mode 1, Mode 2, Mode 3 and DC charging. Modes 1 and 2 are equivalent to Level 1 and Mode 3 to Level 2.

the current power rating limitations of PEVs and charging stations allow for a charging speed of approximately 20 km of range per hour. This implies that charging a BEV with a driving range of 135 km from empty to full takes about 7 hours. Level 2 charging is suitable for households, workplaces and public charging stations.

DC charging is also referred to as rapid charging because it is the fastest way to charge a PEV. A DC charging station operates at 480 volt and can provide a charging speed of more than 50 km of range per 10 minutes of charging. This implies that a 135 km-range BEV would take less than 30 minutes to charge from empty to full. The cost of a DC charging station varies between USD 50.000 and 80.000 and they are used exclusively in public locations.

Two alternative charging methods for PEVs are worth mentioning. The first is inductive charging (IC), which uses magnetic forces to transfer electrical power to the battery without the need of cables or connections. This method is not common nowadays as current commercial PEVs do not include a built-in IC technology, but may become a viable option within the next decade. The second method is battery swapping, where the discharged battery is replaced with a fully charged one in less than five minutes, saving the delay of waiting for the battery to charge. Battery swapping generally implies that the vehicle owner does not own the battery, which reduces significantly the sale price of a PEV. Even though the bankruptcy of Better Place, a company that developed the battery swapping and charging business in Israel, questioned this business model because of the high infrastructure investment required, this charging method may be a viable option once PEVs achieve a higher market penetration, assuming vehicles and battery packs are standardized.

3. MARKET CHALLENGES IN THE LA CONTEXT

This section describes the main market challenges for the introduction of EVs in the LA context. Section 5 outlines the policies available to overcome these challenges. The two sections are then closely linked and follow a similar organization.

Throughout these sections, we present examples of challenges and policies in specific LA countries, with a focus on six countries: Argentina, Brazil, Chile, Colombia, Mexico and Peru. These six countries are expected to have the largest PEV markets in the region within the next decade. Frost & Sullivan (2015) estimate the market size of these six countries to 2023. According to their estimation, annual sales of PEVs in these six countries could range between 52,000 and 220.000 units in 2023, depending on regulatory changes, consumer acceptance and technology development[5]. This represents a market penetration between 0.3% and 2,5%. In general, the study regards Chile and Mexico as the countries with the most promising outlook, followed by Brazil, while Colombia, Argentina and Peru have only a moderate prospect[6].

3.1 COSTS

Cost has always been a major concern for the deployment of EVs worldwide. The manufacturing cost of the electric motor and the battery in an EV is significantly higher than that of a conventional ICEV. Consequently, the sales price must also be higher. Table 1 compares the manufacturer's suggested retail price (MSRP, taxes not included) in USA of some EV models and equivalent ICEV models. The table shows price premiums that range between 10% and 30% for HEVs, 50% to 80% for PHEVs and 80% to 150% for BEVs. If the user decides to buy a Level 2 charging station with the EV, then the price premium would further increase.

The manufacturing costs of EVs are expected to decrease in the following years, mainly as a result of technological innovations in battery production. However, the ever-increasing demand of lithium for electronic products threatens to increase the price of lithium-ion batteries, the main type of batteries for EVs. LA has an important involvement in this respect, having more than half of the world's lithium deposits in the South American lithium triangle: Argentina, Bolivia and Chile (Frost & Sullivan, 2015). This implies important opportunities for these countries in terms of promoting local value-added battery production industries.

On top of the difference caused by higher manufacturing costs, national and local taxes tend to enlarge the price gap between EVs and ICEVs, unless the tax structure favors EVs. Most countries in LA have important tax structures that would increase the price difference. Table 2 shows the taxes that would be applied to EVs for commercialization in six of the largest car markets in LA, in comparison to the taxes applied to ICEVs. Value-

5 Specific numbers for each country in an optimistic scenario are: Brazil, 116.000; Mexico, 58.000; Chile, 32.000; Argentina, 7.500; Colombia, 6.500; and Peru, 2.000.

6 The relative outlooks refer to expected market penetration. Market size is led by Brazil due to its higher population and total car market (see previous footnote).

added and import taxes are the main components of these tax structures. In Argentina and Brazil, EVs would be subject to a higher tax structure assuming that EVs are not produced in Brazil (hence subject to import duties). In Mexico and Colombia, the tax structure would favor EVs because of exemption from consumption and new-vehicle taxes respectively. In Chile and Peru, the tax structures are the same, hence increasing the price gap in absolute terms between EVs and ICEVs.

Besides taxes that increase the sales price difference between EVs and ICEVs, yearly ownership taxes generally tend to disfavor EVs as well, since this type of tax commonly depends on the price of the vehicle.

TYPE OF EV	ELECTRIC VEHICLE			INTERNAL COMBUSTION ENGINE VEHICLE			PRICE PREMIUM
	MANUFACTURER	MODEL	MSRP (USD)	MANUFACTURER	MODEL	MSRP (USD)	
HEV	Toyota	Avalon Hybrid	$36.470	Toyota	Avalon	$32.285	12,9%
	BMW	Active Hybrid 5	$61.650	BMW	528i	$49.750	23,9%
	Honda	Accord Hybrid	$29.155	Honda	Accord	$21.955	32,8%
PHEV	Chevrolet	Volt	$34.170	Chevrolet	Malibu	$22.340	52,9%
	Honda	Accord Plug-in Hybrid	$39.780	Honda	Accord	$21.955	81,2%
BEV	Mitsubishi	i-MiEV	$22.995	Mitsubishi	Mirage	$12.995	76,9%
	Chevrolet	Spark EV	$26.670	Chevrolet	Spark	$12.270	117,3%
	Nissan	Leaf	$29.010	Nissan	Versa	$11.990	141,9%

Table 1.
MSRP comparison of EVs and ICEVs.
Source: www.fueleconomy.gov

On the contrary, the operational cost of EVs tends to be lower than that of ICEVs for two main reasons. First, the maintenance cost of an electric powertrain is generally lower than that of a combustion engine[7]. Second, and more importantly, the cost of fuel consumption is usually higher

7 In the case of HEVs and PHEVs, the total maintenance cost may be higher because they have both an electric motor and a combustion engine.

than the cost of electricity consumption. This difference depends on the local prices of fuel and electricity. The big majority of ICEVs use gasoline and it is expected that EVs will take most of the electricity from household outlets. In this sense, Figure 2 compares the prices of residential electricity and gasoline in several LA countries. Comparing the price of energy (fuel or electricity) consumption per kilometer (part c of Figure 2), it is clear that BEVs achieve important savings in comparison to ICEVs, except in Venezuela, where the price of electricity is higher[8,9]. The reduction in energy prices ranges from more than 90% in countries such as Paraguay and Argentina (reaching 98% in Argentina) to about 70% in countries such as Brazil, Colombia and Ecuador. This reduction may imply significant savings for car owners, depending on the level of use of the car (i.e. number of kilometers per year).

The lower operational costs of EVs may then compensate their higher sale prices. Unfortunately for EVs, international evidence has shown that consumers value up-front costs much more than running costs, which they discount heavily (Element Energy, Ecolane and University of Aberdeen, 2013). Even if EVs make sense in comparison to ICEVs from a financial life-cycle analysis, consumers may still prefer the conventional vehicle. Alternative financing options such as vehicle or battery leasing may help overcome this barrier by converting up-front costs into yearly costs.

