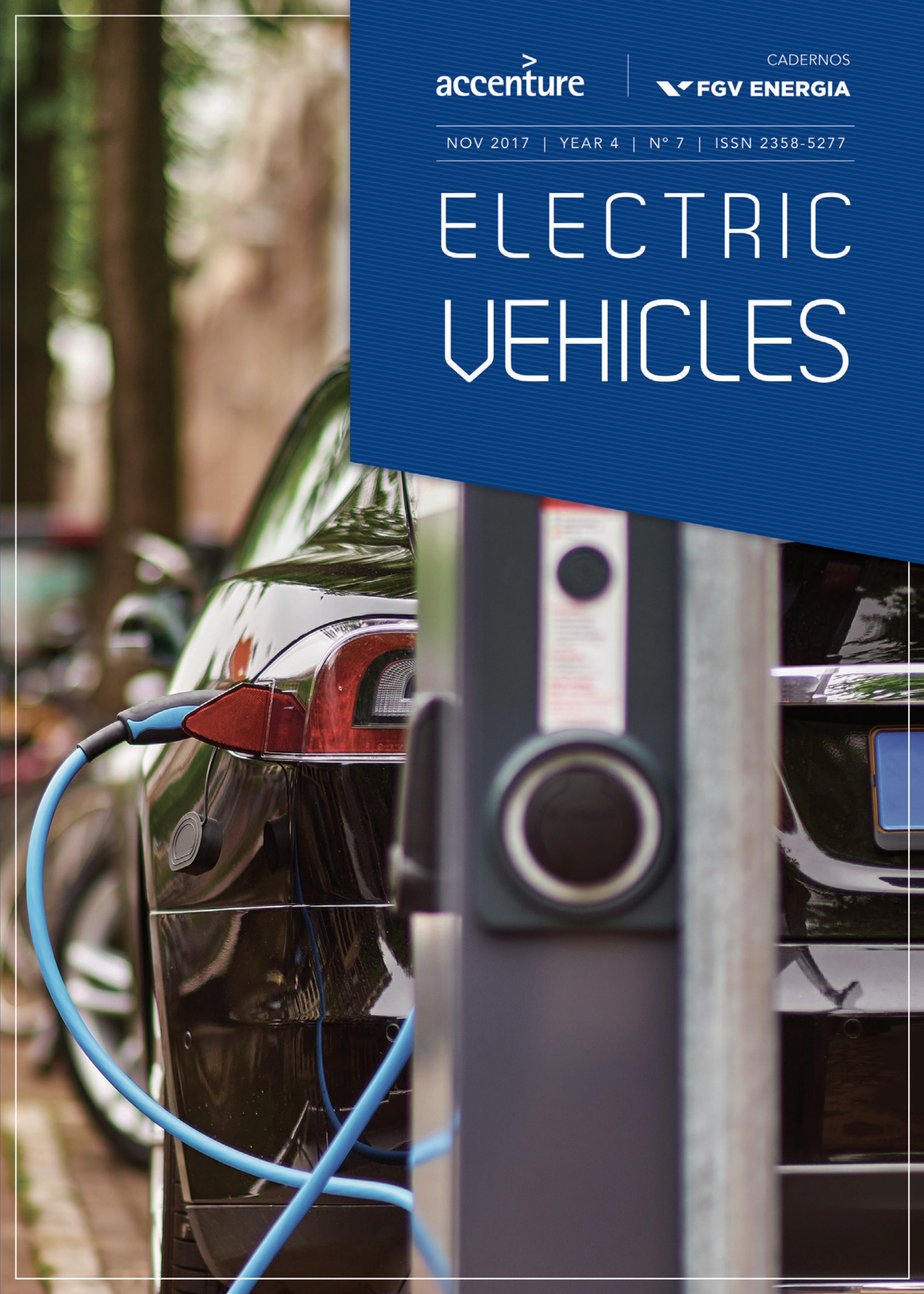

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ELECTRIC VEHICLES

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Indice

Introduction

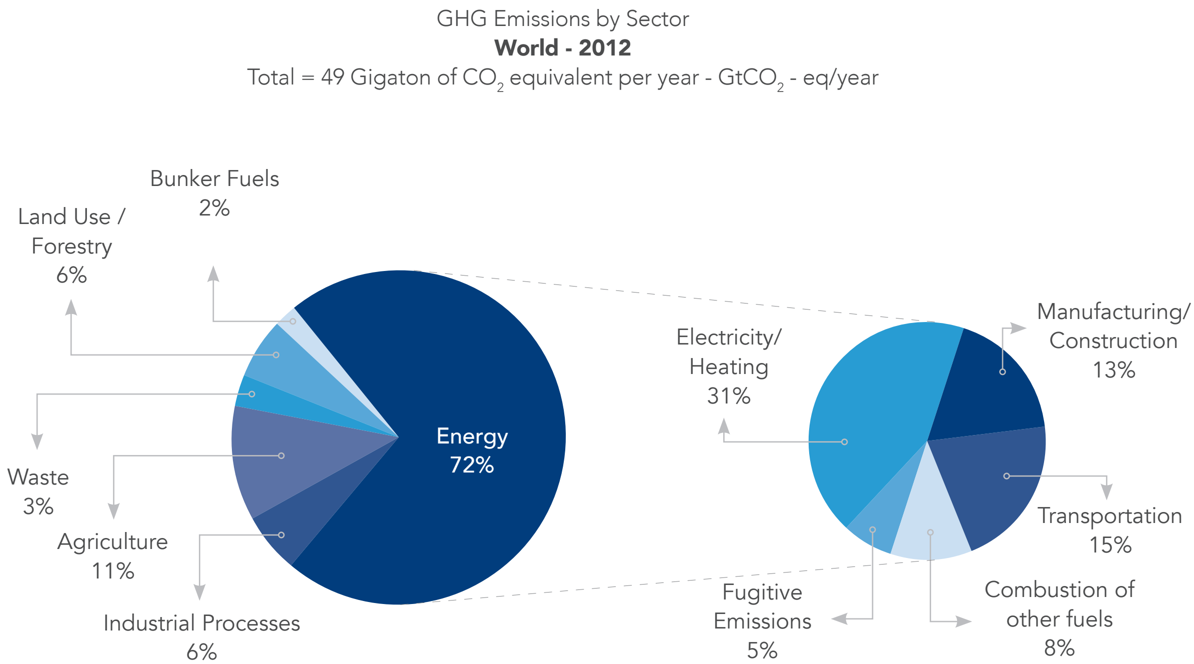
Concerns about climate change and global warming have resulted in the recent formulation and adoption of the Paris Agreement by most of the world's countries, including the world's largest greenhouse gas (GHG) emitters - the US and China.[1]

The message that the Paris Agreement conveys is that the world is willing to transform the way it generates and consumes energy by investing in renewable sources and technology so that its generation and consumption become increasingly sustainable. Along these lines, decarbonization of the transportation sector becomes a key element in achieving this goal. Figure 1 below illustrates the transportation sector's share of global GHG emissions in 2012, the sector with the most greenhouse gas emissions after the Electricity/ Heating sector.

Given the significance of the transportation sector in this great step towards a low carbon economy, this **FGV Energia Publication**, therefore, focuses on electric cars due to their importance in the energy transition for this new economy.

1. For current status of the Paris Agreement ratification see: http://cait.wri.org/source/ratification/#?lang=pt

FIGURE 1: GHG EMISSIONS BY SECTOR - WORLD (2012)



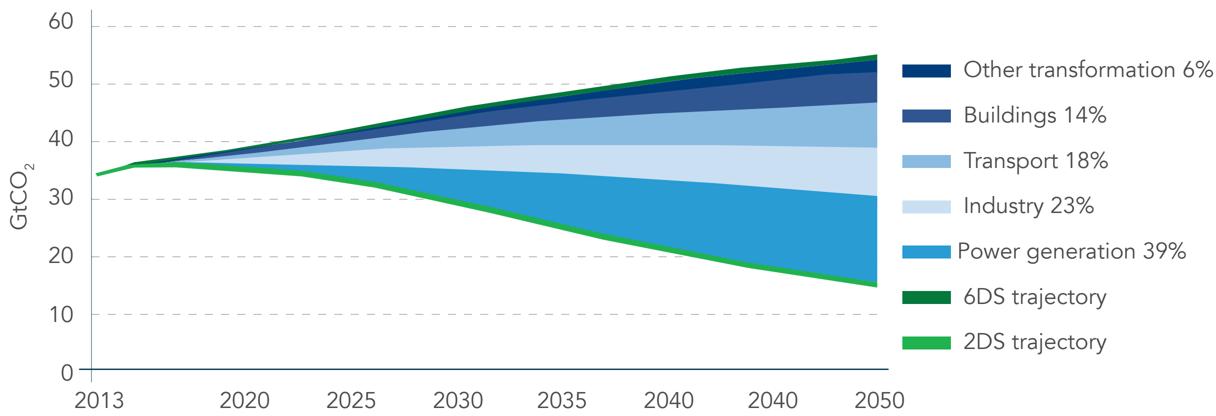
Source: World Resources Institute, CAIT Climate Data Explorer.

But how much to decarbonize so that global temperature increase does not exceed 2° Celsius by the end of this century, as established in the Paris Agreement?

Figure 2 shows projections from the International Energy Agency (IEA), which aim to answer this question. In a scenario in which no action on reducing energy consumption and GHG emissions is taken, global temperature will increase by 6° Celsius by the end of the century (Scenario 6DS). In order to have a 50% chance of limiting this temperature rise to 2°C (Scenario 2DS), the transportation sector must be decarbonized by about 18% by 2050.

And how many electric cars do we need to limit global temperature increase by 2° Celsius? By 2030, the overall stock of electric cars is expected to reach 140 million (Figure 3), 10% of the total light passenger vehicle fleet.

FIGURE 2: GHG EMISSIONS REDUCTIONS BY SECTOR TO 2050 ON A 2DS TRAJECTORY VERSUS A 6DS TRAJECTORY



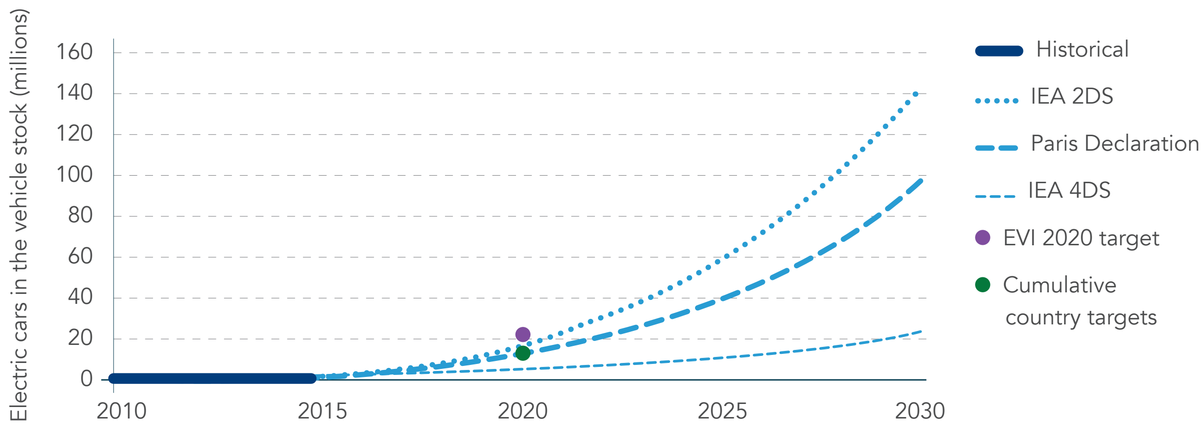
* The IEA 6°C Scenario (6DS) is largely an extesion of current trends and excludes the adoption of transformative policies of the energy system. By 2050, energy use almost doubles (compared with 2010) and total GHG emissions rise even more, leading to an average global temperature rise projected to be at least 6°C in the long term.
Note: $GtCO_2$ – gigatonnes of carbon dioxide.
Key point: Transport accounts for 18% of GHG emissions abatement in the 2DS (decarbonisation scenario) versus the 6DS (conservative projection based on the existing policy framework), by 2050.

Source: Global EV Outlook, IEA, 2016.

Figure 3 also features projections from other institutions for electric car development by 2030: the EVI 20 by 20[2] initiative mentions a global fleet of 20 million electric cars by 2020. The Paris Declaration on Electro-Mobility and Climate Change Call to Action sets a global goal for the deployment of 100 million electric cars and 400 million 2-wheelers and 3-wheelers in 2030. According to the IEA, in order to achieve these goals, substantial market growth is required to increase the current stock of 1.26 million electric cars, as well as implementing more initiatives to further develop other types of electric vehicles around the world - such as 2-wheelers and electric buses.

2. The EVI (Electric Vehicles Initiative) is a multi-governmental policy forum aimed at accelerating electric vehicles introduction and adoption around the world. For more information, see: http://www.iea.org/topics/transport/subtopics/electricvehiclesinitiative/

FIGURE 3: DEPLOYMENT SCENARIOS FOR THE STOCK OF ELETRIC CARS TO 2030



Key point: Reaching 2020 deployment targets for BEVs and PHEVs requires a sizeable growth of the eletric car stock. Meeting 2030 decarbonisation and sustainability goals requires a major deployment of electric cars in the 2020s.

Source: Global EV Outlook, IEA, 2016.

Figure 3 also illustrates the cumulative development goals for electric cars in several countries - which by 2020 will be close to 13 million. Table 1 presents these individual goals. Some of the countries listed have also established or are discussing dates to ban fossil fuel cars: Norway (target for selling only electric cars after 2025), Germany (banning internal combustion vehicles – ICV - after 2030) and India (also banning ICV after 2030).[3] These goals are viewed with skepticism - especially in Germany, a country with a strong automotive industry, but also indicate that policymakers are increasingly considering a low-carbon future for the transportation sector.

3. Deign, 2016.

TABLE 1: GOALS FOR THE STOCK OF ELECTRIC CARS BY 2020 FOR SELECTED COUNTRIES

Countries with announced targets to 2020 or later	2015 EV stock (thousand vehicles)	2020 EV stock target (million vehicles)	EV share of all cars sold between 2016 and 2020	EV share in the total 2020 stock
Austria	5.3	0.2	13%	4%
China*	312.3	4.5	6%	3%
Denmark	8.1	0.2	23%	9%
France	54.3	2.0	20%	6%
Germany	49.2	1.0	6%	2%
India	6.0	0.3	2%	1%
Ireland	2.0	0.1	8%	3%
Japan	126.4	1.0	4%	2%
Netherlands**	87.5	0.3	10%	4%
Portugal	2.0	0.2	22%	5%
South Korea	4.3	0.2	4%	1%
Spain	6.0	0.2	3%	1%
United Kingdom	49.7	1.5	14%	5%
United States***	101.0	1.2	6%	2%

* This target includes 4.3 million cars and 0.3 million taxis and is part of an overall deployment target of 5 million cars, taxis buses and special vehicles by 2020 (EVI, 2016b)

** Estimate based on a 10% market share target by 2020.

*** Estimate based on the achievement of the 3.3 million EV target announced to 2025 in eight US States (California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont). All indicators in this table refer to these eight US states; market share and stock share are asumed to account for 25% of the total US car market and stock.

Source: Global EV Outlook, IEA, 2016.

This transition from conventional internal combustion vehicles to electric vehicles is also the natural evolution of vehicular technology. Existing internal combustion vehicles today are much more efficient than those from years ago, and EV, in turn, are much more efficient than ICV. When EV and ICV reach cost parity - which should occur in the next decade, as will be shown in the following sections – it will be much more advantageous for consumers to have an electric car. Eventually, people will demand EV, basing their choice on the health and environmental benefits that electric cars can bring, especially in large cities, since urban density is expected to increase in the future.

Another interesting benefit of electric cars is the possibility of using their battery as a distributed energy resource - except in some cases, as detailed ahead. Consumers today are increasingly generating and consuming their energy more actively. In a world in which energy consumers become prosumers, electric vehicles and cars become a smart resource for better energy use.

This way, EV are quickly moving towards becoming vehicles of the future. In Brazil, however, this reality is a bit further away, either for technological reasons or because we have a different pace compared to the rest of the world regarding reducing emissions. Nevertheless, given that eventually this technology will have potential to be adopted in this country, the moment is favorable for us to begin the discussion about its implementation and its impacts on the Brazilian energy, environmental, and automotive sectors.

That said, after the initial excitement and technological optimism inherent to adopting any new transformative technology, the purpose of this publication is to present an honest discussion about electric mobility's current status in Brazil and the world, organized as follows: besides this introductory section, Section 2 will explain what are electric vehicles, showing its different technologies, charging infrastructure, batteries, and potential barriers to its expansion. It should be mentioned that, due to the wide scope of electric mobility in various modes of transportation, this paper will focus on light electric vehicles for passenger transportation – or, electric cars. Electric vehicle development in other modes of transportation will be the scope of a future publication.

In Section 3 we will analyze how different countries are using subsidies and incentives to increase electric cars adoption, in addition to how electric cars development will contribute to the rise of new business models. In this Section, we will also discuss how electric cars are another factor contributing to the modernization of urban mobility and the global automotive industry. In the following Section, we'll look at how a wider adoption of electric cars may affect the global environmental and energy sectors - in the latter, the electricity and fossil fuel sectors. Finally, Section 5 will describe the current status of electric cars development in Brazil - current incentives for dissemination and existing initiatives, as well as the impacts that electric cars will bring to the national energy sector.

4. Prosumer: a person who, besides consuming energy from the grid, produces it through distributed generation.

Brief timeline of electric mobility in the world[5]

1801-1850 | The beginning
First models of electric cars are invented in Scotland and the USA

1851-1900 | The first era
Electric cars enter the market and are widely accepted.
Highlights of the period:
1900: EV become the top-selling US road vehicle, taking 28% of the market

1901-1950 | Boom and decline
Electric cars reach a peak, but are soon replaced by internal combustion vehicles (ICV)
Highlights of the period:
1908: ICV Ford Model T goes on the market
1912: The invention of electric ignition eliminates the need for manual cranks, making it easier to drive gasoline cars
1912: Global EV stock reaches the historic mark of 30,000 vehicles
1930s: around 1935, EV are almost extinct due to the predominance of ICV and inexpensive gasoline
1947: Oil rationing in Japan leads Tama automaker to launch an electric car with 4.5cv (horsepower) and a 40V lead-acid battery

1951-2000 | The second era
High price of oil and high levels of air pollution renew interest in EV
Highlights of the period:
1966: US Congress Introduces legislation recommending EV as a measure to reduce air pollution
1973: The Organization of Petroleum Exporting Countries (OPEC) embargo leads to high oil prices, long lines at gas stations, and renewed interest in EV
1976: The French government launches the "PREDIT" program, accelerating R&D in EV
1996: To meet the requirements of California's zero emissions program (ZEV), General Motors begins producing and leasing the EV1 electric car
1997: In Japan, Toyota begins sales of the Prius, the world's first commercial hybrid car. 18,000 are sold in the first year of production.