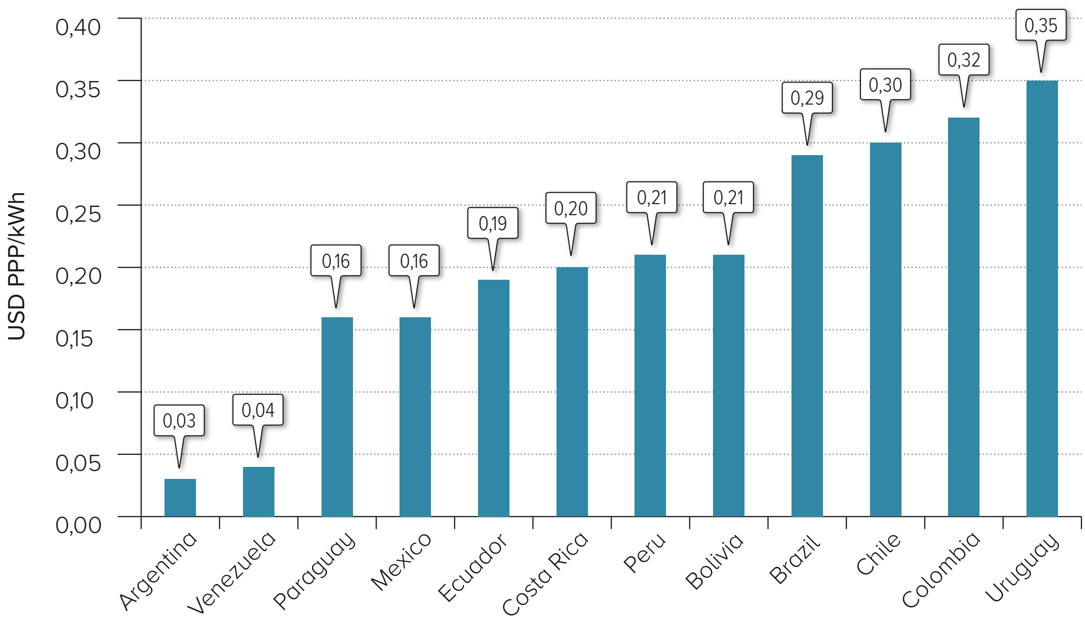


Figure 2a.
Price of residential electricity.
Source: Regional Energy Information System – Latin American Energy Organization, 2011.
Purchasing Power Parity rates from the World Bank.

8 In order to compare energy costs per kilometer, the ICEV was assumed to have fuel consumption of 0,0784 lt/km (30 mpg, approximate fuel consumption of a Nissan Versa) and the BEV electricity consumption of 0,133 kWh/km (approximate electricity consumption of aNissan Leaf).

9 Even though the price of energy in Venezuela is about twice for a BEV in comparison to an ICEV, both prices are relatively low in comparison to other countries (see Figure 2.c). Clearly, this is heavily influenced by government subsidies for electricity and fuel.

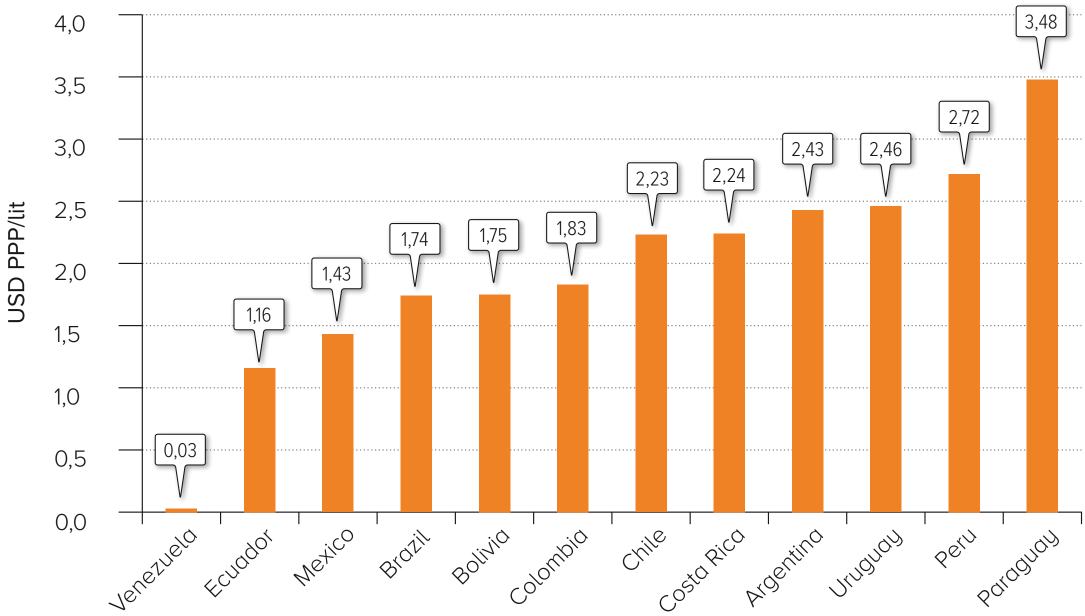


Figure 2b.
Price of gasoline.
Source: German Agency for International Cooperation – GIZ, 2012.
Purchasing Power Parity rates from the World Bank.

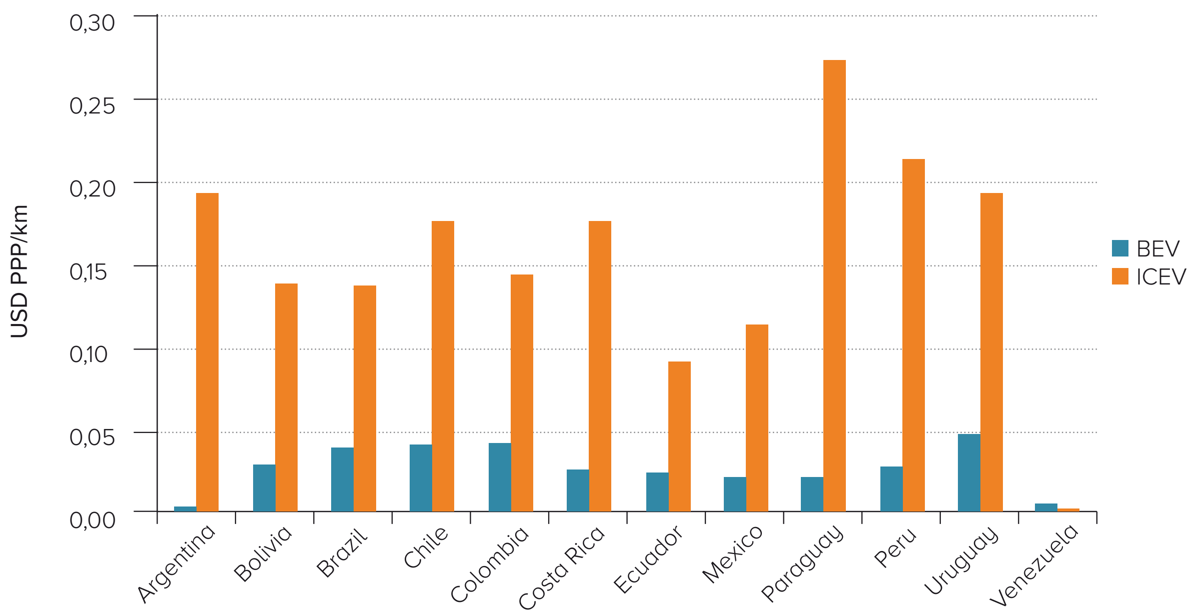


Figure 2c.
Energy price per kilometer.
Source: Prepared by authors based on data from figures 2a and 2b.
Purchasing Power Parity rates from the World Bank.

	ARGENTINA		BRAZIL		CHILE		COLOMBIA		MEXICO		PERU	
TAX	ICEV	EV	ICEV	EV	ICEV	EV	ICEV	EV	ICEV	EV	ICEV	EV
IMPORT DUTY	0,5%[2]	35,5%[3]	0%	35%[5]	6%	6%	35%	35%[8]	0%	0%	9%	9%
VALUE-ADDED	41%	41%	43%[6]	43%[6]	19%	19%	16%	16%	16%	16%	17%	17%
OTHER	8,5%	58,5%[4]	11,6%[7]	11,6%[7]	0%	0%	8%[9]	0%	4%[10]	0%	37%[11]	37%[11]
TOTAL (SUM)[1]	50%	135%	54,6%	89,6%	25%	25%	59%	51%	20%	16%	63%	63%

Table 2.
Tax structure for EVs in six Latin American countries.
Source: Frost & Sullivan, 2015.

1 This is an arithmetic sum of the different taxes. However, some taxes compound on others, so the total price increase may be higher than this arithmetic sum. The arithmetic sum is included in this table just as a reference to compare the relative weight of tax structures in different countries.

2 0,5% statistics tax. Assumes the car is manufactured in Brazil, hence no import duty.

3 Includes a 0,5% statistics tax that is waived for hybrid cars. Assumes full import duty (no production of EVs in Brazil). A quota of 200 hybrid, electric or other alternative energy vehicles was allowed to be imported with a 2% duty.

4 Includes a 50% tax for sumptuous articles (charged to passenger motor vehicles with an import value above USD 20.000 approximately), a 6% income tax and a 2,5% gross revenue tax.

5 Assumes the EV is not manufactured in Brazil.

6 Includes a 25% federal value-added tax (IPI) and a 18% state value-added tax (ICMS). IPI taxes may increase 30% if a car manufacturer fails to achieve the requirements set by the Inovar-Auto incentive program (see section 5.4).

7 Includes PIS and COFINS social contributions at 2% and 9,6% respectively.

8 A quota of 750 hybrid and electric passenger vehicles may be imported with 0% duty until 2015.

9 ICEVs are subject to a 8% or 16% consumption tax according to the price of the vehicle.

10 ICEVs are subject to a new vehicle tax (ISAN), which ranges from 2% to 17% depending on the price of the vehicle.

11 Includes a 30% selective consumption tax (ISC), a 5% general sales perception tax and a 2% municipal promotion tax.

3.2 TOTAL COST OF OWNERSHIP

In order to quantify the cost difference among an ICEV, a HEV and a BEV from a life-cycle perspective, Figure 3 shows the results of a total cost of ownership (TCO) analysis in six LA countries[10]. This analysis includes purchase, ownership and running costs over a period of 8 years.

The cars evaluated in the analysis are a Honda Civic (ICEV), a Toyota Prius (HEV) and a Nissan Leaf (BEV). The Honda Civic and Toyota Prius are among the most common of their type in LA, while the Nissan Leaf is currently the most sold BEV worldwide, but available for sale only in Mexico at the time the analysis was carried out. The retail prices (without taxes) of these models in each country were obtained, when possible, from local websites. Since the Nissan Leaf was available for sale only in Mexico, its retail price in other countries was estimated using the price ratio found in Mexico between the Toyota Prius and the Nissan Leaf. The Toyota Prius was available for sale in all countries, except in Colombia. The retail price of the Toyota Prius in Colombia was estimated using the price ratio found in Peru between the Honda Civic and the Toyota Prius[11].

Given these assumptions and the fact that the market for HEVs and BEVs is in a very nascent stage in LA countries, this TCO analysis must be understood as a preliminary analysis, especially for the Nissan Leaf. Annex 1 presents the main inputs and other assumptions used in the analysis.

The results show that the reduction in running costs (energy, maintenance and replacements) achieved by the HEV and the BEV does not offset their higher purchase cost in comparison to the ICEV. The TCO of the HEV and the BEV are higher in all countries than that of the ICEV. The difference is greater for the BEV than for the HEV. The difference for the HEV ranges from 6,5% in Mexico to 26,4% in Peru (roughly USD 2.300 and USD 12.000 respectively), with the exception of Argentina, where the difference is remarkably high (172% or USD 88.000)[12]. The difference for the BEV ranges from 55% in Mexico to 87% in Peru (roughly USD 19.000 and USD 35.000 respectively), again with the exception of Argentina, where the difference is 320% (USD 163.000).

These differences indicate that HEVs would require a much lower incentive than BEVs to be competitive in terms of costs with ICEVs. HEVs may even achieve meaningful market penetrations without specific incentives, especially among consumers with characteristics that further benefit EVs, such as high level of car use or consciousness about their carbon footprint, and in countries where the TCO difference is small, such as Mexico and Chile. On the contrary, the penetration of BEVs is not likely to go beyond a few technology enthusiasts unless substantial incentives are in place. According to the previous results, such incentives should amount, for instance, USD 19.000 in Mexico and

10 The TCO analysis is based on the work of Frost & Sullivan (2015).

11 Peru was chosen as a reference because it is the nearest country to Colombia, which provides the closest reference in terms of transportation costs.

12 The high differences found in Argentina are mainly the result of a high retail price (without taxes) for the Toyota Prius (USD 42.000) in comparison to the Honda Civic (USD 20.000). This difference is significantly higher than in other countries. The higher-than-average price for the Toyota Prius in Argentina is probably the result of special market conditions for the very nascent market of HEVs (low number of retailers offering HEV models). As HEVs and BEVs achieve higher market penetrations, it is likely that the price differences become similar in all countries.

USD 45.000 in Brazil over a period of 8 years in order to equate the costs of the BEV and the ICEV. These incentives can be financial (such as tax exemptions or rebates) or non-financial (such as access to priority lanes). Section 5 describes the different types of policies available.

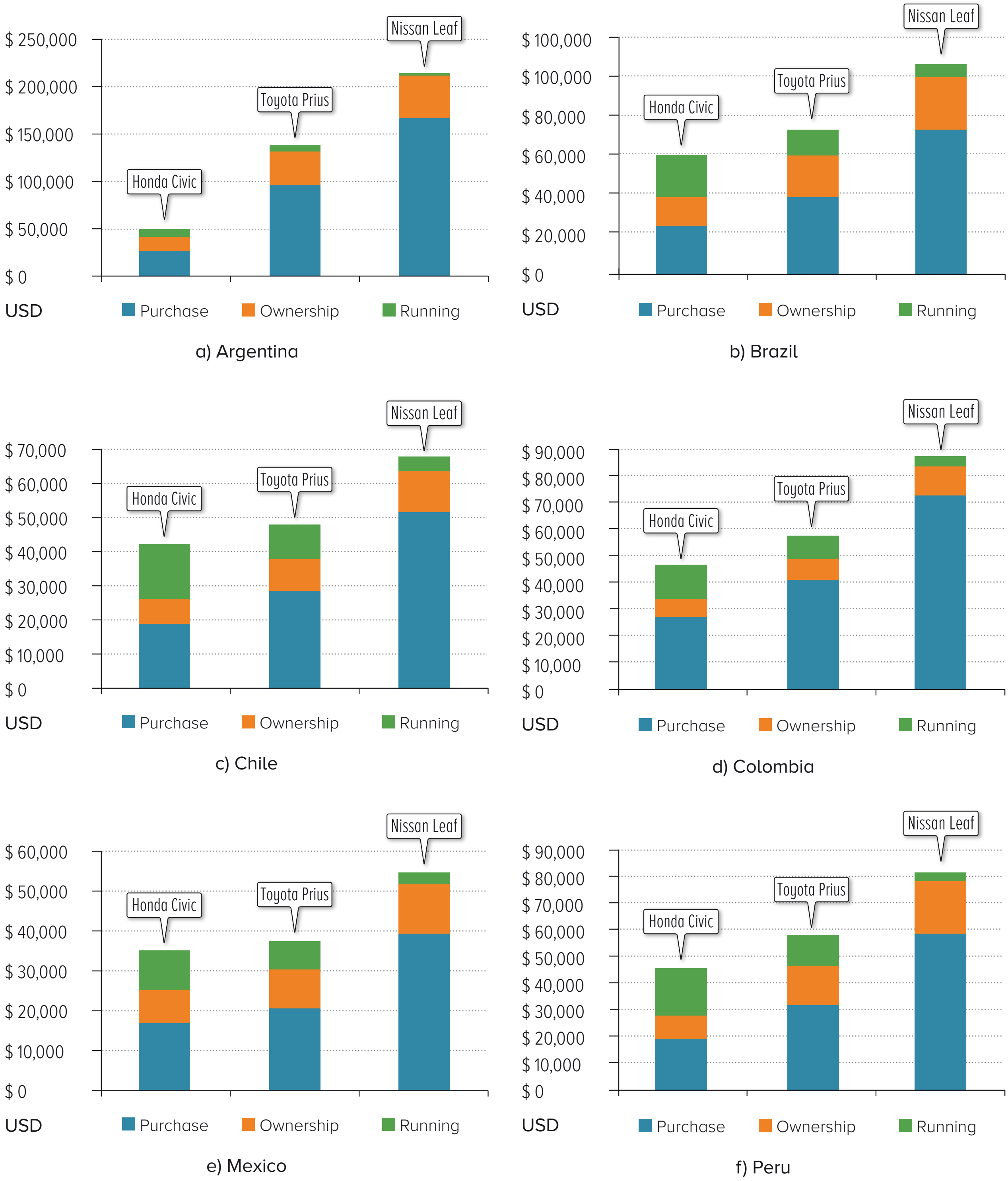


Figure 3.
Total cost of ownership comparison for an ICEV, a HEV and a BEV in six LA countries.
Source: Authors based on Frost & Sullivan, 2015.