2001 | The third era
Public and private sectors commit to electromobility again
Highlights of the period:
2003: Launch of Tesla Motors
2008: Oil prices exceed USD 145/barrel
2010: the BEV (Battery Electric Vehicle) Nissan Leaf is launched
2011: the car-sharing service Autolib is launched in Paris, targetting a stock of 3,000 EV
2011: Global EV stock reaches new historical mark of 50,000 vehicles
2015: Global EV stock reaches new historical mark of 1.26 million vehicles [6]
2015: Charging stations (public and private, slow and fast) reaches 1.45 million in the world – values for 2014 and 2010 were 820,000 and 20,000, respectively
2016: Price of Tesla's battery pack reaches a record low of USD 190/kWh[7] - with Tesla's Gigafactory starting production in December this year, this figure will be increasingly close to USD 100/kWh (a key value for EV massification)
2017: Tesla Model 3 reserves reach 530,000, twenty-four months before expected vehicle delivery[8]

5. Adapted from Global EV Outlook, IEA, 2013.
6. Global EV Outlook, IEA, 2016.
7. Lambert, 2017.
8. Source: http://model3counter.com/


P

Electric Vehicles (EV): definitions

Electric vehicles (EV) are those that use one or more electric engines for propulsion, partially or completly . The fuel electric vehicles use is electricity, which may be obtained in different ways: through direct conection to an external source of electricity, using plugs or aerial cables; using electromagnetic induction system; from hydrogen and oxygen reacting with water in a fuel cell[9]; or by mechanical braking energy (regenerative braking, when braking the vehicle). This electricity is then stored in chemical batteries[10] that power the electric engine.

As mentioned in the introduction, although EV are found in many modes of transport, this publication will focus on light electric vehicles (passenger cars) for passenger transportation.

EV are considered "zero emission" vehicles because they do not emit pollutants (atmospheric and noise). In addition, their engine efficiency (engine capacity to generate work) can be as high as 80%, which makes them much more efficient than vehicles equipped with internal combustion engines, whose energy efficiency is between 12% and 18%.[11] Driving more EV will also reduce dependence on fossil fuels, especially

9. The source of oxygen for this reaction to happen is atmospheric air. As for hydrogen, it can be supplied directly from an external source, from a storage tank, or by a chemical reaction that produces hydrogen from ethanol in the Solid Oxide Fuel Cell (SOFC. Source: Barbosa, 2016).
10. With the exception of fuel cell electric vehicles, which do not need to store electricity in batteries since the fuel needed to power the vehicle is generated by a reaction of hydrogen or oxygen with water.
11. https://www.fueleconomy.gov/feg/evtech.shtml#data-sources

oil. As a result, governments in several regions have invested in this type of mobility: from 2014 to 2016, the number of EV on the roads has doubled.[12] Over 1 million EV were in use in 2015, resulting in an increased market share in seven countries, reaching 23% in Norway, 10% in the Netherlands, and surpassing 1% in 5 other countries: Sweden, Denmark, France, China, and the United Kingdom.

ELECTRIC VEHICLES' DIFFERENT TECHNOLOGIES[13]

There are four different types of EV. First, there are pure electric vehicles (BEV - Battery Electric Vehicles[14]), whose main source of energy is electricity from external sources (the electric grid, for example). Electricity is stored in an internal battery, which feeds the electric engine and moves the wheels. Since these vehicles use exclusively electricity as fuel, they are considered all-electric vehicles. All BEV are plug-in electric vehicles (PEV), since electricity is supplied from an external source – hence, the term plug-in, or "plugged in."

PEV can also include some hybrid EV, which are those that use both electric and internal combustion engines for propulsion. Hybrids are classified as in series (use only the electric engine to power the car, with the internal combustion engine providing electricity to the electric motor) or in parallel (use both motors for propulsion).[15] There are three types of hybrid electric cars[16]:

- Pure hybrid (HEV - Hybrid Electric Vehicle). The internal combustion engine is the main responsible for moving the vehicle. The electric motor just improves the internal combustion engine's efficiency by providing traction at low power. Therefore, this is a parallel hybrid. Electricity for the electric motor is provided by the vehicle's regenerative braking system.

- Plug-in Hybrid Electric Vehicle (PHEV), whose internal combustion engine is also the main one, but can also receive electricity directly from an external source. Like the HEV, the PHEV is a parallel hybrid. Since it also uses traditional fuels (fossil or biofuels), when compared to the BEV, the PHEV generally guarantees greater range.

- Extended Range Electric Vehicle (E-REV) is a hybrid vehicle with motors in series: the main motor is electric - which is powered directly by an exter-

12. Global EV Outlook, IEA, 2016.
13. http://thechargingpoint.azurewebsites.net/knowledge-hub/ev-glossary.html, Global EV Outlook, IEA, 2013.
14. Also known as: BOEV (Battery Only Electric Vehicle), AEV (All Electric Vehicle) or pure electric.
15. Some manufacturers also use the terms full-hybrid or strong-hybrid for parallel hybrids.
16. There are also semi-hybrid vehicles (mild hybrid) and micro-hybrid vehicles, in which the electric motor does not have sufficient power to move the car. For more information, see German, 2015.

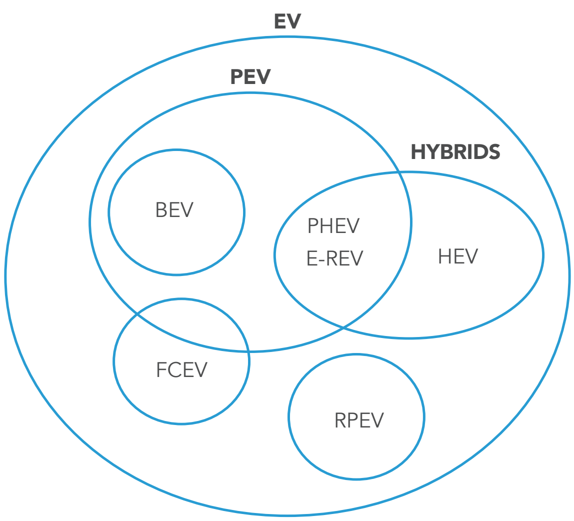
nal electric source - with the internal combustion engine providing power to a generator, which maintains a minimum level of battery power, giving the E-REV extended range.

Electric vehicles powered by hydrogen fuel cell (FCEV - Fuel Cell Electric Vehicles) combine hydrogen and oxygen to produce the electricity that will run the motor. Hydrogen gas conversion into electricity produces only water and heat as by-products; in other words, there are no exhaust emissions. Compared with other types of EV, FCEV's range is similar to gasoline or diesel powered vehicles (300-500 km), and is therefore bigger than most EV. This greater range guaranteed by hydrogen cells makes them more suitable for vehicles that travel long distances (such as cargo vehicles) and also for users who do not have plug-in access in their homes.[17]

In addition, it is worth mentioning the RPEV (Road Powered Electric Vehicle) which, by definition, receives electricity through directly connected external cables, whether above the vehicle - such as trolley buses and trucks on electrified ports and roads - or below the vehicle – such as the Light Rail Vehicle (LRV).

Most[18] electric vehicles have chemical batteries to store the electricity needed to power the engine and move the vehicle - the range (distance traveled per recharge) of each EV depends on the type and model in question. Older EV used lead-acid (NiMH) batteries, while newer ones use lithium-ion (li-ion) batteries. Figure 4 and Figure 5 classify electric vehicles.

FIGURE 4: TYPES OF ELECTRIC VEHICLES (EV)

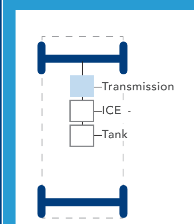
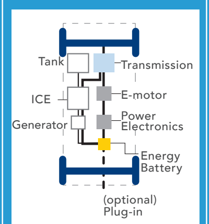
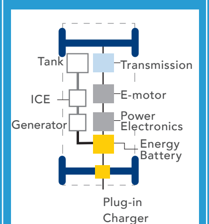
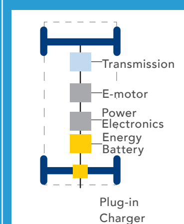
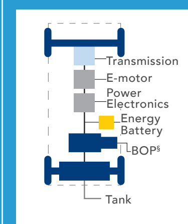


Source: Elaborated by the authors

17. FCEV can also be plug-ins. For more details, see: Fuel Cells Bulletin, 2016.
18. See footnote 10.

FIGURE 5: CHARACTERISTICS OF ELECTRIC VEHICLES

- ☐ Power transmission from an internal combustion engine
- ■ Power transmission from a fuel cell
- Transmission
- Battery
- Power transmission from an electric motor

	ICE IS THE PRIMARY SOURCE OF PROPULSION		ELECTRIC MOTOR IS THE PRIMARY SOURCE OF PROPULSION		
Type of vehicle	Internal combustion engine (ICE) 	Hybrid plug-in vehicle (P)HEV 	Extended range electric vehicle (E-REV or REX) 	Battery electric vehicle (BEV) 	Fuel cell electric vehicle (FCEV) 
Engine type	Internal combustion engine	Electric and internal combustion engines arranged in parallel; optional plug-in system. Combustion engine is the main engine to power the vehicle, aided by a small electric motor.	Electric and internal combustion engines arranged in series. Electric motor is the main motor moving the vehicle, with the internal combustion engine generating electricity for the electric motor.	100% electric	Fuel cell and electric motor system, which powers the vehicle, arranged in series.
Type of fuel	Fossil or biofuel. High fuel consumption and exhaust emissions.	Fossil, biofuel, or electricity. Better fuel efficiency compared to a similar internal combustion model.	Electricity	Electricity	Hydrogen or ethanol

Type of electrical storage	Battery that does not depend on electrical infrastructure	Battery charged through the internal combustion engine or by electricity (for plug-in hybrids)	Battery is charged same as in the hybrid. In addition, it usually has a lower battery capacity than the BEV.	Lithium-ion battery with great capacity, charged by external electric source	Hydrogen fuel cell based on PEM[19] (Proton Exchange Membrane) technology; solid oxide ethanol fuel cell (SOFC)
Range	Great range provided by fossil fuel/ biofuel	Little electrical range, complemented by range provided by fossil fuel/biofuel engine	Average electrical range, complemented by range provided by fossil fuel/biofuel engine	Small to medium electrical range (compared to ICV)	Medium to high electrical range
Additional Information	Some models feature continuous optimization (automatic start-stop system)	Fully electric steering at low speeds and short distances only	Small internal combustion engine for greater range, if compared to BEV (extended range)		
Average entry price of a model in the USA (illustrative examples)	USD 18,000*	USD 34,000**	USD 44,000***	USD 29,000****	USD 60,000*****
Emissions[1]	0.23 kg CO_2/Km	0.062 kg CO_2/km	0.060 kg CO_2/km	Zero	Zero

* Average price of a Toyota Corolla with 148hp ** Chevrolet Volt model 2016, range of 85 km and 149hp *** BMW i3 model 2016, electric range of 184 km and extended range of 290 km. 170hp **** Nissan Leaf model 2016, range of 172 km and power equivalent to a car with 1.0 engine, 120hp ***** Toyota Mirai model 2016, range of 502 km and 152hp.

1 Figures calculated from the US Department of Energy's Vehicle Cost Calculator.

2 Source: Global EV Outlook, IEA, 2013.

3 Ibid.

§ Balance of plant: various required support components (eg. humidifier, pumps, valves, compressor)

Source: Elaborated by the authors, adapted from Amsterdam Round Tables in collaboration with McKinsey & Company.

19. Considered the most versatile type of fuel cells currently in production; they are capable of generating the highest amount of energy for a given volume of cells. http://www.nedstack.com/faq/about-pem-fuel-cells

Given the technologies listed in Figure 5, we would like to point out that this publication will focus on electric cars; that is, road vehicles for private passenger transportation, whose new registrations increased by 70% from 2014 to 2015, and whose sales around the world reached 550,000 in 2015.[20] China is a world leader in new electric car registrations and thus has the largest market for these vehicles, surpassing the United States in 2015. Together, these two countries accounted for over half of new EV registrations made globally in 2015. In addition to these, Norway and the Netherlands stand out as the countries with the largest market shares. These countries have implemented a series of measures to encourage consumers to opt for electric cars, such as significant reductions in registration and circulation charges, and privileged access to some areas of the transportation network.

Other figures justifying the focus of this publication are those referring to electric car stocks[21], which reached 1.2 million in 2015[22], an estimate 100 times higher than predicted in 2010. That same year, 2015, electric car stock growth exceeded 77%, and in 2014 this figure had already reached 84%.

Given that there is still a long way to go, despite all this significant growth, the world's electric car stock is still small (0.1%) when compared to the total number of passenger cars, which was close to 1 billion in 2015. The Electric Vehicles Initiative (EVI) estimates that the goal of 20 million electric cars will be reached by 2020, which will correspond to a global market share of 1.7%.[23]

As already mentioned, EV are present in a variety of modes of transportation, such as public transportion, cargo, and even aviation, as described in the box below.

20. Global EV Outlook, IEA, 2016.
21. We call "Stock" the total number of vehicles in circulation (fleet) plus vehicles available for sale at dealerships.
22. Number of countries included in the Global EV Outlook, IEA, 2016: 40 countries, accounting for 98% of the global stock of electric cars.
23. *Global EV Outlook*, IEA, 2016.

EV in other modes of transportation

EV can be found in all modes of transportation, at different stages of development. Much of the recent innovation happens in the ground transportation sector, especially among light electric vehicles (automobiles and motorcycles, which include e-bikes, e-scooters, 2-wheelers, and 3-wheelers).

However, there is growing interest in implementing EV in the public transportion sector - including trains, buses, light rail vehicles (LRVs), trolley buses, and boats. Electric buses are already becoming more common in large urban centers.[24] Luxembourg and Italy were pioneers in introducing this technology in their large cities, and Beijing (China) and New York (USA) also have electric buses on their streets. In Brazil, for example, there are already over 400 electric buses operating in São Paulo's metropolitan area.[25] Electric buses are beneficial both to the environment - as it is a clean technology – and to passengers, who can travel more comfortably and with less pollution. Residents of these cities will also benefit from cleaner, quieter streets.

As for cargo transport, developing trucks powered only by electricity is a major challenge, but electric trucks are already being tested in different countries and applications. For example, a 40-ton all-electric truck operating in regular service began circulating on the streets of Germany in 2015. This model, by BMW,[26] needs 4 hours to fully charge and has a range of 100 km. It is also worth mentioning that in 2016, in Sweden, Siemens, in partnership with Scania, started testing eHighaway, whose electric trucks promise to have motors twice as efficient as traditional internal combustion engines.

24. In addition to public transportation, electric buses are already being used in private company fleets. For instance: at Itaipu Binacional.
25. Source: Eletra (http://www.eletrabus.com.br/eletra_por/empresa.html)
26. Vincent, 2015.

This innovation by Siemens provides electricity through external cables located above the trucks that are directly connected to them.

In aviation, EV development is still in its infancy. In one of the most ambitious projects, engineers at NASA (National Aeronautics and Space Administration) are developing and testing systems that promise to be part of the "next revolution in aviation." According to them, the increased use of electricity in engines will interest airlines that need to reduce emissions, use of fossil fuels, engine noise, and maintenance costs. Recently, in March 2016, Solar Impulse, an electric plane powered by solar energy, began an unprecedented journey: traveling over 40,000 kilometers around the world using only solar energy. It was 12 years of research and development that sought to demonstrate to the world that clean technologies are already a reality and can change the fate of the planet. In Brazil, the first national electric plane, developed by Itaipu Binational's Electric Vehicle Program, made its first flight in June 2015. These initiatives allow us to imagine a near future with electric airplanes.

Finally, it is worth emphasizing that there is a robust and diversified industry, both in Brazil and abroad - especially in North America and Asia - of light electric vehicles, including forklifts[27]; buses; carts used in airports, industries, and golfing; and for commuting in urban areas, such as neighborhood electric vehicles (NEV, small electric vehicles that do not exceed 40km/h). Most of electric vehicles in Brazil are used as equipment in the industrial sector, such as forklifts, tugboats, and loaders.

27. The port of Los Angeles has several initiatives: https://www.portoflosangeles.org/environment/zero.asp

CHARGING INFRASTRUCTURE

For electric vehicles to become widespread, a main requirement is building a charging infrastructure, since, without having where to charge their cars, users feel limited and less willing to purchase this type of vehicle. Therefore, there is a direct and proportional relationship between EV growth in the market and the type of infrastructure developed: while charging infrastructure is not yet necessary since there are very few electric vehicles in the streets, cars can only get into the market if a well-developed infrastructure already exists. This interdependence exists in the countries studied by the Global EV Outlook 2016 report, which shows that the total number of publicly owned charging stations has grown along with electric cars stock; that is, there is a positive correlation between EV adoption and development of public charging infrastructure. A main variable for charging infrastructure development concerns investment costs, since they are not restricted to the stations themselves, but also consist of adapting the electric power grid network, in addition to, of course, various operation and maintenance costs.

Charging stations (also known as Electric Vehicle Supply Equipment - EVSE, or Electric Vehicle Charging Station - EVCS) provide electricity to charge electric vehicles batteries from an electric power source, communicating with it in order to ensure that adequate and safe flow of electricity is provided. These charging points are distributed in public and private areas. One challenge for home charging is the need of private parking, and once it is available, these parking spaces will require specific outlets. Faced with this issue, public charging stations or workplace charging also become solutions.

In 2015, most countries with high EV sales volumes[28], such as China, Denmark, France, Germany, Japan, the Netherlands, Norway, Portugal, Sweden, United Kingdom, and United States, provided tax incentives for private charging stations. In addition, for public charging, 36,500 charging stations were installed in the USA in 2015 through a federal funding program[29]. The federal governments in Japan and Denmark sought partnerships with the private sector for installing public charging stations.[30] Thus, what we see today is the popularization of EVSE in various parts of the world, as well as ambitious targets for 2020-2030: in China, the goal is to install half a million public and over 4 million private charging stations; France wants to reach 7 million EVSE throughout the country; and India is committed to developing approximately 200,000 charging stations by 2020.[31]

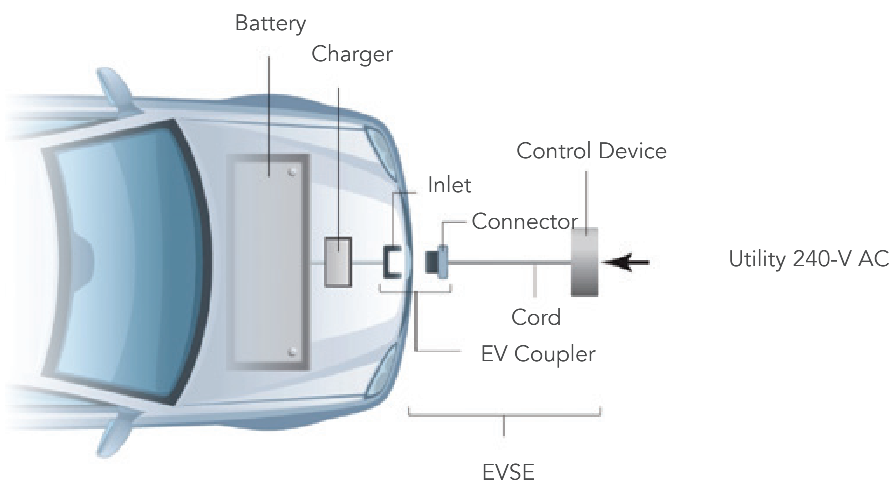
28. Global EV Outlook, IEA, 2016.
29. Ibid.
30. Ibid.
31. Ibid.

EVSE AND EV CHARGING: MAIN FEATURES

EVSE include connectors, conductors (cords), accessories, and other associated equipment,[32] which is plugged into the EV and provides electricity to charge the vehicle battery (Figure 6).

EV charging is classified according to the maximum amount of electricity available, which in turn affects charging speed. The battery type, use, and capacity also affect charging speed - which varies between 30 minutes and 20 hours.[33] Therefore, it is necessary to distinguish charging types considering voltage level and type of current (direct or alternating).

FIGURE 6: EXAMPLE OF EVSE (LEVEL 2 CHARGING – SEE TABLE TABLE 2)



Source: U.S. Department of Energy, 2015.