The expected decrease in the manufacturing costs of BEVs in the following decades would reduce the required level of incentives. For instance, a 20% decrease in the sale price of the Nissan Leaf[13] would reduce the amount of incentives required to equate the costs of the BEV and the ICEV to USD 8.000 in Mexico and USD 25.000 in Brazil. However, even in this case, an important amount of incentives would be required to overcome the cost barriers of BEVs for private consumers. Moreover, the amount of incentives may need to be higher considering that BEVs, and PEVs in general, face several other challenges for deployment, such as range and recharging time, which reduce the utility of PEVs in comparison to ICEVs. The following sections describe these and other market challenges that must be addressed if PEVs are to be deployed in a massive scale.

3.3 RANGE ANXIETY AND CHARGING INFRASTRUCTURE

International research has shown that range anxiety, the fear of being stranded due to a depleted battery, is one of the main barriers to the adoption of PEVs (Hjorthol, 2013; Lieven et al., 2011). The typical electric range is between 15 and 70 km in a PHEV, and between 80 and 250 km in a BEV. This range may be enough for daily urban driving, depending mainly on the commuting distance. In this respect, LA cities are amenable for EVs, since they generally have medium or high densities and relatively short commuting distances (Kenworthy and Laube, 2002).

There are two main ways in which range anxiety from potential customers may be reduced. The first is by increasing the electric range of PEVs. This can be achieved nowadays by increasing the energy capacity of batteries, but this would significantly increase the price of the vehicle. In the long term, further research in new technologies and materials is expected to increase the energy capacity of batteries at a lower cost.

The second way to reduce range anxiety is by increasing the availability of charging points. There are three main charging locations for PEVs: residential, workplace and public stations. Availability of residential charging is commonly considered a precondition to be a potential PEV user, and housing type is generally a good predictor of this availability. A study in the USA found that 59% of households residing in a detached house had access to a 120-volt outlet in their parking place, while only 17% of households residing in an apartment did so (Axsen and Kurani, 2012). This pattern is likely to be similar in LA. However, the percentage of households residing in an apartment is generally higher in LA cities, especially among high-income residents. For instance, about 70% of households in the highest three socio-economic strata in Bogotá reside in apartments (Secretaría Distrital de Movilidad, 2011). Workplaces tend to be even more concentrated in multi-dwelling units. This implies a lower potential for EV sales.

Besides residential and workplace availability, a network of public rapid charging stations (DC charging) is the best way to increase the availability of charging points for PEVs and reduce range anxiety, especially for interurban trips. Some analyses have found that a relatively low

13 This is a significant decrease. It is not likely that a decrease of this magnitude be achieved in less than a decade and without an important market penetration that introduces economies of scale in the manufacturing process.

number of charging stations is required to provide national coverage (2.000 stations in the case of UK; Element Energy, Ecolane and University of Aberdeen, 2013). However, the development of such a network generally faces a "chicken and egg" dilemma: should the network be developed first in order to facilitate the deployment of EVs or does vehicle uptake needs to occur before in order to avoid empty stations? Past experiences with this dilemma, as in the case of ICEVs, have shown that both deployments tend to occur simultaneously, unless governments invest heavily in charging infrastructure development (IEA and Clean Energy Ministerial, 2013).

3.4 ENVIRONMENTAL PERFORMANCE

The tailpipe emission reduction gains achieved by EVs are one of their main benefits. In fact, the current wave of HEVs has been supported to a large extent by increasingly stringent emission and fuel consumption regulations worldwide. Even though technology developments for ICEVs have allowed them to achieve significant reductions in emissions and fuel consumption, full electric technologies may be the only way to achieve ultra-low environmental standards, especially with respect to GHG emissions and fuel consumption.

Tailpipe emissions are central in terms of local pollutants that affect human health, such as particulate matter and nitrogen oxides. However, GHG emission reduction gains must be evaluated from a well-to-wheel (WTW) perspective, which also considers emissions caused in the generation and distribution of electricity for PEVs. WTW analyses have concluded that the GHG benefits of PEVs depend largely on the source used for electricity production. In the case of coal-based electricity production, GHG emissions from PEVs are similar to those from conventional gasoline or diesel ICEVs (Van Vliet et al., 2011). On the other extreme, renewable sources of electricity could reduce the total amount of emissions close to zero. Additionally, GHG emissions from electricity generation for PEVs depend on whether they are charged during peak or off-peak hours of electricity consumption. Off-peak charging reduces the need to provide additional electricity generation (see section 3.5).

Figure 4 shows the percentage of renewable sources used for electricity production in several LA countries[14]. In general, LA is a region with a high share of renewable sources due to the important participation of hydroelectricity. Countries such as Paraguay, Costa Rica, Brazil and Colombia could achieve significant reductions in transportation-related GHG emissions by adopting electric vehicle technologies. Other, such as Argentina, Mexico and Bolivia, which rely mainly on gas and oil as sources of electricity, would achieve much more modest reductions.

Another environmental friendly aspect of EVs is that they reduce noise in comparison to ICEVs, both because pure electric operation is practically noise free and because combustion engines in HEVs and PHEVs are downsized. Unfortunately, less noise is also a potential risk to pedestrians and cyclists unaware of an approaching EV, especially at low speeds. The National Highway Traffic Safety Administration of USA found that HEVs are more likely to be in

14 Hydro, geothermal, solar, wind, biofuel and waste are included as renewable sources.

either a pedestrian or bicycle crash than ICEVs, with odds ratios of 1.35 and 1.57 respectively (Wu, Austin and Chen, 2011). Several countries are currently exploring legislation to require a minimum level of sound for EVs at low speeds (approximately below 30 km/h).

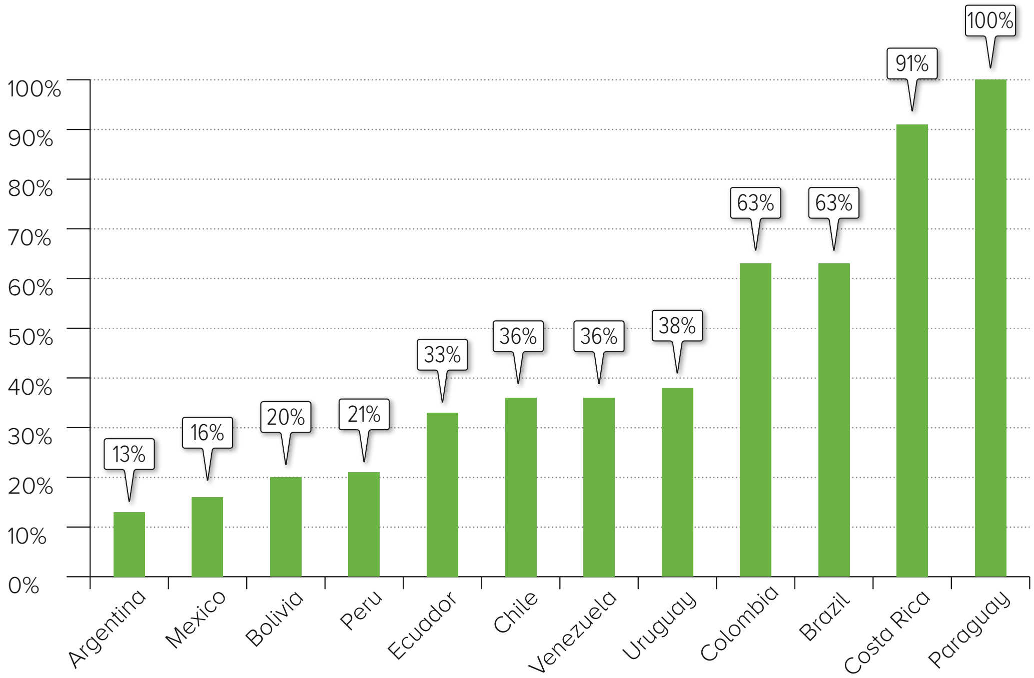


Figure 4.
Percentage of renewable sources for electricity production.
Source: Energy Innovation Center – Inter-American Development Bank, 2012.

A potential negative environmental impact of EVs is the formation of toxic byproducts during battery production and after use. In fact, this was the most unacceptable environmental problem identified by potential EV users in Hong Kong (Delang and Cheng, 2012). This calls for important waste treatment and recycling measures. However, recycling of lithium-ion batteries is currently not profitable as it costs more to recycle than to mine (Frost & Sullivan, 2015). Unless lithium becomes scarce, recycling will have to be driven by environmental laws. This is an important challenge for LA countries in terms of the possible introduction of EVs in the region.