32. Global EV Outlook, IEA, 2013.
33. Industrial equipment, such as forklifts and electric trucks, has specific chargers produced by specialized companies. Small electric vehicles, for domestic use or light services, are charged through adapted domestic outlets.

TABLE 2: CHARGING TYPES ACCORDING TO CHARGING LEVEL[34]

Level*	Typical locations	Voltage and Type of Current	Range per hour of charging
Level I	Homes and workplaces	127 V Alternating current	3km to 8km
Level II	Homes, workplaces, and public spaces	220-240 V Alternating current	10km to 96km
Fast Charger**	Public spaces	Can reach up to 600 V Alternating or direct current	96km to 160km

* Levels I and II are called "slow chargers." Although it would be natural to call DC fast chargers "Level III" chargers, this term is not technically correct because the so-called "Level III" means only that the vehicle has charging ports for both Levels I and II separately. In addition, they provide direct current to the battery through a special adapter, while Level I and Level II chargers only provide alternating current to the vehicle. Some calls Tesla superchargers "Level IV chargers" because they are super-fast.

** Does not include Tesla superchargers, which have charging capacity to provide range of about 270 km in 30 minutes.

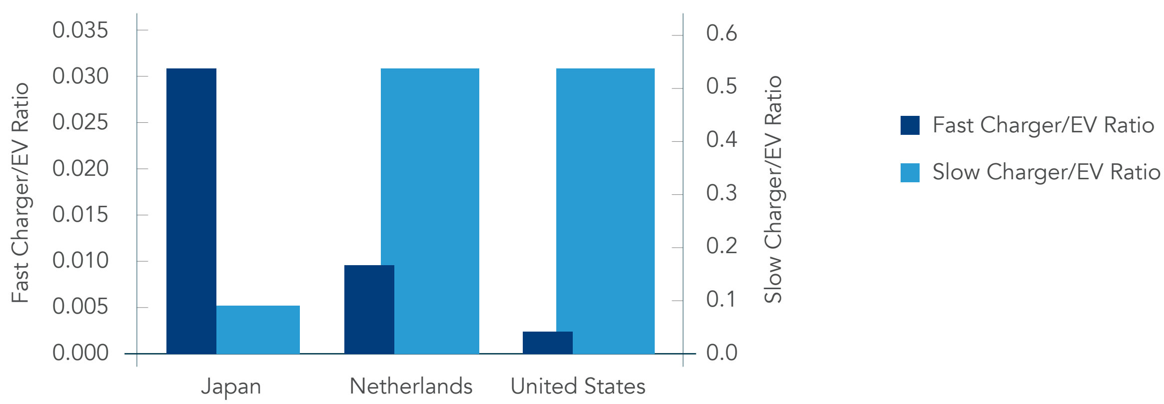
Source: Global EV Outlook, IEA, 2016.

34. Adapted from the U.S. Department of Energy (http://energy.gov/eere/eveverywhere/ev-everywhere-vehicle-charging)

Level I charging may be sufficient for PHEV, since their batteries have lower capacities and, therefore, take less time to charge. For BEV, Level I charging is more suitable for home charging because it takes longer. On the other hand, Level II charging charges both hybrid and all-electric vehicles in a reasonable time and, for this reason, it has been considered the standard charging level. Regarding fast chargers, despite conveniently charging batteries in a much shorter time than other levels, costs for developing this infrastructure are also higher.

Due to these higher costs, fast charging station development has received incentives from BEV manufacturers , which is the case in Japan, where all-electric models mostly dominate the EV market. By 2012, Japan had already installed 1,381[35] fast chargers, more than any other country, paying less attention to developing slower charging levels. In contrast, in the United States, slow charging is more fostered due to PHEV predominance and also preferences for home charging stations. Each country opts for the EVSE network that best meets its local specificities, without having a right alternative that must be followed by all. These differences are clearly shown in Figure 7 below.

FIGURE 7: DIFFERENT EVSE DEPLOYMENT PROFILES, 2012



Source: Global EV Outlook, IEA, 2013.

35. Global EV Outlook, IEA, 2013.

In addition to standard charging using a power cord, as discussed in Table 2, there is induction charging, popularly called wireless, which uses an electromagnetic field to charge vehicles. In other words, it does not require physical connection between the car and the charging station. There are two types of wireless charging: WPT (Wireless Power Transfer), which charges the vehicle while parked[36]; and electrified highways, where charging happens while the vehicle is moving.

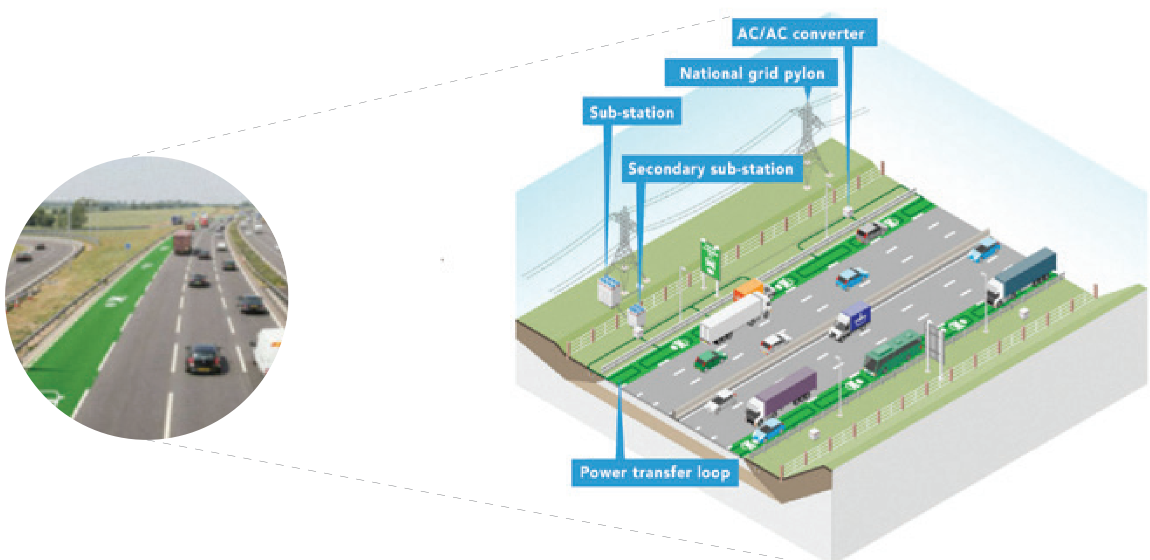
Electrified highways are still not used on a large scale everywhere in the world, but some countries are already taking initiatives: Highways England announced in 2015 that it will carry out wireless road charging tests in the UK as a way to incentivize electric vehicles, since this type of charging allows cars to travel long distances without having to stop and charge. In addition, some EV models, such as Nissan Leaf (BEV), Chevrolet Volt (PHEV) and Cadillac ELR (PHEV), already have or are developing this charging technology.[37] It is expected that in the future, wireless charging, shown in Figure 8, will allow drivers to simply park in a designated location where their cars will be charged. What's more, driveless cars in the near future will be able to park autonomously in an available wireless charging location and return to the road when charging is complete.[38]

36. In early 2017, the new J2954 standard proposed by SAE International for wireless charging equipment was announced. With this, agreement, a higher degree of interoperability between brands and in several countries can be reached in the future. Adopting this standard should make wireless charging cheaper and more attractive (Source: Hanley, 2017).
Note: SAE International is a global association of over 128,000 engineers and technicians specializing in the aerospace, automotive, and commercial vehicle industries (http://www.sae.org/about/board/vision.htm).
37. Plug-In Electric Vehicle Handbook for Consumers, U.S. Department of Energy.
38. Source: Hanley, 2017.

FIGURE 8: WIRELESS CHARGING[39]

TRADITIONAL WIRELESS CHARGING

EXPERIMENTAL CHARGING ON ELECTRIFIED HIGHWAY

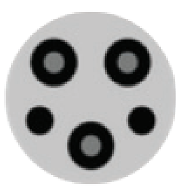
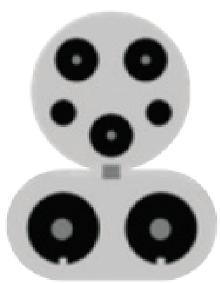
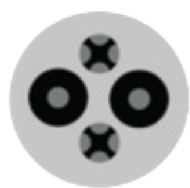
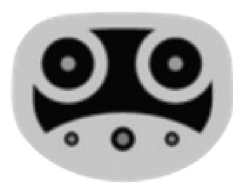


Source: Highways England & Jones.

39. Adapted from: Shahan, 2015.

The charging performed will also depend on the inlet (receptor) in the vehicle (see Table 3). Levels I and II charging are compatible in all vehicles with standard connector and inlet: type 1 (SAE J1772, or Yazaki connector), used in the USA and Japan; and type 2 (VDE-AR-E 2623-2-2, or Mennekes connector), used in Europe and China.[40] Some European countries are advocating a third connector type, type 3, or EV Plug.

TABLE 3: CONNECTOR/INLET TYPES FOR EV CHARGING PER CHARGING LEVEL

SAE J1772/ VDE-AR-E 2623-2-2: Charging levels I and II	**SAE J1772 Combo (*Combined Charging System* – CCS): DC Fast Charger**	**CHAdeMO: DC Fast Charger**	**Tesla Combo Supercharger**
			

Source: adapted from U.S. Department of Energy: https://energy.gov/eere/electricvehicles/all-electric-and-plug-hybrid-vehicles.

40. The American/Japanese and European/Chinese standards for charging Levels I and II have similar requirements, adapted to voltages of each location. Most differences in terminology are superficial. Where the SAE standard describes "methods" and "levels," the European standard talks about "modes," which are practically the same (charging Level I equals Mode I, and so on). Source: Tuite, 2012.

While a standard for charging Level I and II connectors/inlets already exists, a standard for fast chargers has not yet been established. Fast chargers have three different types of connectors/inlets:

- SAE Combo, or CCS, from SAE International: SAE J1772 standard adapter, so that the same inlet can be used for all charging levels (available in models such as BEV Chevrolet Spark EV);
- CHAdeMO (available in the Nissan Leaf and Mitsubishi i-MiEV BEV, for example); and
- Tesla Supercharger (only available in Tesla vehicles[41]).

Despite the absence of a standard, public fast chargers that serve both SAE and CHAdeMO connectors are becoming increasingly common.

FIGURE 9: EV WITH BOTH SAE J1772 INLETS FOR LEVEL 1 AND 2 CHARGING (RIGHT) AND CHADEMO FOR FAST CHARGER CHARGING (LEFT)

Source: U.S. Department of Energy: https://energy.gov/eere/electricvehicles/vehicle-charging.

41. Tesla vehicles can also use CHAdeMO connectors through an adapter. All Tesla vehicles are BEV.

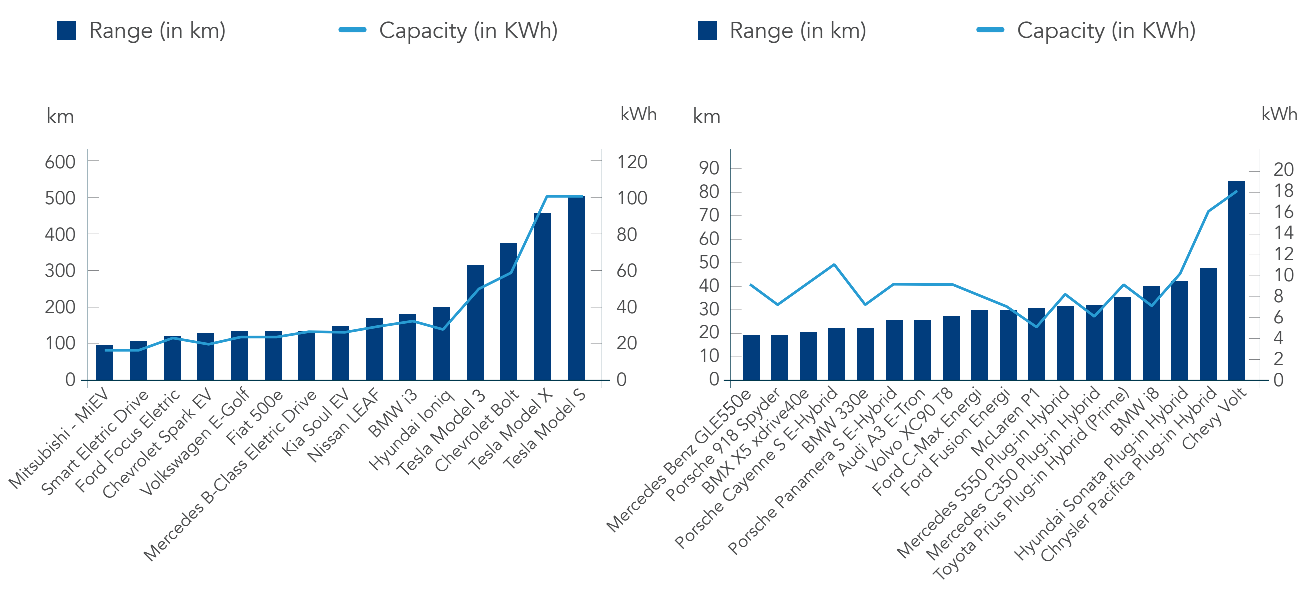
BATTERIES

Electric vehicles batteries are charged when connecting the vehicle to an external source of electricity. EV are also charged, in part, by regenerative mechanical energy, also known as regenerative braking. Depending on EV type, different batteries may be considered:

- Nickel-metal hydride - Ni-MH: available in hybrid models using start-stop technology and micro-hybrids;
- Lithium-ion - Li-ion: available in BEV and hybrid models;
- Sodium nickel chloride - Na-$NiCl_2$: available in heavy electric vehicle models (trucks, buses, etc.) and PHEV.[42]

Due to their reduced cost and improved performance, lithium-ion (li-ion) batteries have been more widely adopted by EV manufacturers. The charts in Figure 10 show battery capacities for some BEV and PHEV models

FIGURE 10: RANGE - BATTERY CAPACITY RELATION IN BEV (LEFT) AND PHEV (RIGHT) MODELS IN THE USA



Source: Developed internally based on data available at PluginCars.com

42. EUROBAT, 2015.

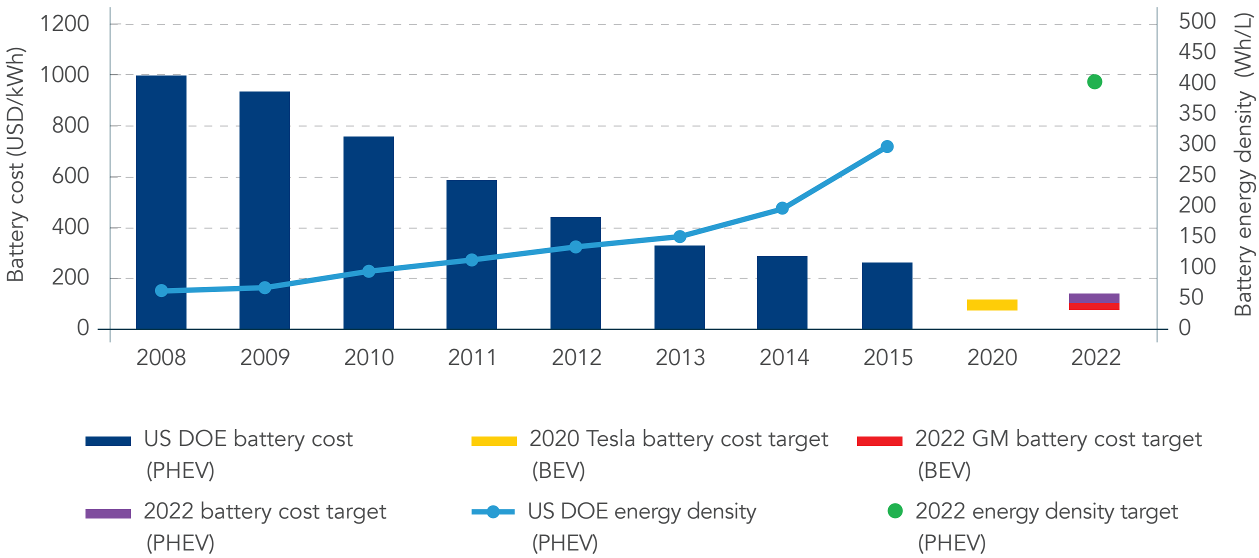
in the USA. Note that, generally, for BEV, the larger the battery capacity, the longer the car's range. In the case of PHEV, this relationship is not very strong.

As for nickel-metal hydride batteries, they have reached a relatively high degree of technological maturity, so small improvements in their performance and cost are expected between now and 2030.[43] Sodium nickel chloride batteries, in turn, are used in heavy electric vehicles (buses and trucks) and PHEV. In the future, new technologies (for example, zinc-air, lithium-sulfur, lithium-air) may become competitive enough to be considered as options for EV batteries, according to a report prepared by the Association of European Automotive and Industrial Battery Manufacturers (EUROBAT).[44] However, these technologies are still in early development stage.

Batteries development is closely associated with a greater diffusion of electric vehicles. Thus, research and development (R&D) needs to focus on performance and cost issues. In particular, for sodium nickel chloride batteries, research priorities are aimed at improving production process and system integration, as well as reducing costs. For lithium-ion batteries, the primary goals are to increase energy and power densities and reduce costs. Improving batteries' energy density is important because the higher the energy density, the more efficient energy storage becomes. These improvements, in turn, will result in batteries and, consequently, lighter,[45] smaller, and less expensive[46] electric vehicles with a larger range. Figure 11 shows cost evolution - which has dropped by approximately 75% since 2008, while battery density has grown over 330% over the same period - and projections for 2022, which point to increased density and decreased kWh value.

43. Ibid.
44. Ibid.
45. For example, the Tesla Model S, which has a 100 kWh battery and weighs 2,086 kg, is much heavier than an ICV like the Toyota Corolla, which weighs around 1,300 kg. With battery density evolution, however, it is expected that future EV will be as light as ICV (DeMorro, 2015). Lighter batteries will also result in more energy efficient EV (Gustafsson & Johansson, 2015).
46. IEA, 2011. In 2012, the battery of a Nissan Leaf equaled one third of the total price of the car (Global EV Outlook, IEA, 2013).

FIGURE 11: EVOLUTION OF BATTERY ENERGY DENSITY AND COST



Notes: USD/kWh = United States dollars per kilowatt-hour; Wh/L = Watts-hour per litre. PHEV battery cost and energy density data shown here are based on an observed industry-wide trend, include useful energy only, refer to battery packs and suppose an annual battery production of 100 000 units for each manufacturer.

Source: Global EV Outlook, IEA, 2016.

Batteries' technological evolution will also address safety issues: lithium-ion batteries have a higher risk of fire when overheated.[47] For example, fires of some Tesla Model S are still under investigation.[48]

Other technological advances may also contribute to EV battery development. An example is recent research on supercapacitors, most commonly used in larger electric vehicles such as buses, which indicates their viability in light electric vehicles. This new technology aims to increase EV range and reduce charging time, approaching internal combustion engine models.[49] Another advantage of supercapacitors over lithium-ion batteries is their better performance at low temperatures. Extreme temperatures (very cold or hot) af-

47. For more information, see: Bullis, 2013a.
48. Lambert, 2016a.
49. Macaulay, 2016.

fect battery performance and, consequently, the range of electric vehicles.[50]

Therefore, all of these improvements would contribute to electric vehicles becoming mainstream. Governments, car manufacturers, and drivers have similar requirements for batteries: they should last longer, charge faster, be denser, cheaper, and lighter. They must also be safe, technically reliable, and easily recyclable.[51] Industry experts usually place batteries cost below USD 100 per kilowatt-hour for EV to become mainstream.[52] Tesla, for example, aims to reach that value by increasing production of lithium-ion batteries at Gigafactory, a Tesla and Panasonic battery "mega-factory," which is being built in the Nevada desert.[53]

BARRIERS TO EV EXPANSION

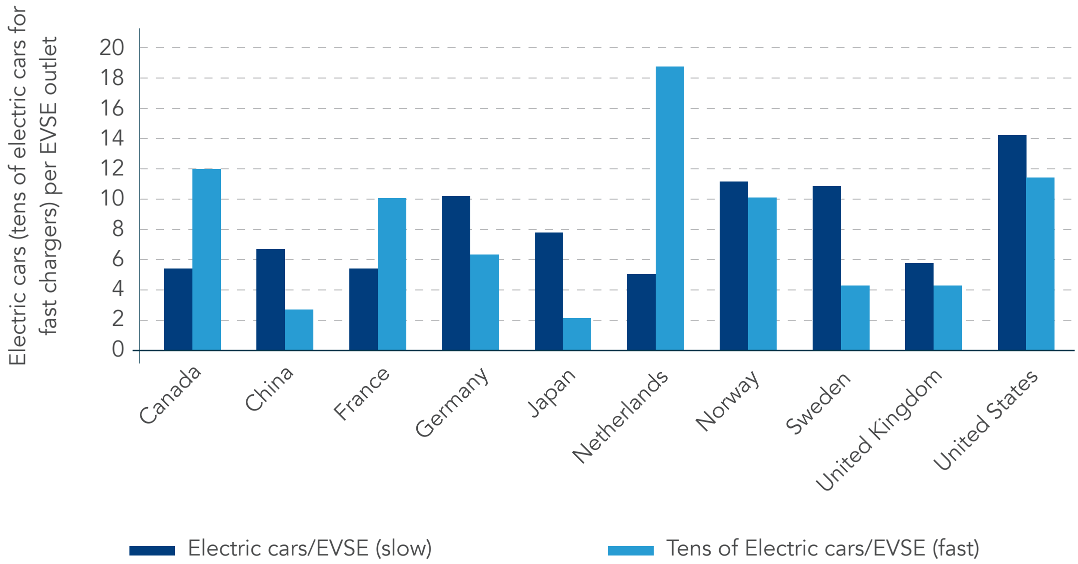
In this section, we will analyze the main barriers to EV adoption expansion, such as increasing availability of charging infrastructure, improving battery range, reducing charging time, and reducing EV prices. Attempts by several countries to overcome these barriers will be described in the following sections.

EVSE NETWORK OPTIMIZATION AND STANDARDIZATION

How many charging stations would be necessary to expand electric vehicles at a given location? As already mentioned, each country invests in a given type of public charging infrastructure that best meets their needs, with the US prioritizing slow charger infrastructure expansion (non-residential slow chargers), while Japan has been investing more in fast chargers. A 2011 study by the European Commission estimated that the ideal ratio between electric cars/public stations is from 1.25 to 3.3.[54] Figure 12 shows that in 2015 this figure is reached only by the US (for slow chargers) and the Netherlands (for fast chargers). There is no consensus, however, among these countries on what would be the optimal ratio.[55] Nevertheless, all agree that there is a positive correlation between EVSE implementation and EV dissemination.[56]

50. U.S. Department of Energy, 2015.
51. EUROBAT, 2015.
52. Pyper, 2016. Battery cost reduction will affect not only EV's final price, but also prices for battery replacement outside the manufacturer's warranty.
53. Wesoff, 2016.
54. International Council on Clean Transportation, 2011.
55. Global EV Outlook, IEA, 2016.
56. Ibid.

FIGURE 12: ELECTRIC CARS/EVSE STOCK RATIO FOR SLOW AND FAST PUBLICLY AVAILABLE CHARGERS IN 2015



Source: Adapted from Global EV Outlook, IEA, 2016.

Standardization would contribute for charging station dissemination. In general, internal combustion vehicle fuel infrastructure does not vary greatly. For EVSE, depending on the country and charging level, charging infrastructure may vary. Also, different EV do not have the same inlet standard for different connector levels - something that has been changing in newer EV models, which have inlets for both slow (Levels I and II) and fast chargers. But most existing connector standards around the world have continental range: driving an EV across Europe will not cause many compatibility problems with existing EVSE in different countries throughout the continent. The same applies to the USA. There are those who argue that a global standard would facilitate EV expansion and reduce costs.[57]

57. Global EV Outlook, IEA, 2013.

ADAPTING TO A NEW TECHNOLOGICAL PARADIGM

A benefit that EV have over internal combustion vehicles is greater freedom from public supply infrastructure, since they can be charged at the user's home or workplace - which may be less expensive. However, infrastructure development for charging EV in public areas is strategic so that users may adapt and accept this new technological paradigm. Internal combustion vehicles drivers are accustomed to fueling their vehicles when and where they want, as they rely on a very wide network of gas stations available[58] - a network that has grown since it came into existence in the 19th century. Therefore, changing this fueling standard - from public space to the residence - can take time and should occur gradually, and a public EV charging network development will play an important role in this transition.

RANGE CONSIDERED LIMITED

Although range still needs to improve, enhancements in battery energy density, as shown in Figure 11, were responsible for recent progress, significantly contributing to reducing range anxiety,[59] which is anxiety caused by the fear of not being able to charge an EV when necessary. Charging infrastructure dissemination, increase in battery range, and charging time reduction will also contribute to reducing or eliminating this problem.

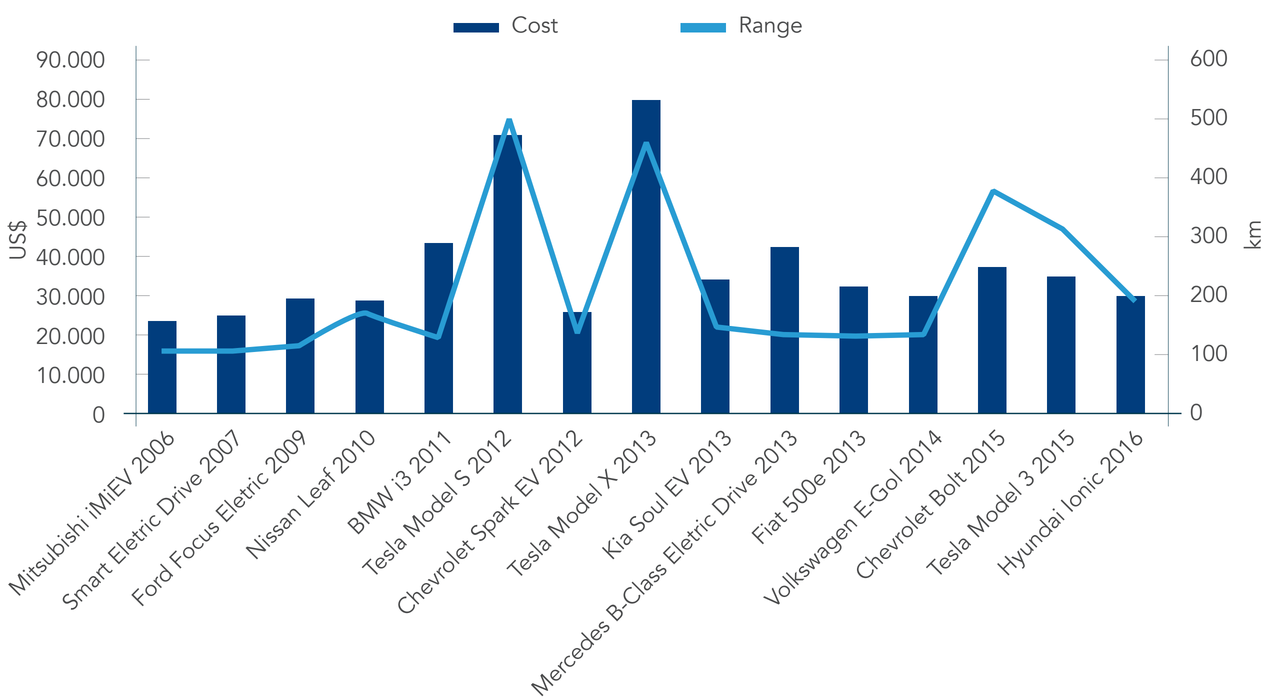
This anxiety, however, may be overstated: in a recent study,[60] based on analysis of travel standards data in the US and other evidence, researchers found that 87% of vehicles currently on the road could be replaced by a low-cost electric vehicle available on market, even if there is no possibility of charging during the day. Reducing charging time with increased use of fast chargers can also mitigate range anxiety.

58. It is believed that by promoting a network of public charging stations, the already existing network of conventional gas stations could be used. However, these stations are structured to serve owners of internal combustion vehicles whose refueling takes place in a few minutes. For electric vehicles, since the charging time is longer - at least 20 minutes - it would be necessary to restructure these stations, developing service options and commerce in their surroundings. This discussion of potential new business opportunities will be further explored in Section 3 of this paper.
59. Global EV Outlook, IEA, 2016.
60. Needell et al., 2016.

HIGHER PRICES FOR ELECTRIC MODELS

Finally, electric vehicles' high prices are still an obstacle for its global dissemination. Since, on average, approximately 1/3 of an electric vehicle total price is attributed to the battery, reducing its cost becomes essential for a greater market penetration of electric models. Figure 13 provides a non-exhaustive list of manufacturer-suggested retail prices – that is, pre-purchase subsidies - for some BEV models in the United States. There is a positive relationship between price and range. However, in recent years, this trend has been reversed. Two BEV models announced in 2015, Chevrolet Bolt and Tesla Model 3, have high range and lower price, which may signal the beginning of an era of more efficient and affordable EV.[61]

FIGURE 13: PRICE-RANGE RATIO OF SOME BEV MODELS AND THEIR LAUNCH YEARS



Source: Elaborated by the authors based on data available at PluginCars.com

61. Increasing production scale should contribute to reducing EV's prices.

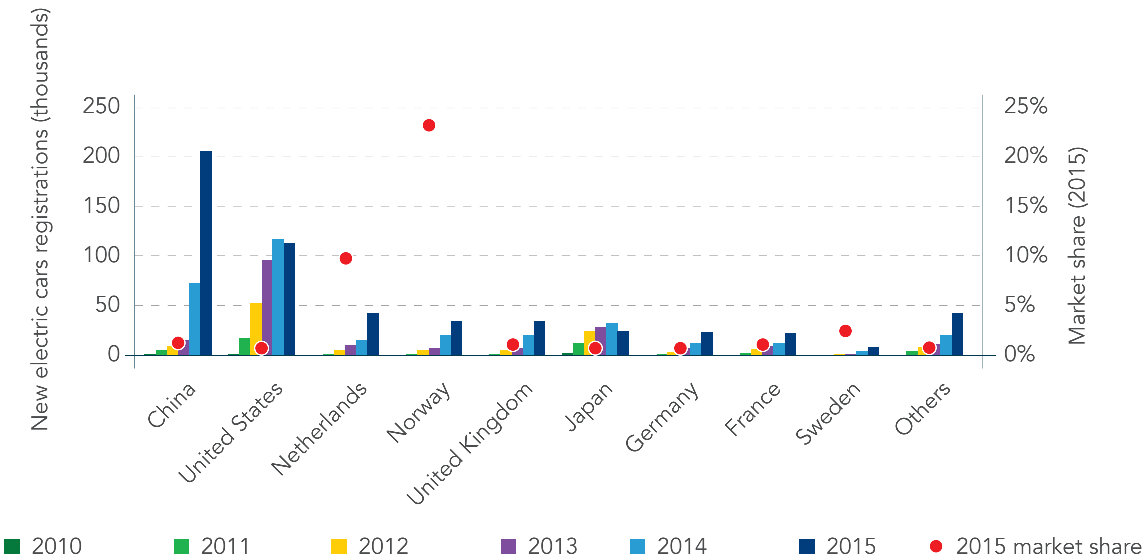
Incentives and business models for EV dissemination

Given the importance of decarbonizing the world and how the transportation sector can contribute in this regard, several countries are looking for ways to encourage further EV adoption. This section will discuss initiatives that these countries are implementing in order to create conditions for a market based on viable business models, and thus overcome the challenges described in the previous section that prevent greater EV adoption.

Electric vehicles sales growth has been remarkable since 2014, as shown in Figure 14. Sales in China are noteworthy, where the number of EV sold in 2015 more than doubled over the previous year.[62] This sales growth is affecting EV's share in automobile markets of these countries. As mentioned in Section 2, in seven countries (UK, China, France, Denmark, Sweden, the Netherlands, and Norway), EV already account for more than 1% of the auto market. In Norway, more than 20% of all vehicles in the country are electric.

62. China is one of the countries most affected by air pollution, which is a major driver for developing electric vehicles in the country.

FIGURE 14: EV SALES AND MARKET SHARE IN SELECTED COUNTRIES



Source: Global EV Outlook, IEA, 2016.

Some variables allowing this expansion were: financial incentives to purchase electric cars and install residential EVSE; licensing fees and other taxes exemption for new electric vehicles; regulatory measures such as standards for reducing greenhouse gases emitted by automobiles and increasing fuel energy efficiency, as well as other targeted instruments such as exemption from parking fees and access to restricted traffic areas (such as bus lanes, carpool lanes,[63] high-traffic zones,[64] and low emission zones[65]).[66] These incentives will be described below.

63. Road traffic lanes restricted to vehicles occupied by two or more people. Also known as high-occupancy vehicle lane (HOV lane).
64. Heavy traffic areas where a fee is charged in order to reduce high flow of vehicles.
65. Low emission zones (LEZ) are areas where the most polluting vehicles are regulated. Generally, this means that vehicles with higher emissions may not enter the area. In some low emission areas, the most polluting vehicles have to pay more to access them (Source: http://urbanaccessregulations.eu/low-emission-zones-main).
66. Global EV Outlook, IEA, 2016.

INCENTIVES FOR EV DISSEMINATION IN DIFFERENT COUNTRIES

Why incentives for purchasing electric vehicles are necessary? First, because of high costs for purchasing or charging - the latter due to still restricted infrastructure availability. Second, because EV bring benefits to society by reducing noise and air pollution. Commitments to reduce GHG emissions made in the Paris Agreement (in force since November 2016) led to increased policies and markets for EV in order to reach these goals. To this end, a number of countries have been implementing measures and incentives so that barriers to further EV dissemination are overcome. Thus, the incipient market for electric vehicles will have greater potential to thrive once public policies, either through purchase subsidies or other incentives, monetary or otherwise, are in place.

PURCHASE INCENTIVES

For now, electric vehicles are still substantially more expensive than internal combustion vehicles, essentially due to battery technology issues. Although a cost-benefit analysis - which considers factors such as engine efficiency and fuel and maintenance costs - that will be exemplified below, indicates that EV may be more advantageous than internal combustion vehicles, consumers are still startled by an electric car's nominal price.

For example, using the US Department of Energy's Vehicle Cost Calculator, we compared cumulative costs of ownership[67] of an internal combustion vehicle (Toyota Corolla gasoline, model 2016) with a BEV (Nissan Leaf, model 2016) in the state of California.[68] Table 4 shows cost information for both vehicles. The Nissan

67. The cumulative cost of ownership per year for each vehicle includes expenses with fuel, tires, maintenance, registration, licensing, insurance, and loan repayment. The calculation assumes a five-year loan with a 10% down payment. The first year of Figure 15 represents a 10% increase in total operating costs this year. The calculation does not include an estimate of electric cars resale value. If included, total cost of ownership would be higher given that electric cars do not perform well in resale markets because of battery depreciation, which may lose 40% capacity after a few years, depending on usage (Voelcker, 2016). Tesla vehicles, however, are an exception to this rule, showing excellent performance in the resale vehicle market due to: greater battery capacity, and consequently, lower depreciation over time and greater range; growing network of superchargers; still restricted supply; commercial appeal of the Tesla brand; among other factors (Shahan, 2016). For more details on the electric car resale market, see: NADA, 2016. NADA is the acronym for the National Automobile Dealers Association, an association representing US automotive dealerships.

68. Toyota Corolla 2016 gasoline - Price: USD 17,830.00. 148hp. Nissan Leaf BEV 2016 - Price: USD 29,010.00. Power equivalent to that of a 1.0-liter engine car: 120hp.

While electric cars are much more expensive than their conventional counterparts, subsidies that reduce their purchase price potentially increase their attractiveness.

Leaf is supeior to the Corolla in terms of fuel and maintenance costs, in addition to being more efficient per kilometer driven and having fewer emissions. When comparing the cumulative cost of ownership, which includes vehicle purchase costs, the Nissan Leaf loses that advantage. However, when considering purchase subsidies, which can reach up to USD 10,000 in the state of California, Nissan Leaf's cost of ownership over time is lower, as shown in Figure 15. Thus, while electric cars are much more expensive than their conventional counterparts, subsidies that reduce their purchase price potentially increase their attractiveness. It is worth noting that, like any industrial policy, subsidies or incentives must support the initial phase of a business, in order to promote conditions for technological improvements linked to the value chain, until the business model is self-sustaining.

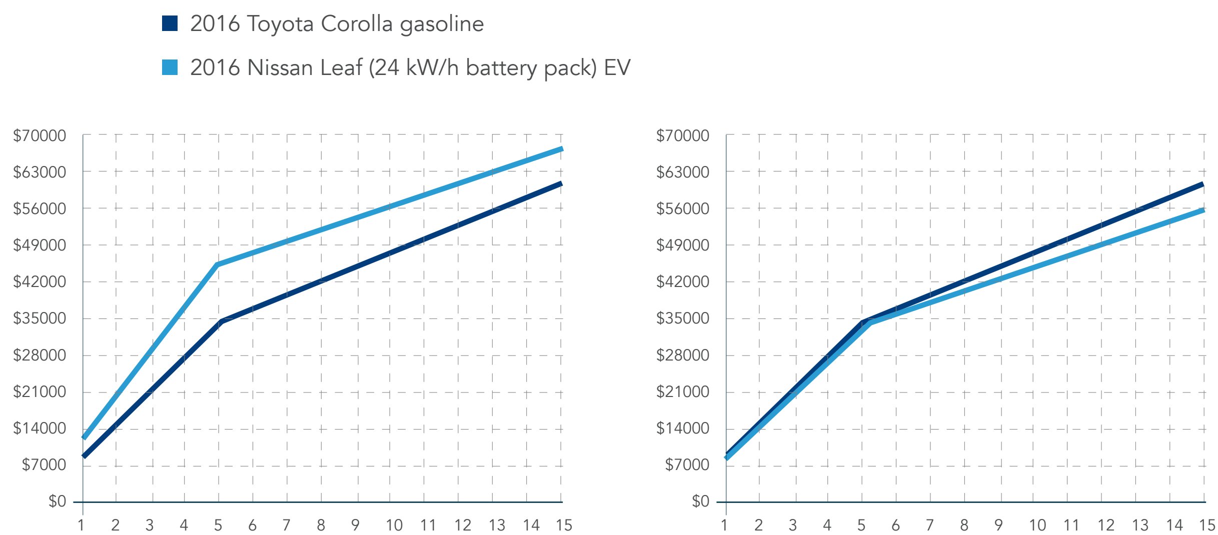
69. Since they also have an internal combustion engine, PHEV maintenance is similar to that of an ICV. For BEV, however, since they use less oil and transmission fluid, in addition to having fewer parts and using regenerative braking - which is less aggressive to brakes, their maintenance costs are much lower. A study conducted by the Institute for Automotive Research (IFA), Nürtingen-Geislingen University, concludes that EV maintenance may cost 35% less than that of a traditional vehicle (Diez, 2014). Regarding battery replacement costs , taking into account a value of USD 227/kWh (Knupfer et al., 2017), for a Nissan Leaf, whose battery has a 24 kWh capacity, for example, replacement would cost around USD 5,450.00. Most manufacturers, however, offer 8 to 10 years, or 100,000 km, warranties for batteries. However, warranties depend on manufacturer, which may or may not cover capacity loss. For more details, see Voelcker, 2016.