3.5 ELECTRIC SYSTEMS

One major advantage for the deployment of PEVs is that most countries in LA already have a mature and robust system for the generation, transmission and distribution of electricity, with ample coverage, especially in urban areas. This is not the case for hydrogen FCEVs, for instance, which would require high capital investments to set-up hydrogen production, distribution and fueling infrastructure.

Nevertheless, the additional electricity demand caused by the introduction of PEVs may require the expansion of the current electric systems. A study in the state of Sao Paulo, Brazil, for instance, found that every increase of 10% in the percentage of BEVs in the total passenger car fleet would increase total electricity demand in the state by approximately 2% (Dias et al., 2014). This is not a minor effect. It implies that a complete transition to BEVs would increase electricity demand by roughly 20%. Fortunately, this result does not necessarily imply that electric systems would have to be expanded by about 20% in such scenario. Electricity demand varies strongly by time of day, so there is generally excess capacity during off-peak periods (late night and early morning). If PEVs are charged mostly during off-peak periods, their electricity demand may be supplied mainly with this excess capacity. For instance, a study in the Netherlands found that if off-peak charging were successfully introduced, even a 100% switch to electric driving would not require additional generation capacity (Van Vliet et al., 2011). Moreover, off-peak charging would allow for more efficient electricity management by reducing the need to bring some generators on and off as the day goes on (M.J. Bradley & Associates LLC, 2013).

The most common method to promote off-peak charging is by introducing time-of-use pricing, which charges consumers lower rates during off-peak periods. This would incentivize PEV owners to charge at night in their homes using Level 1 or Level 2 charging methods, instead of charging at public stations during peak periods using DC charging, softening the impact on the electric system. Some utility companies in LA countries already apply time-of-use electricity pricing (Frost & Sullivan, 2015).

Future trends propose an even better integration between PEVs and electric systems. The vehicle-to-grid (V2G) technology would allow PEVs to communicate with the electric grid in order to function as distributed energy storage devices, storing excess electricity during off-peak periods and giving it back to the grid during peak loads. In this scenario, PEV owners may receive monetary compensation from utility companies, who employ the storage capacity of the vehicles to manage electricity more efficiently. Although using PEVs as storage devices may reduce the service life of the batteries, because of increasing charging cycles, the potential monetary compensation from utility companies would likely exceed this cost (Habib, Kamran and Rashid, 2015).

3.6 SOCIAL AWARENESS

Another important barrier to the deployment of EVs, as is usually the case with new technologies, is the lack of social awareness and knowledge of the technology (Hjorthol, 2013). This implies that potential consumers are unaware of its benefits and may even distrust or misunderstand the technology.

Fortunately, there are several initiatives that governments can support to overcome this barrier. Among these are electric taxi pilot projects, public procurement and labeling schemes. Several LA cities, such as Santiago, Bogotá, Sao Paulo and Mexico, have already implemented BEV taxi pilot projects in the past three years (Frost & Sullivan, 2015). These projects have been generally supported by car manufacturers, electricity utility companies and by governments in the form of exemptions from registration fees and tax reductions. The size of these projects has been of less than 100 electric taxis. Besides creating social awareness, they intend to test the performance of BEVs in real driving conditions. Even though there are not formal analyses of the results from these projects, the majority of electric taxis have not faced major problems to provide service in urban areas.

Public procurement of electric governmental fleets is another way to increase public awareness of EVs, as well as a way of leading by example. There are not currently significant examples of this type of initiative in LA. An additional benefit of pilot projects and public procurement is that they force national governments to modernize the regulatory framework for homologation and registration of vehicles in order to include EVs. This prevents future problems with the commercialization of EVs. In Colombia, for instance, private companies have struggled to register EVs because local authorities require emission certificates (Frost & Sullivan, 2015).

Finally, labeling schemes are generally employed to increase consumers' awareness of fuel economy characteristics, so that they include running costs and environmental impact as an important decision factors when purchasing a car. Labeling schemes can also emphasize EVs. For instance, the city of Mexico will implement a distinctive license plate for EVs (Frost & Sullivan, 2015). Besides increasing EVs' public awareness, this initiative will also facilitate the implementation of benefits for EVs, such as exemption from license plate based restrictions or exclusive parking.

4. COSTS AND BENEFITS

The potential impact of the introduction of EVs in LA countries can be evaluated within a cost-benefit framework, in which expected costs and benefits for the society as a whole are quantified, monetized and compared in terms of their net present value (NPV). This framework provides a useful perspective to determine whether governments should promote or not the introduction of EVs. This analysis can also be understood as a way to evaluate the feasibility of a public subsidy directed to equalize the costs of EVs to ICEVs. However, this framework has limitations in terms of the difficulties related to the identification, quantification and monetization of all costs and benefits. In this case, the difficulties related to the monetization of environmental benefits, such as reduction of GHG emissions and local air pollution, are especially relevant. It is also inherently uncertain to forecast the cost of fuels in the following decades.

Table 3 presents the results of a cost-benefit evaluation of the introduction of a BEV (Nissan Leaf), instead of an ICEV (Honda Civic), in six LA countries[15]. The costs of this introduction refer to the higher manufacturing (including transportation due to required import) cost of the BEV and the need for residential and public charging stations. The difference in manufacturing costs was approximated from the difference in retail prices without taxes[16]. Since the market of BEVs is in a very nascent stage, this is a crude approximation to the real difference in costs. As BEVs achieve higher market penetrations, prices should reflect costs more closely[17]. In this sense, the cost-benefit evaluation must be understood as a preliminary evaluation.

The benefits refer to lower operational costs (general maintenance and replacements), energy consumption (fuel or electricity), and CO2 and particulate material (PM) emissions[18]. In order to monetize CO2 emission reductions, we use the last update of the social cost of carbon (SCC) of the United States Government (Interagency Working Group on the Social Cost of Carbon – United States Government, 2013). The SCC is an estimate of the value of global climate change damages avoided due to reductions in CO2 emissions. It includes damages related to net agricultural productivity, human health and property damages from increased flood risk, among others. Due to model and data limitations, it is likely that the SCC underestimates the total damages, so we use the 95th percentile of the SCC estimates. This corresponds to a SCC of USD 116 in 2015 and USD 187 in

15 Although this evaluation refers to only one vehicle, the benefit/cost ratios obtained would be the same independent of the number of vehicles or market penetration assumed, because all costs and benefits depend linearly on the number of vehicles.

16 As in the TCO analysis, the retail prices (without taxes) of the Nissan Leaf in countries other than Mexico was estimated from the price ratio between the Nissan Leaf and the Toyota Prius in Mexico.

17 In particular, the difference in manufacturing costs between countries should not vary as much as in Table 3, because most countries would be importing (rather tan locally producing) BEVs.

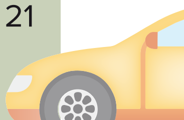
18 Other potential benefits, such as noise reduction or energy independence, are not considered. Among local pollutants, only PM is considered. PM is generally the pollutant that exceeds the limits set by health organizations and directly affects human health in LA cities.

2035 per ton of CO2 (in 2011 dollars)[19]. In order to monetize PM emission reductions, we use the value estimated from the Decennial Plan for the Reduction of Air Pollution in Bogotá (Secretaría Distrital de Ambiente and Universidad de los Andes, 2010). This value is USD 411.000 per ton of PM (in 2008 dollars) and includes all effects in human health. We assumed that fuel and electricity prices presented in Figure 2 remain constant during the evaluation period. Finally, we used an evaluation period of 20 years and a discount rate of 12%. Other data inputs and assumptions for the cost-benefit evaluation are presented in Annex 2.

COUNTRY		ARGENTINA	BRAZIL	CHILE	COLOMBIA	MEXICO	PERU
NPV OF COSTS	MANUFACTURING	50.006	18.668	29.255	35.468	20.852	25.997
	CHARGING STATIONS	1.679	1.679	1.679	1.679	1.679	1.679
	TOTAL	51.685	20.347	30.934	37.147	22.531	27.676
NPV OF BENEFITS	OPERATIONAL	661	1.420	991	925	991	991
	ENERGY	8.092	11.351	10.113	7.513	5.845	11.942
	CO_2 EMISSIONS	1.405	3.587	1.912	2.583	1.884	2.364
	PM EMISSIONS	373	803	560	523	560	560
	TOTAL	10.531	17.162	13.576	11.544	9.280	15.857
B/C RATIO		0,204	0,843	0,439	0,311	0,412	0,573
COST PER TON OF CO_2 REDUCED		1.470	92	489	530	390	291
PERCENTAGE REDUCTION REQUIRED IN MANUFACTURING COST OF BEV FOR B/C =1		60,8%	9,2%	37,1%	47,3%	36,7%	30,6%

Table 3.
Cost-benefit analysis of the introduction of a BEV instead of an ICEV in six LA countries.
Source: Authors.