TABLE 4: TOYOTA COROLLA GASOLINE AND NISSAN LEAF BEV COST COMPARISON

	Toyota Corolla gasoline – 2016	Nissan Leaf BEV (24 kW-hr battery) – 2016
Annual Gasoline Use*	1,438 liters (380 gallons)	0 liters
Annual electricity use*	0 kWh	3,620 kWh
Performance (city/highway)	12/16 km/l	27/33 kWh/100 miles
Annual Fuel/electricity costs**	USD 844	USD 615
Maintenance cost in the first year ***	USD 3,102	USD 2,720
Cost per mile	USD 0.26	USD 0.23
Annual emissions (pounds of CO_2)	9,129	2,602****

* Assuming that distance traveled annually is 19,193 km (11,926 miles). ** Fuel cost is the average gasoline price in the United States in the last quarter of 2016, according to the US Department of Energy's Alternative Fuel Price Report. Electricity cost is that prevalent in the state of California. *** Includes fuel, tire, maintenance, registration, licensing, and insurance expenses. In the following years, it is assumed that BEV maintenance costs are, on average, 28% lower than in an internal combustion vehicle based on a study by DeLuchi et al, 2001. **** CO_2 emitted generating electricity that supplies the BEV in the state of California. For more information on calculation methodology, see: http://www.afdc.energy.gov/calc/cost_calculator_methodology.html

FIGURE 15: ANNUAL CUMULATIVE COST OF OWNERSHIP - TOYOTA COROLLA GASOLINE VS. NISSAN LEAF BEV, WITHOUT PURCHASE SUBSIDIES (LEFT) AND WITH PURCHASE SUBSIDIES (RIGHT)



Source: US Department of Energy Vehicle Cost Calculator.

This example clearly illustrates the need to offer purchase subsidies to EV at this initial stage when their prices are not yet competitive. In the US, the federal government grants subsidies with a minimum credit amount of USD 2,500, reaching USD 4,000 for PHEV (with a range of 18km to 40km) and USD 7,500 for BEV (and some PHEV with greater range, like the Chevrolet Volt).[70] Several states also award grants for purchase,[71] so that total credit may exceed USD 10,000.00[72] (as in the example above, California. In Colorado, the statewide incentive is up to USD 5,000[73]). In addition to subsidies that reduce the vehicles' nominal value, some governments offer incentives such as exemption from licensing fees and other taxes.[74] Table 5 provides examples of electric cars purchase incentives in certain countries in Europe and Asia.

Another way to overcome the initial resistance to purchasing an EV is to assign subsidies for installing residential EVSE. Almost all countries where EV market share is above 0.5% (China, Denmark, France, Germany, Japan, the Netherlands, Norway, Portugal, Sweden, the United Kingdom, and the US) provide direct or tax incentives at national level for installing a home charging station.[75] Several governments also encourage public EVSE development.

70. Source: Global EV Outlook, IEA, 2016 and http://www.afdc.energy.gov/laws/search?loc%5B%5D=US&tech%5B%5D=ELEC. The US federal government also provides subsidies of 10% over face value, up to USD 2,500.00, for purchase of two-wheelers.
71. Credit, vouchers or rebates (reimbursements), depending on the program in use. For more information, see: http://www.afdc.energy.gov/laws/matrix?sort_by=tech
72. Source: Schaal, 2017.
73. State of Colorado, 2016, and The Denver Post, 2016.
74. Global EV Outlook, IEA, 2016.
75. Ibid.

TABLE 5: EXAMPLES OF EV PURCHASE INCENTIVES IN EUROPE AND ASIA[76]

	Monetary incentive	Other
China	Between USD 6,000.00 and USD 10,000.00	Exemption from sales tax
France	• USD 7,100.00 for BEVs • USD 1,100.00 for PHEVs*	
Japan	Up to USD 7,800.00	
Netherlands		The less CO_2 the vehicle emits, the lower the licensing fee, reaching zero for those that do not emit CO_2 (BEV)
Norway		Exemption from sales tax (about USD 12,000) and VAT (value added tax, for BEV).
United Kingdom	• Up to USD 6,300.00 for BEV • Up to USD 11,200.00 for light commercial vehicles • USD 3,500.00 for PHEV under USD 84,000.	

* Diesel vehicles replacement allows for a supplementary premium of USD 11,000 for BEV and USD 4,000 for PHEV.
** Subsidies are based on the price difference between an EV and a comparable gasoline car.

TABLE 6: EXAMPLES OF INCENTIVES FOR RESIDENTIAL AND PUBLIC EVSE INSTALLATION[77]

Denmark	• Subsidy of up to USD 2,700.00 for installing a home EVSE • Initiative from the Danish Energy Agency supports public charging stations deployment
France	• Regulation requires that all new buildings include charging points • Tax deductions for private operators who invest, maintain, or operate EVSE in public spaces in at least two different regions. The goal is to create a national EVSE network.
United States	• Since 2015, a federal program has already financed the installation of 36,500 public charging stations • Several states also provide subsidies for home EVSE installation[78]
Japan	• The federal government funded 2/3 of 500 fast chargers and 650 slow chargers in retail stores
United Kingdom	• Up to 75% financing, or USD 700, for installing a home EVSE

76. Ibid.
77. Ibid.
78. http://www.afdc.energy.gov/laws/matrix?sort_by=tech

OTHER MEASURES TO ENCOURAGE GREATER EV ADOPTION:

Regulatory measures

Decarbonization fosters the adoption of standards for greater fuel efficiency and reducing greenhouse gas emissions, which in turn stimulate the development of more efficient vehicles. For more efficiency, electric vehicles meet these new requirements perfectly because they are more efficient than traditional internal combustion vehicles, as seen in the previous section.

Several countries[79] have regulatory measures for fuel efficiency and GHG emissions control for new registered vehicles. But, among them, India, South Korea, some European countries, and Japan have general regulations - applicable throughout the territory - for greater fuel energy efficiency, which indirectly favors electric vehicles development. The others countries conidered implement policies in certain areas, but these measures affect over half of the population in each country.

Among the initiatives to control GHG emissions, some US states' efforts to increase the number of Zero Emission Vehicles (ZEV: BEV, PHEV and FCEV) in their fleets stand out. Led by California, nine other states[80] are part of the ZEV Mandate, a state program that aims to sell over 3 million ZEV by 2025, or 15% of total US sales. This is an ambitious goal, since, from 2013 to 2015, the percentage of these vehicles' sales in California, the state with the highest percentage of ZEV in its fleet, was only 2.8%, and throughout the country, did not exceed 1%.[81] Hence the importance of incentives for purchasing electric vehicles and promoting their overall dissemination so that sales increase.

In addition to US states, China is pursuing ambitious targets to increase the ZEV fleet: by 2018, these vehicles' sales are expected to account for 8% of total sales, and, by 2020, their market share is expected to reach 12%.[82]

There is also the newly formed ZEV Alliance, consisting of 8 states in the United States (California, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont), as well as Québec (Canada), Germany, the Netherlands, Norway,

79. They are: Canada, China, Denmark, France, Germany, India, Italy, Japan, the Netherlands, Norway, Portugal, South Korea, Spain, Sweden, the United Kingdom, and the United States. Source: Global EV Outlook, 2016.
80. Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont.
81. https://autoalliance.org/energy-environment/zev-sales-dashboard/
82. Lambert, 2016b.

and the United Kingdom, which works toward reducing greenhouse gas emissions through greater incentives for electric vehicles sales. The Alliance was officially founded in September 2015, when its members accounted for 7% of overall vehicle sales and 38% of electric vehicle sales.[83]

All these efforts to encourage zero-emission vehicles are very important. However, it should be noted that until now regulations around the world have ignored upstream emissions, in other words, those produced when electricity that supplies the EV is generated, as well as emissions and energy use associated with manufacturing the materials used to make the vehicles. In the United States and the European Union, emissions control takes the form of average emission limits in the entire fleet circulation, which are reduced annually. According to these regulations, both the US and the European Union consider that electric vehicles emit 0g of CO_2/km. Unlike internal combustion vehicles, however, a significant proportion of EV emissions is upstream. Regarding the manufacturing process, the biggest difference lies in batteries type and size: while ICV require only a small battery to start the engine and perform other small commands when the engine is turned off, EV need a much larger battery to perform all controls in the car. According to a UCSUSA study,[84] emissions resulting from manufacturing a BEV with a 135km range are 15% higher than those emitted during manufacturing an equivalent gasoline model, which is 1 ton of CO_2eq more.[85]

Current regulations, which consider only exhaust emissions, do not fully capture EV emissions. Therefore, in order for EV to effectively contribute to reducing GHG emissions, there must also be upstream emissions control that, according to the IEA, should not exceed 700 grams of CO_2 per kWh.[86] This requirement may be considered a challenge for those countries heavily dependent on coal for electricity generation.

A study[87] carried out in the United States revealed that when upstream emissions are included, an electric vehicle charged with electricity generated on the North American grid emits, on average, 56% less CO_2 than a similar gasoline vehicle (166g/km versus 380g/km). These values change according to each state's electricity generation sources.

83. http://www.zevalliance.org/
84. Nealer et al., 2015.
85. CO_2 equivalent
86. Energy Technology Perspectives, IEA 2014.
87. Lutsey & Sperling, 2012.

Other targeted instruments, such as exemption from parking fees and access to restricted transit areas

In addition to regulatory measures that indirectly encourage increased electric vehicles adoption, several countries have been using instruments designed as incentives for their development, such as circulation and ownership fees exemption. In China, EV are exempt from both these fees. In France, BEV and PHEV do not pay the annual circulation fee, and in Denmark, this applies to BEV weighing less than two tons. Countries such as the Netherlands, Japan, Sweden, the United Kingdom, and the United States also have tax exemptions as incentives for electric vehicles circulation and use.[88]

Other strategies are focused on EV charging, which seek to reduce these costs for users. France, Japan, Norway, the United Kingdom, the United States, South Korea, and Portugal already use this type of incentive. In Wuhan, China, from 2014 to 2016, there were specific places assigned for new electric vehicles to charge at no cost. In Denmark, tax refunds of approximately USD 0.15/kWh were offered to companies supplying EV on business premises.[89]

Lastly, there are also incentives for EV to access restricted transit areas, such as exclusive bus lanes in large cities. China, France, Norway, and the United Kingdom are among the countries that use this instrument in their cities to favor EV use.

THE ELECTRIC VEHICLE AS A TRANSFORMATIVE AGENT IN THE GLOBAL AUTO INDUSTRY

Electric mobility evolution has potential to affect the oil industry, automobile manufacturers, and manufacturers of parts and equipment for internal combustion vehicles. Appearance of a new technology can potentially replace an existing one; for example, digital cameras entrance in the market, which generated the so-called "Kodak effect," that contributed to the disappearance of renowned companies that did not adapt to this new technology. However, history has already shown that one product's disappearance does not necessarily prevent the emergence of another, with new demands boosting the new industry.[90]

Electric vehicles are changing the auto industry, which in turn is seeking to transition to new

88. Global EV Outlook, IEA, 2016.
89. Ibid.
90. Novais, 2016.

In addition to electric vehicle production itself, the value chain spreads to other areas, such as charging infrastructure and information management.

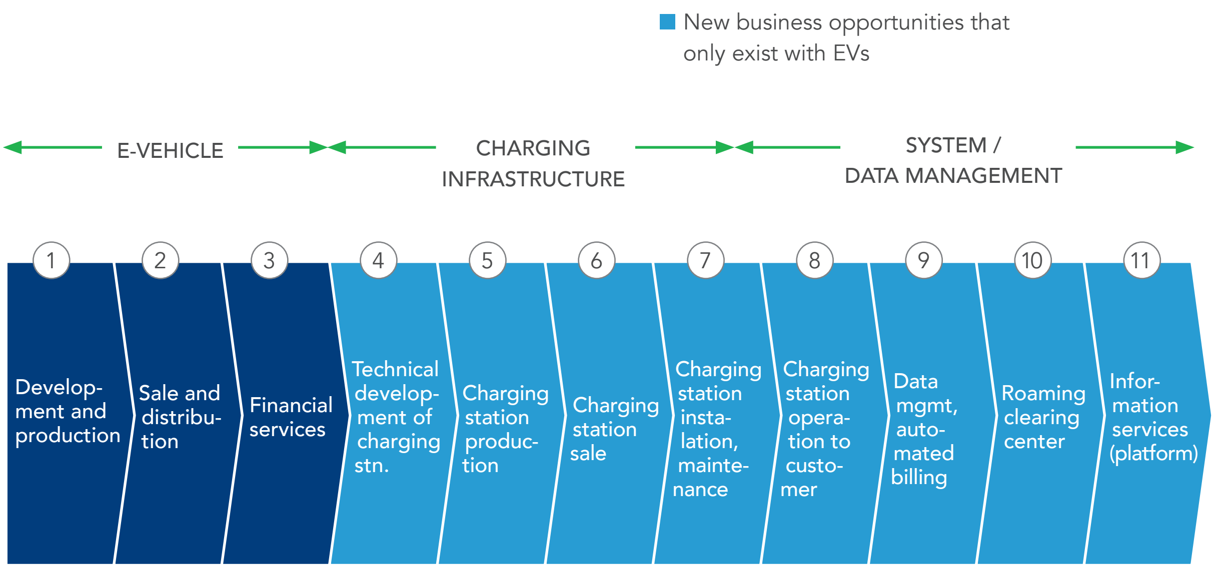
business models. It is argued that, as the current electric mobility industry is designed, it demands a much larger value chain than that of traditional internal combustion vehicles, leading to the emergence of new business opportunities. If on one hand new markets for products and services are a result of adopting EV, on the other these markets also contribute to electric vehicles gaining more space in the auto industry.

In addition to electric vehicle production itself, the value chain spreads to other areas, such as charging infrastructure and information management. New opportunities are in producing batteries, power inverters, electric motors, and many other products, which end up offsetting those areas that have their demand reduced.[91] In Figure 16, the stages highlighted in orange exist only in the electric vehicles value chain.[92]

91. This new value chain's emergence implies creating jobs in previously non-existent areas. Despite possible jobs lost in the conventional vehicle industry due to their replacement by electric cars, studies have shown that the balance will be positive, that is, the number of new jobs created will be greater than those that will disappear. For further discussion of the job creation potential in the electric car industry, see Todd et al., 2013 and Becker & Sidhu, 2009.

92. We can also find stages 4 to 7 in the ICV supply chain.

FIGURE 16: NEW EV VALUE CHAIN



Source: Amsterdam Round Tables & McKinsey & Company, 2014.

This new value chain implies that traditional internal combustion vehicle manufacturers will have to create relationships with other players outside the automotive sector in order for electric mobility to gain space and market in the industry. Among the participants in this new chain are power utilities, charging station owners, charging infrastructure operators, vehicle users, and financial services companies. All of these participants need to be interconnected for electric vehicles development to succeed.

With electric mobility evolution, automakers have the possibility of expanding "vertically" in the chain; that is, they may also participate in the supply infrastructure, not only in vehicle production. A good example of this vertical expansion is superchargers developed by Tesla, compatible only with their vehicles and already spread throughout the United States and Europe. With superchargers, Tesla is making its way into the charging infrastructure business and contributing to its dissemination, as well as increasing demand for electric vehicles, especially those produced by Tesla.[93]

Another area being structured by auto manufacturers is battery leasing. Selling vehicles separately from batteries is a strategy that aims to reduce the EV's high purchasing price. In addition to making the purchase more attractive to consumers, there is the possibility of switching batteries when necessary, reducing users' concern about their durability and performance.

As seen in the previous section, charging infrastructure expansion is closely related to electric vehicles's greater adoption. As a result, many of the new business opportunities are found in this area. Software industries will assist electric vehicle owners with applications and navigation programs to help them find the nearest charging station compatible with their vehicle model. There is still much to be explored regarding charging services, such as remote payment, user access and registration, as well as charging stations installation and maintenance. As for installation, many companies are turning to private charging: they install the charging points in homes and workplaces, as well as offer maintenance service.

Another business area that can be explored is service area development around public charging stations. Unlike internal combustion vehicles, whose fueling takes only a few minutes, electric vehicles currently take at least 20 minutes for battery charging. Therefore, there is a significant waiting time for EV owners at the stations, which is an opportunity for developing an infrastructure that caters to drivers while their vehicles are being charged. Charging stations can be installed in places where support infrastructure already exists, such as restaurants, malls, and other shopping center parking lots.

In short, incorporating electric cars into their business models provides many opportunities for the auto industry. EV, by themselves, are already a considerable innovation compared to the existing model. In addition, their association with other mobility trends, such as car sharing and full mobility solutions, further extend the range of possibilities for the automotive industry, as we will see below.

93. Amsterdam Round Tables & McKinsey & Company, 2014.

MOBILITY AS A SERVICE

Society as a whole has come to see mobility as a service, that is, one that can provide easy access to all modes of transportation so that travel from one point to another occurs in the most efficient and satisfactory way possible for users. According to a recent survey conducted by KPMG,[94] by 2025 over half of current car owners will no longer be interested in buying another new car[95]. Because the business model that prevails and sustains the automotive industry is vehicles sale, these results may symbolize a significant drop in revenues for this industry and the inevitable collapse of its current business model.