19 Recent estimates suggest that the SCC could be as high as USD 220 per ton of CO2 if temperature affects economic growth rates (Moore and Diaz, 2015).



The results show that costs are greater than benefits in all countries. The benefit/cost ratio ranges from 0,2 in Argentina to 0,84 in Brazil. Table 3 shows also the cost per ton of CO2 reduced. This cost is computed as the difference between the NPV of costs and benefits, divided by the amount of CO2 reduced. This indicator shows the net cost that would have to be borne by the society to reduce one ton of CO2 through the introduction of BEVs. Since several countries are committed to reduce CO2 emissions to specific targets, this type of indicator allows for comparisons to find the most cost-effective ways to achieve those targets. The cost per ton of CO2 for BEVs is relatively high, considering that investments in public transportation generally have negative costs (i.e. benefits exceed costs even without the effect of CO2 emission reductions).

These results do not imply that LA countries should not act with respect to the future introduction of BEVs in the region. Even though costs are currently greater than expected benefits, several conditions may change in the following decades that would favor BEVs significantly. First, the manufacturing cost of BEVs is expected to decrease considerably in the following decades, mainly due to a reduction in the cost of battery manufacturing. In this respect, Table 3 shows the required percentage reduction in the manufacturing cost of BEVs that would equate total costs and benefits. With the exception of Argentina, the required percentage reduction ranges from 9% to 47%. All or a significant part of this reduction may be achieved within the following two decades. Second, the SCC may continue to increase as better modeling techniques are developed and data gathered to evaluate the value of global climate change damages. Finally, the results presented in Table 3 assume that the cost of fuel will remain constant in the following two decades. Despite the high uncertainty of predicting the future price of fuels, this assumption is likely to be too conservative in the long-term given the rising global oil demand and the limits of oil reserves and production.

In this scenario, LA countries can start now to implement diverse initiatives and policies to prepare the future introduction of EVs in the region, especially if these initiatives do not compromise substantial public or private resources. Furthermore, EVs can be a viable alternative today for target cities or urban areas with conditions that favor the introduction of EVs, such as very poor environmental conditions or high levels of car use. In these cases, the marginal benefits of introducing EVs are higher than national averages. The following section evaluates the general set of policies available for LA countries to facilitate the introduction of EVs.

5. POLICIES AVAILABLE FOR LA COUNTRIES

5.1 FINANCIAL INCENTIVES

Since high sales prices are one of the main barriers to the introduction of EVs, financial incentives are one of the most direct options for governments to promote EVs. There are two main ways in which governments can provide financial support to EV buyers: offering rebates and lowering taxes. In practical terms, both methods can achieve the objective of reducing the sales price of EVs.

Tax structures in each country (Table 2) determine the options available to reduce the sales price of EVs through tax exemptions or reductions. The most common alternatives are value-added and import taxes, which are generally an important share of the tax structure. Even if tax reductions apply to both EVs and ICEVs, for instance as a result of free trade agreements, they tend to benefit EVs because the price difference, measured in monetary terms, is reduced. Countries with light vehicle tax structures, such as Mexico or Chile, may have to use rebates in order to reduce the purchase price of EVs.

Since tax exemptions or rebates imply important fiscal efforts, and since these effort may be catalogued as socially regressive because initial EV buyers tend to belong to high-income classes (Hjorthol, 2013), a less controversial approach for LA countries would be to implement revenue neutral financial incentives to EVs. In this approach, EVs are offered rebates or tax reductions, while ICEVs are imposed fees or tax increases (such as pricing their environmental externalities). An advantage of this approach is that it makes it easier for countries to sustain financial incentives for EVs during a longer period of time. This approach has been proposed for Chile, as part of an E-mobility readiness plan to be presented as a Nationally Appropriate Mitigation Action (NAMA; Gobierno de Chile 2012).

Financial incentives can also be directed to reduce the yearly costs of owning and/or using an EV. The set of options is much ample in this case: reductions in yearly ownership or circulation taxes, tolls, parking fees, insurances, subsidies to electricity and so on. For instance, several states in Brazil are currently offering full exemption of the Imposto sobre a propriedade de veículos automotores (IPVA, motor vehicle property tax; Frost & Sullivan, 2015). The main difference is that this type of incentives does not reduce the purchase price of the EV. Instead, it reduces costs over a multiple year time spam. Given that consumers value purchase costs much more than yearly costs, this approach may reduce the effectiveness of the financial incentives. In fact, the majority of the financial incentives offered to EVs worldwide focus on purchase costs, not on yearly costs (Sierzchula et al., 2014). Another important difference is that reductions in use costs are likely to increase the use of cars, increasing congestion problems. In any case, financial incentives to reduce the owning or use costs of EVs can also be designed to be revenue neutral by increasing the respective fees for ICEVs.

5.2 NON-FINANCIAL INCENTIVES

Another important set of policies for countries to promote EVs is to implement non-financial benefits for the use of EVs. The specific options in this set depend on the regulatory framework of each country or city, but three of the most common benefits are:

- Permitted use of exclusive bus lanes, high-occupancy vehicle (HOV) lanes or exclusive EV lanes
- Exemption from vehicle use restrictions, such as license-plate-based restrictions
- Exclusive parking spaces

Permitted use of exclusive bus lanes has been one of the most important benefits in Norway's successful promotion of EVs (Vergis et al., 2014)[20]. Given the high number of Bus Rapid Transit (BRT) systems in Latin America, this policy could be replicated in many cities of the region. However, it is probably not a good policy in the context of high public transportation use in LA cities, even more if a high penetration of EVs is achieved. Allowing EVs into exclusive bus lanes is likely to reduce the service quality of public transportation, prompting users to shift away from public transportation. This result would not be desirable in terms of urban transportation sustainability. HOV lanes are not common among LA cities, while the idea of providing exclusive EV lanes is not likely an efficient use of scarce public space.

License-plate-based restriction to the use of cars during certain weekdays and peak hours is also a common policy in LA cities (e.g. Bogotá, México D. F. and Sao Paulo). These policies have been enacted in order to mitigate environmental and/or congestion problems. However, they have generally had important unintended consequences, such as increasing car ownership and use levels due to the propensity of some households to buy a second car (usually an old car with high emission levels) in order to avoid the restriction. In this context, exempting EVs from license-plate-based restrictions is probably one of the best options for LA cities to provide non-financial incentives to EVs.

Cities generally have the possibility to mandate a minimum percentage or number of exclusive parking spaces for EVs in public parking lots. This is likely to be a good policy to promote EVs, since it will affect only marginally the parking availability of ICEVs while providing a valuable benefit for EVs.

5.3 CHARGING INFRASTRUCTURE

In order to increase the availability of charging points at homes and workplaces, some cities, such as London, require all or a minimum percentage of parking spaces in new developments to be provided with electric infrastructure (Element Energy, Ecolane and University of Aberdeen, 2013). Even though this policy has a significant effect only after several years in place, installing electric infrastructure in new developments is far more cost-effective than adding it to old ones. In this sense, this type of policy represents the best option for LA countries to increase household and workplace charging availability for future years.

With respect to a network of public rapid charging stations, governments can support financially

20 Norway is currently the world leader in EV market penetration with close to 15% in 2014 (Vergis et al., 2014). The vast majority of EVs correspond to BEVs, following policies that have promoted BEVs much more tan PHEVs.

its development. However, the high cost of rapid charging stations and the interest of private sectors, such as car manufacturers and electricity utility companies, in its deployment suggest that private investment will play major role. In fact, car manufacturers and utility companies have joined forces in order to establish the first public charging stations in LA (Chilectra, Petrobras and Nissan in Chile; Edesur and Renault in Argentina; Frost & Sullivan, 2015).

Governments can further promote private investment on public charging infrastructure by providing clarity on how potential charging services from non-utility companies, such as hotels, retailers and shopping centers, would be regulated. In most LA countries, only utility companies are allowed to sell electricity directly to consumers. This impedes the development of charging services from non-utility companies that would be willing to invest in establishing charging infrastructure as long as they can levy fees for its use to recover the costs and earn profits (IEA and Clean Energy Ministerial, 2013). Brazil, for instance, is following this path by enacting a law that creates the figure of the retail seller of electricity for automotive purposes (Frost & Sullivan, 2015). This type of innitiatives are highly recommended for LA countries, as they facilitate private investment by allowing new business models.

Finally, LA countries can facilitate the deployment of public rapid charging infrastructure by supporting the harmonization of standards and interoperability of charging systems. This would prevent EV drivers from encountering incompatible charging stations (IEA and Clean Energy Ministerial, 2013).

5.4 ENVIRONMENTAL REGULATIONS

There are different types of environmental regulations that governments can impose to passenger cars. The most common type is limiting tailpipe emission of criteria pollutants, such as particulate matter, nitrogen oxides and hydrocarbons. These regulations have to be coupled with the availability of low-sulphur fuels that permit the adequate functioning of advanced emission control technologies. LA countries vary greatly in their level of control of local pollutant emissions and in the sulphur content of the available fuel, from practically no emission standards in countries such as Bolivia and Paraguay, to world-class fuel quality and emission standards in countries such as Chile (UNEP, 2015)[21].

Even though the establishment of more stringent vehicle emission regulations of local pollutants would bring important benefits to LA countries in terms of health impacts, it is not likely to spur significantly the sales of EVs. Emission control technologies have been developed for ICEVs to achieve even the most advanced standards at a lower cost than electric technologies. In fact, the establishment of more stringent standards generally follows the development of such technologies.

Several countries worldwide regulate also fuel consumption or tailpipe GHG emissions (Miller and Facanha, 2014)[22]. These regulations generally follow a corporate average approach, in which each

21 Chile limits sulphur content in fuels to 15 ppm and imposes emission standards at Euro 4 or 5 levels (UNEP, 2015).

22 Fuel consumption (or fuel economy) and GHG emission regulations are generally analyzed together, because GHG emissions depend directly on the quantity of fuel consumed.

car manufacturer must achieve a sales-weighted fleet average in terms of fuel consumption (kilometers per liter or miles per gallon) or GHG emissions (gCO2/km). This approach gives car manufacturers high flexibility in terms of market strategies and technologies to achieve the required target.

Only two LA countries have implemented this type of regulation: Brazil and Mexico. In 2012, Brazil enacted the Inovar-Auto incentive program. This program imposes important tax increments to car manufacturers that fail to achieve a set of requirements, one of which is to increase the average fuel efficiency of light-duty vehicles (LDVs) by 12% by 2017 (ICCT, 2013a). The other requirements refer to a minimum number of manufacturing processes to be carried out in Brazil, R&D investment and participation in a vehicle labeling scheme. This fuel efficiency target is not likely to spur EV sales significantly, except for HEVs. There are technological advancements, such as light weighting and improved aerodynamics, which can be applied to ICEVs in order to increase fuel efficiency at a lower cost. Nevertheless, a second phase of the program, post 2017, may focus on promoting EVs (Frost & Sullivan, 2015).

In 2013, Mexico established corporate average GHG emission and fuel economy standards for LDVs over the period 2014-2016. The stringency of these standards is similar to that of standards in USA and Canada, leading to an average fuel economy of 14,6 km/l in 2016 (ICCT, 2013b). The regulation offers special credits to car manufacturers that offer or produce HEVs, PHEVs, BEVs or other highly efficient vehicle technology in Mexico. This feature may increase the commercial availability of EV models in Mexico, but it is not likely to spur PEV sales significantly unless much more stringent targets are set after 2016.

A more intrusive type of environmental regulation would require car manufacturers to achieve a minimum share of total sales of an specific low-emission technology (e.g. BEVs). This was the case with the initial design of California's Zero-Emission Vehicle (ZEV) Program. This program, established in 1990, required that ZEVs sales constitute a minimum share of total sales for each major car manufacturer. In practical terms, this was a mandate for BEVs, the only technology able at the time to meet the zero-emissions standard. Due to the unexpected slow progress in BEV technology, the program had to become more flexible and give credits to other low-emission technologies, such as HEVs and PHEVs. Even though the program fostered the development of electric technologies, it illustrated the advantages of designing flexible programs that can adapt to a broad range of emerging technologies (Bedsworth and Taylor, 2007).

In summary, even though EVs offer important benefits in terms of tailpipe emissions reductions and fuel economy, further improvements in ICEVs and other technologies are also capable of achieving low standards. Since it is not clear which technological path will be more cost-effective, it is important that environmental regulations follow a flexible and technology-neutral approach.

From a WTW perspective, the GHG emissions reductions from PEVs can be enlarged from shifting to cleaner sources of electricity production. Fortunately, most countries in LA have a high potential to increase the use of renewable sources and have already set ambitious goals in this respect (Vergara, Alatorre and Alves, 2013).

5.5 PROMOTION OF LOCAL INDUSTRIES

A significant penetration of EVs worldwide would imply an important demand of batteries, which will be lithium-based for the foreseeable future (National Research Council, 2013). In this context, and considering that LA (mainly Chile and Bolivia) has over half of the of the world's lithium reserves, there would be an opportunity for LA countries to promote local value-added battery production industries. However, it will not be easy for LA countries to take advantage of this opportunity, since battery production requires high capital investments and very sophisticated technology and labor force (Frost & Sullivan, 2015). National governments can help overcome these barriers by supporting private capital investments and R&D activities. Bolivia and Chile are already moving in this direction with initiatives such as a pilot battery plant and an innovation lithium center, respectively.

In terms of vehicle manufacturing, Brazil and Mexico are the largest producers in the region, being seventh and eighth largest in the world, respectively. Both countries are already promoting the local production of EVs, as part of their efforts to increase fuel efficiency and reduce GHG emissions from passenger cars (see section 5.4). It would be difficult for LA countries to promote the creation of an EV manufacturing industry without a current vehicle manufacturing expertise. Norway, for instance, failed in its attempt to support a BEV manufacturing industry over a decade ago (Vergis et al., 2014).

6. SUMMARY AND RECOMMENDATIONS

The current wave of EVs in the world has reached record numbers since the appearance of electric drive technologies more than a century ago. Government support in developed countries is largely responsible for this increase, responding to growing concerns about climate change and energy independence. However, it is still not clear whether this current wave will mark the beginning of an inexorable transition from fuel to electricity as the main source of energy for transportation. In the following years, EVs will have to prove superior to ICEVs as public support decreases, overcoming long-standing barriers such as cost, range and recharging time.

Even though the current high manufacturing cost of EVs (especially PEVs) imply that the costs of a transition from ICEVs to PEVs are greater than the expected benefits, several conditions may change in the following decades that would favor EVs significantly. Among these are: reduction of manufacturing costs as a result of less expensive battery manufacturing, increasing concerns and better knowledge about the global damages of climate change, and rising fuel prices due to increasing oil demand and limited reserves and production.

In this scenario, LA countries may act early on to allow for a faster and less traumatic transition to EVs in the following decades. Among the most relevant policies and initiatives that LA countries can implement at a low cost in this respect are:

- Require a minimum percentage of parking spaces in new developments to be provided with electrical infrastructure, in order to increase the availability of charging points at homes and workplaces.
- Establish clear regulations to facilitate the development of charging services from non-utility companies such as hotels, retailers or shopping centers.
- Support the harmonization of standards and interoperability of charging systems.
- Introduce time-of-use electricity pricing in order to incentivize charging of PEVs during off-peak periods. This would reduce the need to expand the current electric systems due to the additional demand generated by PEVs.
- Promote initiatives that increase the social awareness of electric vehicle technologies, such as electric taxi pilot projects, public procurement of electric fleets and labeling schemes.
- Countries with large vehicle production industries (Mexico and Brazil) or with significant lithium reserves (Argentina, Bolivia and Chile) may support private capital investments and R&D activities to expand or create value-added industries in the EV and battery markets.
- Implement increasingly stringent local pollutant and GHG emission standards for passenger cars. These regulations should follow a flexible and technology-neutral approach.

In the following years, as the outlook for the introduction of EVs becomes clearer (mainly in terms of cost reductions and market penetrations), LA countries may evaluate the need to implement more aggressive support measures such as financial or non-financial incentives and investment in public charging infrastructure. In terms of financial measures, revenue neutral incentives would be preferable in order to mitigate the fiscal effort required. Additionally, incentives that reduce sale prices are in general preferable to those that reduce yearly ownership or use costs, because consumers tend to value up-front costs more than yearly costs. In terms of non-financial measures, exemptions to license-plate-based restrictions and exclusive parking spaces for EVs may provide important benefits to EV owners.