When the cost of buying a car, added to the inconveniences of this purchase (such as traffic jams, taxes, difficulty finding parking, pollution, etc.), is greater than the usage gains obtained with the car, consumers and owners will tend to migrate to other types of mobility.[96] Society is realizing that there are other more efficient and comfortable ways to move from one point to another: according to KMPG's Global Automotive Executive Survey 2017, future car buying criteria will be different from today's, with consumers preferring to relax, socialize, work, and enjoy themselves while they commute - see Figure 17. Autonomous cars should gain strength in the coming decades as they meet the new consumer criteria.[97]

Therefore, in order to remain relevant in the future, the automotive industry needs to adapt to this new concept of mobility as a service and provide it, rather than operating in vehicle production only. The link between the concept of mobility as a service and electric vehicles lies in the fact that, despite having a higher acquisition cost than internal combustion vehicles, EV's maintenance and per kilometer costs are lower. So, the more used in services like car sharing, for example, the faster the EV's payback - especially if made available in dense urban areas.[98]

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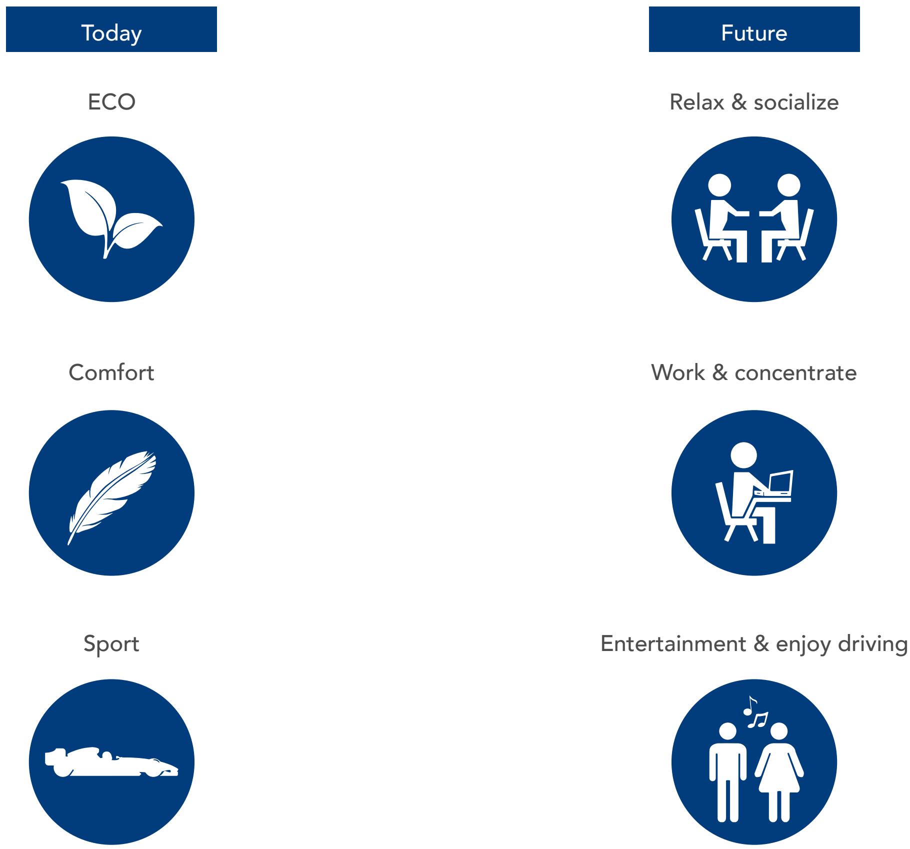
94. KPMG, 2017.
95. Contributing to this behavior is the growing trend in European cities, such as London, Paris and Barcelona, of becoming increasingly difficult to drive a vehicle in its urban centers, whether to reduce traffic in historic areas or to address environmental issues. See, for example, Barcelona, that wants to ban the circulation of vehicles over 20 years old in its historic center on working days, beginning 2019 (Jones, 2017).
96. KPMG, 2017.
97. Still in their infancy, autonomous vehicles should not become economically viable until 2020. But by then, regulators, consumers, and corporations will need to be prepared for a new reality with fully autonomous vehicles accounting for 15% of new vehicle sales in 2030. The biggest challenges for these vehicles to gain space on the market are high prices, consumer acceptance, and safety issues (McKinsey & Company, 2016).
98. This argument is also valid for taxi fleets and public transport.

FIGURE 17: DIFFERENT CRITERIA FOR CAR PURCHASING: CURRENT VS. FUTURE



Source: KMPG, 2017.

Car sharing consists of vehicle rental service specifically for quick use, since the customer rents the car for the amount of hours used. The concept is that individual transportation is used more rationally when it is really needed. Another advantage of this service is the possibility of "alleviating" the obstacle of range anxiety, since users may use this service to test electric cars, driving within distances in which they feel comfortable, adapting better to electric mobility before purchasing an EV. In addition, regarding purchasing, car sharing allows users to use electric vehicles without having to buy them, helping to eliminate another obstacle to EV use: high purchase price.

This new business model has gained strength in many European countries. In Germany, for example, a market survey by McKinsey found that one-third of the urban population is a potential car-sharing user: about 40% of the young population (18 to 39 years) living in cities with over 100,000 people replied that in 10 years they will be using car sharing more often.[99]

One of the largest car-sharing programs is Autolib' in Paris. This was the first public electric car rental service developed in a major European metropolis. The cars are 100% electric, produce less noise and do not contribute to direct greenhouse gases emissions into the atmosphere. Currently, the 4,000 cars available through Autolib' are already responsible for reducing the private car fleet by over 36,000 vehicles, equivalent to 165,000,000 km that will no longer be driven by internal combustion vehicles.[100] Therefore, in addition to contributing to greenhouse gases emission reduction, the greater use of these vehicles leads to fewer traffic jams, less stress, and frees up more time to the entire population.

Complementing the car sharing service are full mobility solutions,[101] which are those responsible for ensuring that mobility users "reach their destinations." That is, considering all the intermediate steps between their homes and the final destination. An example of a full mobility service offered by BMW is ParkNow, which aims to assist in vehicle parking. This service transmits real-time information of the availability of places according to the user's geographic location, and also facilitates parking fees payment. Another example is Moovel, a mobile application developed by Daimler that offers all the possible routes to reach the requested destination, taking into account real-time information on the availability of public transport, taxis, ride-sharing, bike-sharing, and others.

According to the survey conducted by KMPG, [102] most of the executives who participated in the survey believe that ICT (information, communication, and technology) companies, such as Google, will be increasingly present in the mobility market. It is not yet clear where these companies will operate, but certainly existing mobility providers will have to interact with these new competitors on the market. There are still questions regarding how the interaction between companies in the automotive and ICT sectors will occur . Will they cooperate or compete? Communication and technology companies' lack of experience in actual car production could be offset by their vast experience connecting people and providing

99. Amsterdam Round Tables & McKinsey & Company, 2014.
100. www.autolib.eu
101. Amsterdam Round Tables & McKinsey&Company, 2014.
102. KPMG, 2017.

mobility services, with mutual cooperation among different companies.

In the future, it is expected that automobile manufacturers will have their revenues coming primarily from the "digital ecosystem," selling parts and products separately, as well as services that meet consumer needs at various stages of their lives, not necessarily associated with mobility.

All of these new business opportunities may be responsible for significantly increasing revenues in the automotive industry, driven primarily by on demand mobility services and data services. The industry's revenue growth is expected to reach 30%, or USD 1.5 trillion, by 2030. This new configuration of the automotive industry may reach an annual growth of 4.4% already by 2030 (up from 3.6% from 2010 to 2015).[103]

Despite all these new business opportunities for the automotive industry of the future, in the short term, electric vehicles are still far from becoming a lucrative option for auto manufacturers, mainly due to batteries cost. Research and development spending is also high, as is the cost of a strong structural change in these companies, that for decades have been focused on producing internal combustion vehicles. Companies that have already been investing in electric cars, such as Tesla, General Motors, and Renault-Nissan, have not yet made a profit on selling these models.[104] Other auto manufacturers, however, such as BMW and Daimler, have advantages in this transition because they are already focused on the luxury car market. The same is not true for those companies that manufacture more popular vehicles, such as Fiat and Peugeot, which still have a long way to go before they are able to produce affordable electric vehicles for their consumers.

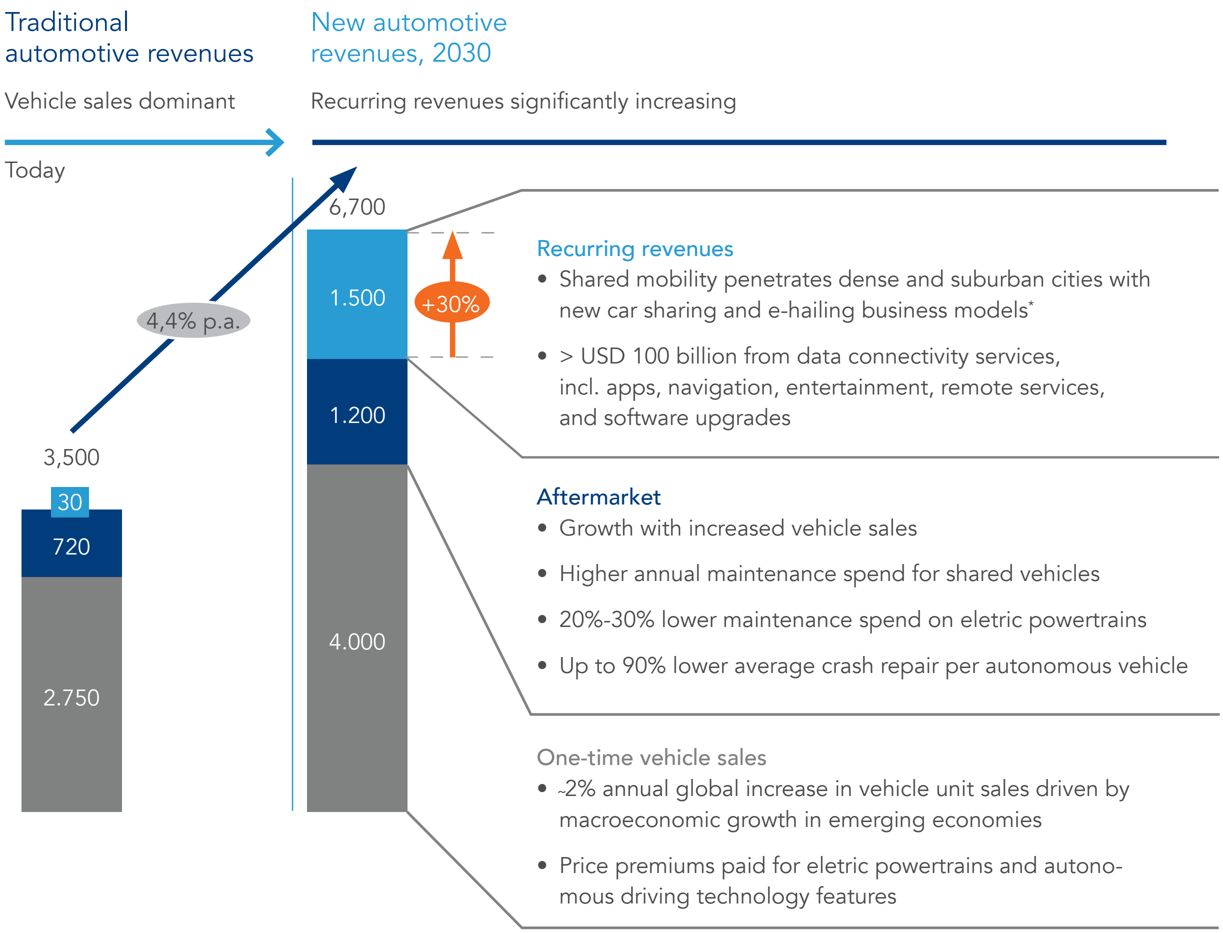
Notwithstanding these factors, companies in the industry should think in the long run. In the future, electric vehicles are likely to be more profitable than internal combustion vehicles as battery prices drop. Demand for these vehicles also tends to grow, due to all the factors presented: concern about the environment and change in consumer behavior, as they are beginning to see cars as a mean of transportation. In addition, when battery prices are competitive enough, and public, fast charging options are more available, it will be much more advantageous for consumers to purchase an electric car because of its greater efficiency. However, before we reach this stage, we must go through a difficult and costly transition, which requires companies in the sector to increasingly seek to innovate by investing in business models that incorporate all the changes that society is demanding. But as complicated as this transition may seem, the choice to get stuck in the past may be disastrous.

103. McKinsey&Company, 2016.
104. The Economist, 2017.

FIGURE 18: SALES GROWTH IN THE AUTOMOTIVE SECTOR

The automotive revenue pool will grow and diversify with new services potentially becoming a ~ USD 1.5 trillion market in 2030
USD billions

HIGH-DISRUPTION SCENARIO



*Does not include traditional taxi and rentals

Source: McKinsey&Company, 2016.

Direct and indirect impacts from EV expansion

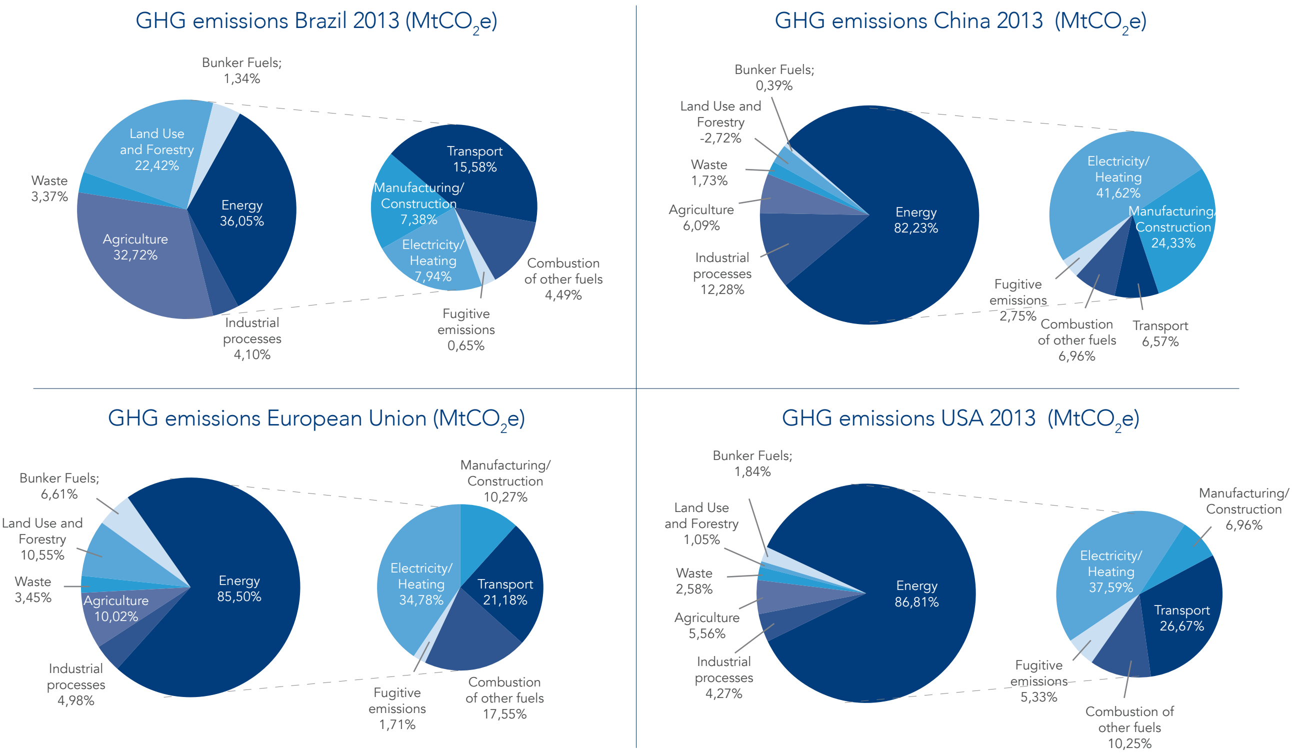
In addition to the automobile and mobility sectors, increasing electric vehicles' participation on the streets and roads of the planet results in several impacts on different sectors, such as the environmental and energy sectors - in the latter, impacting the electricity and fossil fuel sectors. In this section, we will analyze the direct and indirect effects of EV implementation and development on these sectors.

IMPACTS ON THE ENVIRONMENT

Electric vehicles are seen as a way to decarbonize the global transportation sector. As we can see in Figure 19, the transportation sector[105] is responsible for a considerable part of Brazilian, European, and American emissions - in Brazil, it is responsible for most GHG emissions in the energy sector. In the US, the transportation sector surpassed the electricity sector in GHG emissions in early 2016 and has been leading ever since because of the increasingly participation of renewable sources in power generation.[106] In China, although it is not a significant part of the country's total emissions, the

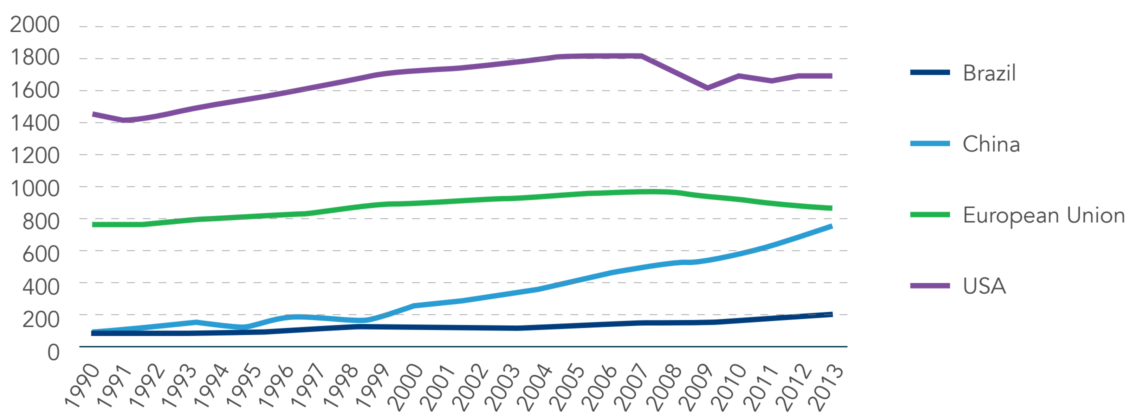
105. Within the transport subsector, for all countries considered, road transport is the one that emits the most. For more information, see IEA, Energy Balance Flows: http://www.iea.org/Sankey/#?c=World&s=Final%20consumption.
106. U.S. Energy Information Administration, February 2017 Monthly Energy Review.consumption.

FIGURE 19: TOTAL GHG EMISSIONS - BRAZIL, CHINA, EUROPEAN UNION[107] AND THE USA, 2013



Source: Elaborated by the authors based on data from the World Resources Institute, CAIT Climate Data Explorer, 2017.

FIGURE 20: GHG EMISSIONS IN THE TRANSPORTATION SECTOR - BRAZIL, CHINA, EUROPEAN UNION AND THE USA, 1990-2013



Source: Elaborated by the authors based on data from the World Resources Institute, CAIT Climate Data Explorer, 2017.

107. Includes the 28 Member States of the European Union: Germany, Austria, Belgium, Bulgaria, Cyprus, Croatia, Denmark, Slovakia, Slovenia, Spain, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, the United Kingdom, the Czech Republic, Romania, and Sweden.

transportation sector's emissions are steadilly increasing , as seen in Figure 20. This upward trend is also observed in Brazil, while the European Union has already managed to reduce emissions linked to this sector.

Electric mobility expansion can help reduce GHG emissions in the transportation sector since electric vehicles do not produce emissions, or emit much less exhaust gases when compared to ICV.[108] As mentioned in Section 3, in several countries around the world, there are fuel efficiency targets for emissions reductions to be achieved, and EV have much to contribute to achieving these goals. One way to measure how this contribution could be made is through an index called the EV gap, which refers to electric vehicles sales that are needed to meet energy efficiency targets for passenger cars. Without considering other technologies that promote improved fuel efficiency,[109] an additional 1.4 million EV in Europe (10% of sales in 2020), 900,000 in the USA (11% of sales in 2020), and 5.3 million in China (22% of sales in 2020) will be needed to meet emissions targets in each country/region by 2020. Assuming a constant demand, EV sales in the European market, for example, would have to grow by 60% per year during the period. The current annual growth rate of EV sales in the US is 40%, for example. Therefore, with more incentives, such as those described in Section 3, this growth goal could be achieved.[110]

Reducing vehicle exhaust pollution has a positive impact on the population's health. In a 2013 study, it was estimated that pollution from the US ground transportation sector is responsible for approximately 58,000 premature deaths per year. By comparison, in 2015, car accidents were responsible for 43,500 fatalities in the United States.[111] In the United Kingdom, a similar study estimates that air pollution caused by road transport kills approximately 5,000 people a year - again, by comparison, road accidents in the country killed 1,850 people in 2010.[112] Therefore, zero emission vehicles could potentially avoid all these deaths. However, as already mentioned in Section 3, electricity generation to fuel electric vehicles must also emit zero pollutants, or as few as possible, so that EV's effect on GHG emissions is indeed significant.

108. See Section 3.
109. Such as improvements in aerodynamics, vehicles' weight, and alternative fuels, for example.
110. World Energy Council, 2016.
111. Caiazzo et al., 2013.
112. Yim and Barrett, 2012.