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ANNEX 1: INPUTS AND ASSUMPTIONS FOR TCO ANALYSIS

The results of the TCO analysis presented in section 3.2 are based on several data inputs and assumptions, which are describe below. The structure of the analysis is based on the work of Frost & Sullivan (2015), and several data inputs and assumptions are also taken from that work.

PURCHASE COSTS:

The retail prices (without taxes) of the Honda Civic and Toyota Prius were taken from local websites in each country, except for Colombia, where the Toyota Prius was not available for sale. The price ratio found in Peru between the Honda Civic and Toyota Prius (1,60) was used to estimate the retail price of the Toyota Prius in Colombia. The Nissan Leaf was only available for sale in Mexico, so the retail price of the Nissan Leaf in other countries was estimated using the price ratio found in Mexico between the Toyota Prius and the Nissan Leaf (1,61).

Taxes were applied to each country using the information in Table 2. Tax exemptions for a quota of vehicles in Argentina and Colombia were not considered. A financial cost was added in all cases considering down payment of 20% and loan term of 5 years. The annual interest rate used for Chile, Colombia, Mexico and Peru was 13%, while for Argentina and Brazil was 17%, because the interest rate is generally higher in these two countries (Frost & Sullivan, 2015). A cost of USD 2.000 was added in all countries to the Nissan Leaf in order to account for the purchase and installation costs of a Level 2 charging station.

Finally, a residual value after 8 years was considered in all cases. An annual depreciation rate of 8% was used for the Honda Civic, Toyota Prius and Nissan Leaf without the battery. A depreciation rate of 20% was used for the battery of the Nissan Leaf in order to account for a shorter service life.

OWNERSHIP COSTS:

The main ownership cost considered for all types of vehicles was a full-coverage insurance cost. Insurance costs were collected from local insurance companies in each country (Frost & Sullivan, 2015). Since the Nissan Leaf was available only in Mexico, the ratio between the insurance prices of the Toyota Prius and the Nissan Leaf in Mexico was used to estimate the insurance cost of the Nissan Leaf in other countries. A yearly cost of USD 32 was added to the Nissan Leaf in all countries to account for the maintenance of the Level 2 charging station. Ownership costs related to parking were not considered.

RUNNING COSTS:

In all countries, the price of general maintenance and replacements was assumed at USD 0,758 per 100 km for the Nissan Leaf, and USD 1,647 per 100 km for the Toyota Prius and the Honda Civic

(Frost & Sullivan, 2015). We used the prices of energy (electricity and fuel) presented in Figure 2. We assumed that these prices would remain constant during the analysis period (8 years). Energy consumption was assumed at 31 and 50 miles per gallon for the Honda Civic and the Toyota Prius respectively (www.fueleconomy.gov), and 0,133 kWh per km for the Nissan Leaf. The level of car use was taken from mobility studies in the different countries (Frost & Sullivan, 2015). The annual number of kilometers used was 10.000 in Argentina, 21.500 in Brazil, 15.000 in Chile, Mexico and Peru, and 14.000 in Colombia. Running costs related to parking were not considered.

TIME PERIOD FOR ANALYSIS:

The time period for analysis was 8 years. This period is short in comparison to the average service life of a car, which can exceed 15 years in most LA countries. The 8-year period reflects the fact that consumers discount yearly costs heavily. The typical period for TCO analyses in UK is 4 years (Element Energy, Ecolane and University of Aberdeen, 2013). We use a longer period to reflect the fact that cars in most LA countries tend to have longer service lifes.

The following table shows the details of the results presented in Figure 3 (in 2015 dollars).

COST		ARGENTINA			BRAZIL		
		HONDA CIVIC	TOYOTA PRIUS	NISSAN LEAF	HONDA CIVIC	TOYOTA PRIUS	NISSAN LEAF
PURCHASE	RETAIL PRICE	20.000	42.000	67.688	18.300	21.500	34.650
	TAXES	10.430	71.497	115.904	12.061	25.449	40.830
	FINANCIAL COST	11.023	41.115	66.508	10.999	17.008	27.343
	CHARGING STATION LEVEL 2	-	-	2.000	-	-	2.000
	RESIDUAL VALUE	15.617	58.249	85.247	15.582	24.095	31.542
	TOTAL	25.836	96.363	166.853	25.778	39.862	73.281
OWNERSHIP		15.072	36.096	46.586	14.320	20.320	26.337
RUNNING		10.181	6.812	807	20.975	14.080	7.296
TOTAL		51.089	139.271	214.246	61.073	74.262	106.914

Table A.1.
Total cost of ownership comparison for an ICEV, a HEV and a BEV in six LA countries.
Source: Authors based on Frost & Sullivan, 2015.

COST		CHILE			COLOMBIA		
		HONDA CIVIC	TOYOTA PRIUS	NISSAN LEAF	HONDA CIVIC	TOYOTA PRIUS	NISSAN LEAF
PURCHASE	RETAIL PRICE	19.800	29.000	46.737	21.000	33.600	54.150
	TAXES	5.526	7.931	12.567	14.954	19.918	31.549
	FINANCIAL COST	6.955	10.143	16.287	9.874	14.698	23.536
	CHARGING STATION LEVEL 2	-	-	2.000	-	-	2.000
	RESIDUAL VALUE	12.998	18.953	26.253	18.452	27.466	38.789
	TOTAL	19.283	28.121	51.338	27.376	40.750	72.446
OWNERSHIP		7.000	9.200	12.064	6.320	8.080	10.626
RUNNING		16.181	10.782	4.288	12.722	8.588	3.684
TOTAL		42.464	48.103	67.690	46.418	57.418	86.756

COST		MEXICO			PERU		
		HONDA CIVIC	TOYOTA PRIUS	NISSAN LEAF	HONDA CIVIC	TOYOTA PRIUS	NISSAN LEAF
PURCHASE	RETAIL PRICE	17.566	22.400	36.100	15.000	24.000	38.679
	TAXES	4.747	4.855	7.472	11.335	17.896	28.597
	FINANCIAL COST	6.128	7.485	11.967	7.233	11.506	18.476
	CHARGING STATION LEVEL 2	-	-	2.000	-	-	2.000
	RESIDUAL VALUE	11.452	13.988	18.515	13.516	21.502	28.793
	TOTAL	16.989	20.752	39.024	20.052	31.900	58.959
OWNERSHIP		8.048	9.536	12.495	8.800	14.664	19.077
RUNNING		9.805	6.829	2.484	16.818	11.177	2.966
TOTAL		34.842	37.117	54.003	45.670	57.741	81.002

ANNEX 2: INPUTS AND ASSUMPTIONS FOR COST-BENEFIT EVALUATION

Besides those mentioned in section 4, the results of the cost-benefit evaluation rely on the following data inputs and assumptions.

COSTS:

The difference in manufacturing costs is based on the difference in MSRPs presented in Table A.1. It was assumed that the battery of the BEV would have to be replaced at year 10 at the current price of batteries.

For charging stations, one Level 2 station per two BEVs and 1 DC station per 100 BEVs were assumed (IEA and Clean Energy Ministerial, 2013). The cost of a Level 2 station was USD 2.000 and of a DC station USD 50.000. Maintenance costs were USD 32 and USD 800 per year respectively.

BENEFITS:

- Operational and energy consumption costs followed the same data inputs used for the TCO analysis (see Annex 1).

- CO_2 emissions from ICEVs were based on fuel consumption and a parameter of 8.887 gCO_2 per gallon, plus a 20% increase to account for fuel production and transportation. In Brazil, the parameter was 7.857 gCO_2 per gallon to account for the high ethanol mix.

- CO_2 emissions from electricity generation for BEVs were based on the electricity matrix of each country (Figure 2). The estimated emissions in terms of gCO_2 per kWh are 165,3 for Brazil, 231,1 for Colombia, 364,9 for Peru, 425 for Argentina, 459,6 for Chile and 471,7 in Mexico.

- It was assumed that only half of the electricity required by BEVs would imply additional electricity generation. This is intended to account for the fact that most of the charging for BEVs is likely to take place during off-peak hours, using current excess generation capacity of the system.

- PM emission reductions were based on an emission factor of 0,01 gr per km for ICEVs in all countries.