Environmental impacts of lithium exploration for battery manufacturing

As mentioned in Section 2, due to recent technological advances and expected future progress that will allow for lower costs and improved performance, lithium-ion batteries have been the most suitable for developing light electric vehicles. As a consequence, the lithium mining market has developed rapidly in recent years. Compared to 2014 prices, lithium carbonate's spot price increased from 10% to 15% in 2015 and is expected to grow by 75% this decade until 2025 (Figure 21). Demand for the commodity is expected to grow by 20,000 tons per year until 2021, with supply also growing to meet market needs - which include not only electric vehicles, but also batteries that are used as distributed energy resource by households and power utilities. Currently, the commodity mining market is dominated by four companies[115], which are located in Australia and South America (in the so-called "lithium triangle" formed by Chile, Bolivia and Argentina - which, due to reductions in mining barriers by the Macri government, could supply half the lithium used in the world by 2020[116]). Proved lithium reserves are concentrated in these countries and in the USA and China (Figure 21).

Given the projected annual growth for the commodity, one may wonder if there is enough lithium available to satisfy all of this demand. Studies indicate there is enough, but more investments in mining and refining infrastructure are needed. At current production rates, existing producers have over 70 years of available reserves, with approxi-

113. Crabtree, 2016.
114. In 2014, the demand for lithium was 27,000 tons. Source: Goldman Sachs Global Investment Research, 2015.
115. Sanderson, 2016.
116. Attwood and Gilbert, 2017.

mately triple that capacity available on proven resources that are not yet being mined. Similar to oil, lithium mining will become economically viable at higher prices (i.e., the operating cost curve is accentuated) to meet new demands. Recycling lithium is also a future possibility, as we will see further ahead.[117]

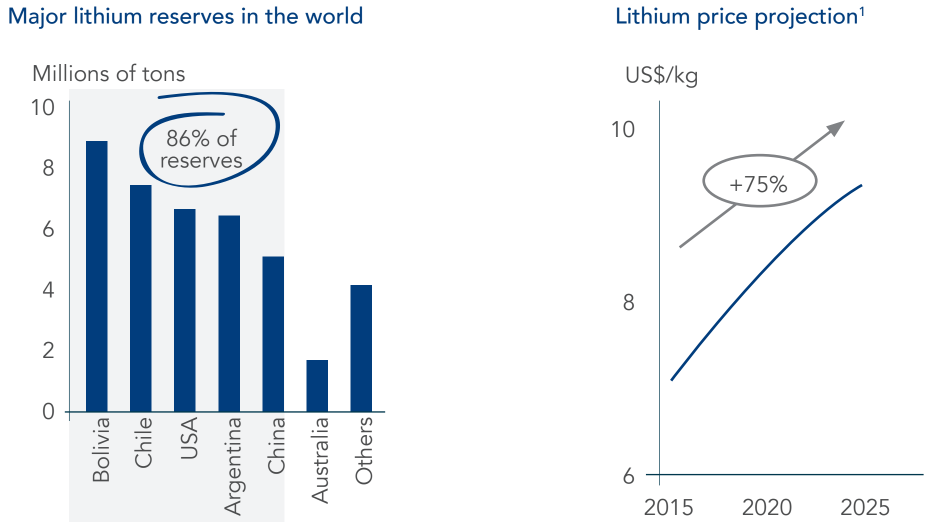
What will lithium mining environmental impact be? Lithium is a rare metal, whose mining releases toxins that are harmful to miners' health and the environment. Its extraction takes place in small quantities and in places difficult to access, so a great mining effort is necessary to obtain small amounts of the metal. Extraction waste is generally released in nature.[118]

This mining activity also has "hidden" emissions. The more difficult, the greater the possibility of extraction requiring powerful equipment, which consumes energy that does not always come from renewable sources. As a whole, depending on the model, it is estimated that an EV emits between 15% and 68% more greenhouse gases than a conventional vehicle during its production - this disadvantage, however, is overcome after 6 to 18 months of vehicle use, depending on how the electricity that supplies it is generated, and lasts for the remainder of its lifespan. In the end, EV emit approximately half the amount of GHG that internal combustion vehicles do.[119]

Finally, battery components may be recycled at the end of the vehicle's life - an activity that is increasingly developing as the electric car market evolves[120] and battery components[121] become more standardized globally.[122] In addition, the whole battery may be reused in other electric vehicles or as energy storage in homes and in the electric grid- an application that could even give rise to new business opportunities.[123]

117. Goldman Sachs Global Investment Research, 2015.
118. Wade, 2016.
119. Nealer et al., 2015.
120. Wade, 2016.
121. Urban Foresight Limited, 2014.
122. Urban Foresight Limited, 2014.
123. Amsterdam Round Tables & McKinsey&Company, 2014.

FIGURE 21: MAJOR LITHIUM RESERVES THROUGHOUT THE WORLD AND PROJECTION OF LITHIUM PRICES UP TO 2025



[1] Considering 99.5% lithium carbonate.

Source: Lins and Morais, 2016.

IMPACTS ON THE ENERGY SECTOR

Electric vehicles development impacts the energy sector in several ways: first, through a greater demand for electricity and, second, through the decreased demand for fossil fuels to supply vehicles. This second factor, coupled with renewable energy expansion, which is generally produced locally, potentially reduces dependence on imported fossil fuels, contributing to increased energy security in a given country.[124]

In addition, electric vehicles can be used as a distributed energy resource by storing electricity generated by external sources in their bat-

124. See: Pressman, 2016.

teries and returning that energy to the electric grid - that is, by charging the vehicle outside of peak hours and dispatching electricity from the vehicle during peak hour. Depending on the model, electric vehicles themselves can be distributed generation sources - the energy generated by hybrid EV or fuel cells (FCEV or SOFC) can be consumed by the vehicle or injected into the electric grid. Combined with dynamic fee charging and smart grids, the energy stored in batteries can also be used in demand response mechanisms.[125] In addition, EV's association with the electric grid can help offset intermittent renewable sources variability. In this section, we will discuss all these electric vehicles impacts on the energy sector, beginning with the electricity sector and ending with the fossil fuel industry.

ELECTRICITY SECTOR

We use equipments that constantly consume electricity, from refrigerators to cell phone chargers. Along these lines, electric vehicles are just "another appliance" consuming electricity from the electric grid. Studies indicate that, when added up, EV impacts on the grid are manageable - by 2021, if 10% of cars on the roads in California, Norway, and Japan are electric, the increase in demand for electricity will be, respectively, 8%, 2%, and 3.4%.[126] However, depending on where and how EV are charged, impacts may be more pronounced. For example, if multiple consumers in the same neighborhood install fast chargers in their homes, electricity demand will increase significantly in that region. The electrical system must therefore be prepared to supply demand for these EV clusters by sizing the network to meet the need for more power, which is an impact much more significant than increased aggregate electricity demand.

Proper management of charging these vehicles has as its central variable a smart grid infrastructure that informs where EV clusters are located and encourages owners to charge their vehicles at off-peak hours - demand response mechanisms, using time of use tariffs to fulfill this role. Utilities in California,[127] for instance, are already upgrading their power grids to better manage not only the increase in electricity consumption - which may be caused by EV or other equipment that consumes even more energy because of their increased connectivity - but also because of the development of technologies that demand greater interface with the network, such as distributed generation.

Smart grids will also enable electric vehicles use in vehicle to grid (V2G) systems, in which

125. See FGV Energia - Distributed Energy Resources Booklet (2016) for a detailed discussion on demand response and management.
126. Barnard, 2016.
127. Bullis, 2013b.

the vehicle injects the energy stored in its batteries into the grid - a counterpoint to the grid to vehicle (G2V) system, which only consists of charging vehicles from the power grid.[128] Injecting energy in the network can occur at times of peak demand, with EV therefore contributing to easening a given residence's energy needs during the most critical moments of the day.[129] Combined with smart grids, a more complex demand management system can be developed in which utilities advise consumers on the best times to inject power into the grid or charge their cars. As more EV become available, the V2G system can in fact become a distributed power resource to be dispatched by the system operator at critical demand times.[130]

This energy storage functionality is also very useful when it is associated with intermittent renewable generation, when energy that is generated in moments of greater solar radiance or wind availability is stored for later use. Frequently using car batteries as energy storage may, however, affect their performance.[131] In addition to being used for this purpose, the car would have to be parked during the day if the energy to be stored were from solar source - which could be a disadvantage for the consumer. This way, using EV batteries for storage would be more appropriate in occasional uses.

In short, well-managed electric vehicles bring more advantages than disadvantages to the power grid, especially in a scenario in which several changes are already occurring regarding the way consumers handle their electricity use, more actively manage their demand and even generate their own energy. EV become, therefore, another tool to be used by electricity consumers in the future.

FOSSIL FUELS INDUSTRY

The potential future use of electricity for fueling vehicles will have an impact on the fossil fuel industry. But what impact, exactly?[132] Bloomberg New Energy Finance (BNEF) estimates that if the increase in demand for EV continues to grow at the current rate of 60% per year, there

128. GESEL, 2014.
129. EV can be used, for example, to soften the so-called "duck curve," which is the imbalance between production by renewable sources, such as solar, and peak consumption, occurring when the net load decreases in the middle of the day and increases at night, creating a longer and steeper ramp after sunset, thus requiring a rapid response from electric generators. For further details, see: Trabish, 2016.
130. An alternative to the vehicle to grid system is the vehicle to home (V2H) system, in which the energy stored in the EV is used as a local backup for homes or housing complexes, as in a local power generator (GESEL, 2014).
131. Less intense uses of V2G systems depreciate the car battery at lower rates. For a more in-depth discussion, see Ribberink et al., 2015.

will be a new "oil crisis" in 2023, with oil demand suffering an impact equivalent to the one that caused the crisis of 2014 - which was caused by an oversupply of 2Mbd in production.[133] In a more conservative analysis, using a growth rate of 35% a year, this "oil shock" would occur in 2028. Other institutions also projected when electric cars would affect oil demand (Figure 22). The IEA, for example, in its "450 Scenario"[134] from World Energy Outlook 2016, estimates that electric cars will be responsible for replacing 2Mbd of oil by about 2027, but in its New Policies Scenario, this figure is not even projected to be reached by 2040. In the Carbon Tracker Initiative scenario (NDC_EV), this limit is reached by 2025. In BP's (British Petroleum) Energy Outlook 2017, EV adoption will replace 1.2 Mbd only by 2035.[135]

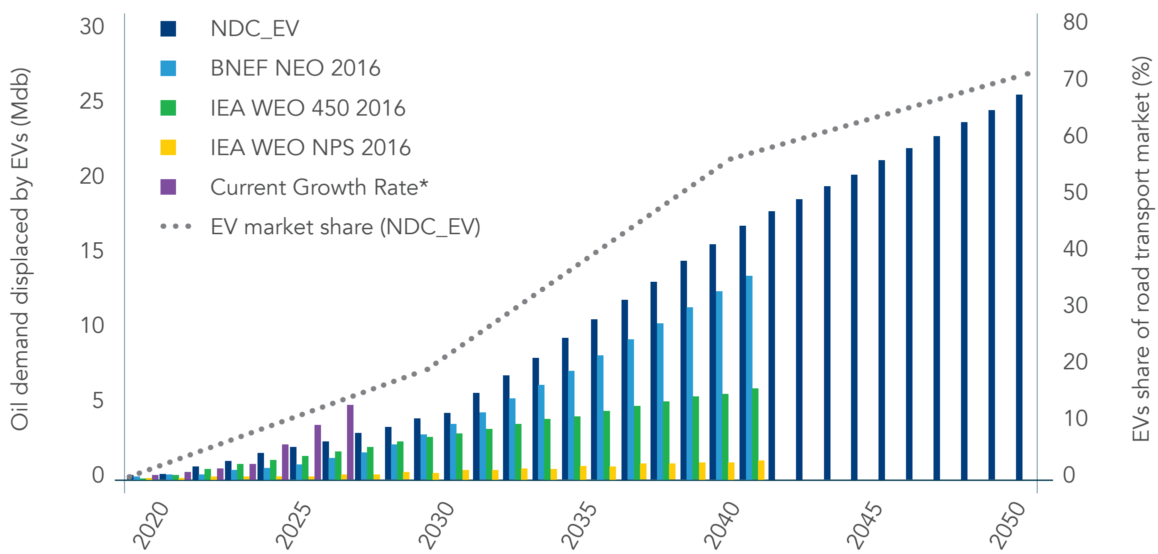
132. The adoption of a new technology over time follows a trajectory called "The S curve" (Randall, 2016). There is no consensus, however, on how the S curve will be for electric cars adoption, whose trajectory may be influenced by the large number of ICV still in stock when EV begin to become mainstream.

133. The supply crisis of 2014, which led to falling prices, was caused by an extra 2 million barrels of oil per day (Mdb) being injected into the market. BNEF's analysis predicts that a substitution in demand for oil equivalent to 2Mbd, caused by increased EV use, will occur in 2023 if EV adoption continues at the current growth rate of 60% per year. Source: Randall, 2016.

134. Scenarios of the IEA's World Energy Outlook: New Policies Scenario - IEA's baseline scenario. It takes into account political commitments and general plans announced by the countries, including national commitments to reduce greenhouse gas emissions and plans to phase out fossil fuel subsidies, even if measures to implement these commitments have not yet been identified or announced; Current Policies Scenario - does not assume changes in policies from the midpoint of the year of publication (formerly referred to as Reference Scenario); 450 Scenario - presents a coherent energy trajectory with the goal of limiting global temperature increase to 2° C, limiting the concentration of greenhouse gases in the atmosphere to about 450 parts per million of CO_2.

135. Carbon Tracker Initiative & Grantham Institute, 2017.

FIGURE 22: COMPARISON OF DIFFERENT OIL DEMAND REPLACEMENT PROJECTIONS DUE TO GREATER ELECTRIC CARS ADOPTION



*"Current Growth Rate" is derived from BNEF and assumes EV sales increase by 60% year on year. Data can be found at: https://www.bloomberg.com/features/2016-ev-oil-crisis/. IEA projections shown assume linear interpolation between given data points in the 2016 WEO.

Source: Carbon Tracker Initiative, February 2017.

According to Carbon Tracker Initiative projections, assuming they achieve cost parity with ICV in 2020, EV will account for approximately 70% of the road transportation market by 2050.[136] This assumption is one of the most optimistic presented. For BNEF, with cost parity between EV and ICV occurring in 2022, a total of 35% of cars sold in 2040 will have a plug.[137]

136. The issue of cost parity is important because EV are more energy efficient than ICV. This way, once both types of vehicle reach the same price, it will be more advantageous for consumers to buy an electric car - as long as range and charging infrastructure availability are not problems as well.

137. Randall, 2016. In this analysis, the main factor listed that has not yet occurred for further EV adoption is falling battery prices - whose cost must fall below USD 100/kWh for massification, as explained in Section 2.

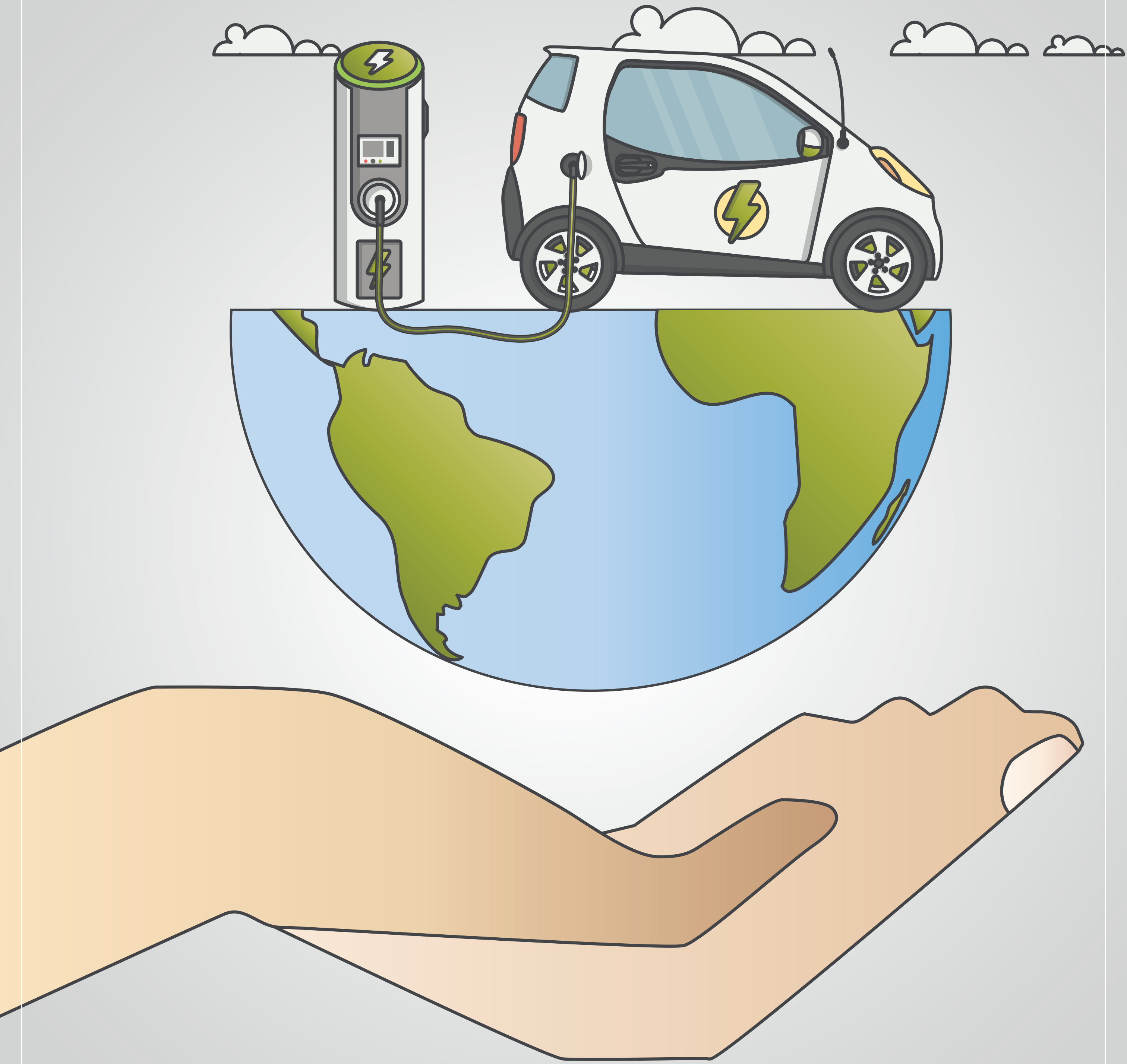
Public policy makers must analyze all these EV growth projections and the impacts on all sectors involved, taking into account the evolution not only of costs, but also of technologies and new business models.

The IEA predicts that 8% of passenger vehicles on the roads in 2040 will be electric in their New Policies Scenarios - this figure in the 450 Scenario is five times higher.[138]

When weighing these scenarios' conclusions, however, one must be conservative due to some factors: despite existing estimates, manufacturers have not yet been able to reduce battery prices ; there are not yet enough fast chargers for long-distance travel; many first-time vehicle consumers in countries like China and India will probably still opt for ICV; and growing demand for oil in developing countries may reduce the impacts of increased electric cars adoption, especially if oil prices return to USD 20/barrel and remain so. On the other hand, development of the mobility as a service market, in which vehicles are used more frequently, making electric cars use more advantageous due to their greater efficiency, has potential to accelerate their adoption.[139] In short, public policy makers must analyze all these EV growth projections and the impacts on all sectors involved, taking into account the evolution not only of costs, but also of technologies and new business models.

138. World Energy Outlook, IEA, 2016. According to the Global EV Outlook 2016, "electric vehicles" for the IEA are BEV and PHEV.

139. Ibid.



Electric mobility in Brazil: opportunities and challenges

As in the rest of the world, concerns about fuel prices, energy efficiency, and environmental issues, as well as the search for new business models, are present in Brazil, leading to the search for cleaner and more efficient vehicles during the past few decades. Although hybrid and pure electric vehicles in the country still account for a very small portion of the total fleet, some public policies to stimulate this technology, as well as incentives for greater use of these vehicles, are already being implemented. Technical and regulatory challenges, however, as well as overall impacts on the national energy sector, limit greater EV insertion in the Brazilian fleet.

Considering the Brazilian energy sector, the transportation sub-sector accounted for 46% of GHG emissions[140] in 2014, meaning that fleet electrification would play an important role in reducing this sector's total emissions. And in Brazil, where hydroelectric generation has a large share in the electricity matrix, EV are even more advantageous than in countries whose electricity generation is mostly from fossil fuels[141] because, as seen in Section 3, EV upstream emissions must also be taken into account.

140. 2016. Greenhouse Gas Emission Estimate System (SEEG) and Climate Observatory, 2016.
141. EPE, 2016a.

In August 2016, the fleet of pure and hybrid electric vehicles in Brazil was only 2,500 units,[142] still extremely small, considering the over 41.5 million vehicles in circulation in the country. According to projections made by the Energy Research Company (EPE),[143] conventional hybrids will represent 2.5% of car licenses in 2026 and 0.4% of the fleet for the same year. For pure electric vehicles, EPE has not yet made projections considering the very low expected number of vehicles with this technology in the coming decades.

Electric cars in the Brazilian market

Electric cars in the Brazilian market are still products within reach of consumers only in Classes A and B. Even though these vehicles, in the world context, are not classified in premium categories, they arrive in the country in a price range that does not compete with domestic popular combustion models due to the still high manufacturing costs and expenses associated with logistics and importing - although since 2015 there are import subsidies equivalent to: 100% import tax exemption for fully electric models with a range of at least 80 kilometers; aliquot from 0% to 7%, out of a total of 35%, for hybrid models depending on their size and efficiency. The current national market still presents a small variety of models given volumes avalaible. The following is an overview of models available in the country.

Virtually every auto manufacturer has been developing its models aiming towards the mass market, such as the Nissan Leaf, Renault Zoe, or GM Bolt, but it is still unlikely that a model more competitive than the Toyota Prius will hit the Brazilian market in the short term. Several auto manufacturers announced models would launch in the Brazilian market in 2013 and 2014, with subsequent cancellation, however, due to the adoption curve, the international political scenario, and the Brazilian economic scenario.

142. Brazilian Association of Electric Vehicles - ABVE (http://www.abve.org.br/noticias/brasil-tem-frota-de-so-25-mil-carros-eletricos-e-hibridos)

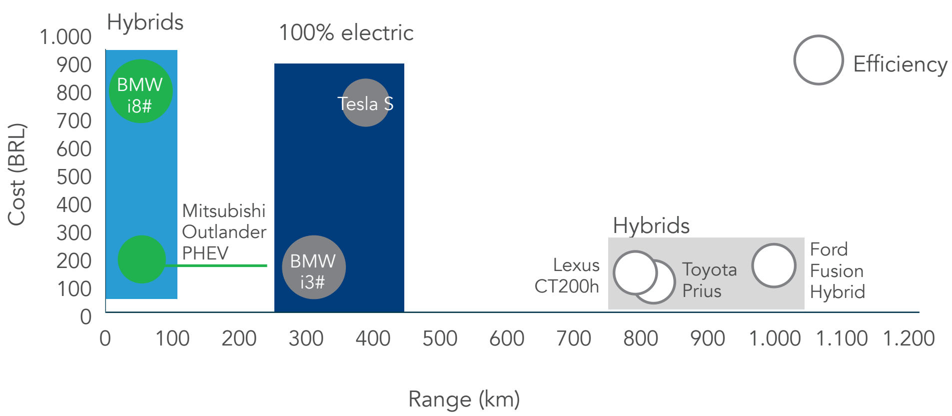
143. EPE, 2016b.

Regarding a potential Brazilian market for electric cars, only 2.2 million Brazilians declared gross monthly income above 20 minimum wages (Brazilian Internal Revenue Services data, 2013). Assuming an 1 vehicle average for each inhabitant in this income bracket, with a five years vehicle replacement rate, besides considering that one-third of these individuals would opt for electric vehicles, we would reach 150,000 licenses in one year - approximately 7% of licenses registered in 2016, a year of economic crisis. Given a low likelihood of price reductions, incentives for electric cars are needed to encourage a considerable adoption rate.

Financial viability analysis for electric cars, however, should consider greater efficiency in terms of cost per kilometer driven and possibly lower maintenance cost, and should not be limited to a direct comparison between purchase price and battery renewal cost. With lower battery costs and aligned incentives, the market may gradually expand.

FIGURE 23: ELECTRIC VEHICLES MODELS IN BRAZIL ARE AVAILABLE IN 3 GROUPS

Map of vehicles offered in Brazil



ELECTRIC CARS AVAILABLE IN BRAZIL, AFFORDABLE ONLY TO CONSUMERS IN CLASSES A AND B

MAIN FEATURES OF MODELS AVAILABLE IN THE BRAZILIAN MARKET

Toyota Prius: the "popular" model in the Brazilian market

Technology	+ Hydrid	Price	BRL 120 thousand
Comments	• Electric engine only in speeds up to 50km/h • Battery durability: 10 years. New battery costs around BRL 10 thousand	Range	613 km
		Efficiency	6,2 km/BRL

Lexus CT200h - a little more premium

Technology	+ Hydrid	Price	BRL 150 thousand
Comments	• Available in 2 models. The cheapest one costs BRL 135 thousand • More luxurious than Toyota Prius, but with similar technology	Range	790 km
		Efficiency	4,8 km/BRL

Ford Fusion Hybrid: the hybrid sedan

Technology	+ Hydrid	Price	BRL 160 thousand
Comments	• Imported from Mexico. Available only in more complete version • Battery warranty: 8 years. Battery exchange outside warranty costs BRL 36 thousand	Range	1000 km
		Efficiency	4,6 km/BRL

BMW i3 - the more fuel efficient BEV in Brazil

Technology	100% electric	Price	BRL 170 thousand
Comments	• Only BEV sold in Brazil • It features a small 2-cylinder engine to recharge the battery and a 9-liter tank	Range	312 km
		Efficiency	11,8 km/BRL

Mitsubishi Outlander PHEV - the hybrid SUV

Technology	Hydrid	Price	BRL 205 thousand
Comments	• Hybrid version of Mitsubishi's largest SUV • Range and consumption data are displayed according to the 100% electric mode	Range	62 km
		Efficiency	6,4 km/BRL

Tesla Model S - the pioneer BEV

Technology	100% electric	Price	BRL 750 thousand
Comments	• Sales started in 2016 in SP	Range	390 km
		Efficiency	7,0 km/BRL

BMW i8 - a sports model

Technology	Hydrid	Price	BRL 800 thousand
Comments	• It has the option of using the electric engine all the time • Both combined engines reach 100km/h in 4.4s • Range and consumption data are displayed according to the 100% electric mode	Range	37 km
		Efficiency	10 km/BRL

INCENTIVES FOR ELECTRIC CARS IN BRAZIL

Compared to the rest of the world, incentives and subsidies to encourage EV adoption in Brazil are still incipient - for example, purchase incentives offered to consumers, which is the main factor responsible for increasing EV acquisition in the rest of the world, are not offered in the country. Of the existing initiatives, however, public policies encouraging vehicular technology, such as Inovar-Auto and Inova Energia, as well as reductions in the Manufactured Products Tax (IPI) and Importation Tax on BEV and hybrids, are worth mentioning.

Inovar-Auto, an incentive program for technological innovation in the automotive industry, "stimulates competition and the pursuit of systemic gains in efficiency and increased productivity in the automotive chain, from the manufacturing stages to the technological services network and marketing."[144] The program, among other initiatives, aims to stimulate greater energy efficiency of several vehicular technologies: gasoline and ethanol powered cars , flex fuel engines, and those with hybrid and electric propulsion. Although the IPI for hybrid and pure electric vehicles remains high (25%), the search for greater energy efficiency can be seen as an incentive for these technologies to increase their participation in the domestic market.

The program, which started in 2013, will remain in force until December 2017[145] - and, as of this year, vehicles that are at least 15.46% and 18.84% less expensive will have, respectively, a reduced IPI of 1 and 2 percentage points.[146] It is important to keep in mind that the IPI for gasoline and flex-fuel vehicles ranges from 7% (up to 1.0 cylinder) to 25% (above 2.0 cylinders, gasoline only). Therefore, despite the reductions provided by Inovar-Auto, the IPI for electric cars remains high and may be considered a barrier to their dissemination. One suggestion would be a policy that tied the IPI tax rate to the car's emissions and energy efficiency, thus making electric vehicles more attractive.

Inova Energia, in turn, is "an initiative designed to coordinate actions fostering innovation and improve the integration of incentives provided by Finep, BNDES, and ANEEL."[147] One of its purposes is to support initiatives that promote densifying electric vehicle production's components chain, preferably ethanol, and improving energy efficiency of the country's entire vehicular fleet. In addition, one of the program's lines of research is composed of these technologies, as well as energy efficiency.

Regarding tax incentives, in 2015, the Import Tax for vehicles powered solely by electricity or hydrogen went from 35% to zero. The requirement is that these cars have a range of at least 80 km, which may benefit unassembled or semi-assembled units. Regarding hybrids, the import tax rate remains between zero and 7%, depending on engine capacity and energy efficiency characteristics of each model.

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144. Ministry of Development, Industry, and Foreign Trade (MDIC): http://www.mdic.gov.br/competitividade-industrial/principais-acoes-de-desenvolvimento-industrial/brasil-produtivo/acordos-internacionais-3
145. New automotive policies to succeed Inovar-auto are already being considered. See Reis, 2017.
146. MDIC (http://www.mdic.gov.br/competitividade-industrial/principais-acoes-de-desenvolvimento-industrial/brasil-produtivo/acordos-internacionais-3)
147. Finep (http://www.finep.gov.br/apoio-e-financiamento-externa/programas-e-linhas/programas-inova/inova-energia)

After these changes, the BMW i3, which came to the country costing almost BRL 220,000, may now be sold for BRL 170,000. Other BEV, such as Renault ZOE and Mitsubishi i-MiEV, are also found in the country costing around BRL 130,000.[148] Large reductions have been achieved, but for these prices, it is still possible to buy 5 new, 1000 cc cars with the money needed to purchase one electric car.

In addition to the Import Tax exemption, BEV and hybrids benefit from motor vehicle property tax (IPVA) exemption in seven states (Ceará, Maranhão, Pernambuco, Piauí, Rio Grande do Norte, Rio Grande do Sul, and Sergipe), as well as partial reduction in three states (Mato Grosso do Sul, São Paulo, and Rio de Janeiro). In the city of São Paulo, BEV and hybrids are also exempt from vehicle circulation restriction rules ("rodizio"), which prohibit some vehicles from getting access to the expanded city center at certain times of the day or one day each week.

Another incentive for electric vehicles is found in BNDES Finame,[149] which, by reducing incentives for diesel buses and trucks acquisition by large companies, indirectly encourages electric vehicles. The bank will gradually reduce long-term interest rates (TJLP) stake[150] in these vehicles, which is now at most 50%, to a maximum of 40% in 2018 and 30% in 2019. Energy-efficient goods will benefit from a maximum of 80% TJLP stake.

In view of these examples, we can conclude that more incentives may be used to develop EV in Brazil. It is worth mentioning, however, that, like all industrial policy measures that include subsidies, those for developing the Brazilian EV fleet are necessary as long as their technology is not competitive, costs are high, and the electric car industry is not yet developed – with a plan to end incentives the moment this reality changes.

148. Martins, 2016.
149. Program finances purchasing, sales, and production of machinery and equipment.
150. TJLP - Long Term Interest Rate.

DIRECT AND INDIRECT IMPACTS OF ELECTRIC MOBILITY EXPANSION IN BRAZIL

Electric cars should have an impact on the national energy sector in a way similar to what is seen in other countries. The magnitude and strategies to mitigate these impacts are already being studied. In this subsection, we will analyze the impact that electric cars will have on the national energy, environmental, and automotive sectors.

Regarding the automotive sector in Brazil, although it is still too premature to evaluate how prepared the Brazilian industry is for such a change, an effect similar to what will happen in other countries is expected, with the current automobile production chain adapting to that of electric cars. Creation of a new value chain linked to electric cars must also occur in the country - as we described in Section 3. When this change will occur, however, is still uncertain, being based on expectations that, once there is sufficient demand, electric cars will also be manufactured in Brazil.

As for the national fossil fuel industry, the real impact of electric mobility's expansion in Brazil will depend on the electric vehicle technology to be adopted. If hybrids flex fuel or fuel cell that uses ethanol are chosen, when these technologies are available for EV production, there will still be demand for biofuels. As for oil, given that it is expected that electric cars will begin to be adopted significantly in the country after 2025, there should be no immediate effect on these fuel's demand.[151]

What about EV impacts on the national transportation sector's emissions? Again, the answer to this question depends on the technology being adopted: flex PHEV will potentially have negative emissions, as explained previously; if BEV is the technology to be prioritized, emissions magnitude will depend on the electricity source supplying the vehicles. In a scenario with predominantly renewable electricity generation, increasing EV's participation in the national fleet will potentially reduce the transportation sector's GHG emissions. Otherwise, EV adoption may further increase these emissions.[152]

151. EPE, 2016a. In addition, Brazil is a case similar to China and India, countries in which there is still a repressed demand for automobiles due to the lower social and economic status of the population. Once that portion of society can afford to buy a car, it will be as affordable as possible - which, given the price of today's technology, is still a gasoline-powered vehicle.

152. Brajterman, 2016, comes to this conclusion in a model where increased electricity demand associated to greater electric cars adoption in Brazil is supplied by coal.

IMPACTS ON THE NATIONAL ELECTRICITY SECTOR

As seen in Section 4, EV should be treated as additional load to the system and therefore as another device that will interact with the distribution network. The main impact will be caused by more power being locally required by these vehicles, while the increase in demand caused by their insertion in the electric grid has less aggregate impact. According to the Electric Mobility Report developed by the Grupo de Estudos do Setor Elétrico of the Federal University of Rio de Janeiro (GESEL), in a scenario where EV represent 20% of the fleet and cover 8,000 km per year, with consumption of 6kWh/km, these vehicles would demand less than 2% of all electricity consumed in the country in 2011. Regarding power, the increase would be 10% if vehicle charging occurred after 6:00 p.m.[153]

The Companhia Paulista de Força e Luz (CPFL) also conducted simulations of electric vehicles use in its concession area. Considering a share in total vehicle fleet from 4% to 10% by 2030, the additional electricity consumption caused by these vehicles would increase from 0.6% to 1.6%, which would be completely manageable by the Brazilian electricity system, which already is accustomed to dealing with much greater load oscillations than those foreseen in the simulations. In the case of grid impacts, computer simulations concluded that the current capacity would be able to withstand the EV use – it would be a situation similar to constructing a new mall or commercial building, for example. A possible solution for these new charging station clusters would be to increase power transformers' capability, which is already possible in the current scenario. In the future, this situation will be more manageable using smart grid technology.

The greater or lesser impact of electric mobility in the National Interconnected System (SIN) depends on how the vehicles' batteries will be charged. In the case of unorganized charges, there will most likely be an increase in the system's peak demand. To avoid this situation, differentiated tariffs throughout the day would encourage charging to happen during the night, outside the peak demand hours for electricity.

In view of these possible scenarios, the National Electricity Agency (ANEEL) opened a Public Consultation[154] in April 2016 to evaluate the need to regulate electricity supply for charging

153. GESEL, 2014.
154. ANEEL, 2016.

EV. The goal was to discuss the matter with consumers, utilities, and society in general. The main issue to be considered is that, although electric vehicles are mobile loads, such as cell phones, power required to charge them is much higher, thus assuming electricity commercialization among consumers - which is not allowed in Brazil. A public hearing to address these issues should be held in 2017.

Since 2014, the National Congress has been developing a Bill[155] that seeks to mandate electricity utilities to install charging stations by public roads, residential and commercial locations, and require the government to develop mechanisms that promote EV charging plugs installation in residential building garages.

Thus, although electric vehicles are not yet fully developed in the country, utilities are already studying how to prepare for the impact they will cause in their concession areas, as well as considering the resulting business opportunities, while the government is acting to reduce regulatory uncertainty for pioneering users and entrepreneurs interested in electric mobility.

OPPORTUNITIES TO INCREASE ELECTRIC CARS' PARTICIPATION IN THE BRAZILIAN MARKET

As in the rest of the world, introducing electric cars to the Brazilian market brings opportunities and challenges to sectors connected to its development. As seen so far, when compared to other countries, incentives for electric cars dissemination in Brazil are not very developed. Even so, some initiatives by private agents are already happening in the country. Some utilities are using the percentage of their net operating revenues that must be used for R&D[156] investments to invest in electric vehicle demonstration projects. These projects[157] involve everything from developing technology to studying EV impacts on the electricity network, as well as developing new business models, such as car sharing, in partnerships with private companies (see BOX).

155. Brazilian House of Representatives, 2014.
156. Electricity utilities are required to allocate 0.75% of their net operating revenues to R&D projects.
157. For access to R&D projects by electricity utilities, see ANEEL's R&D Program Management page: http://www.aneel.gov.br/pt/programa-de-p-d

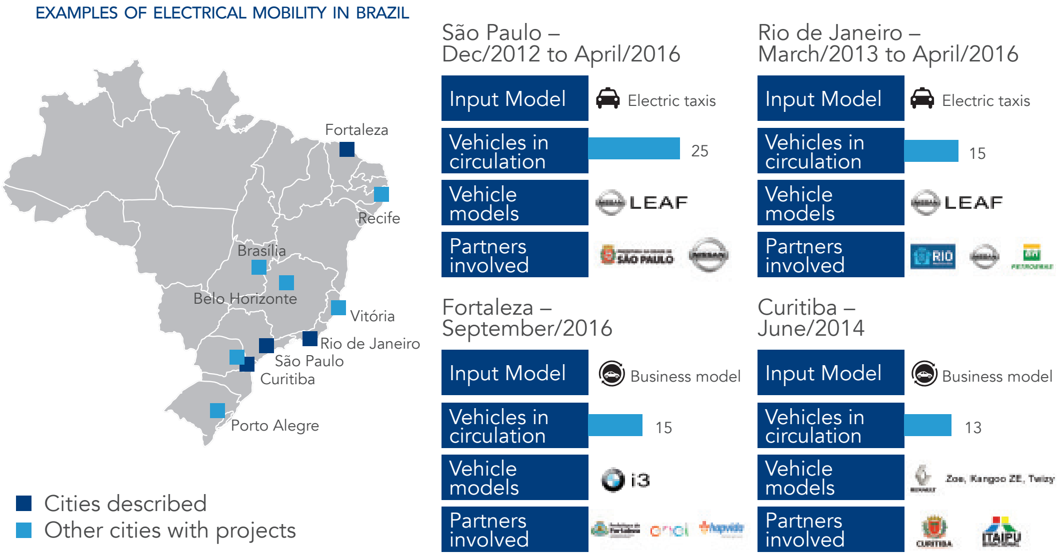
Public electric mobility in Brazil

It is still uncertain how electric propulsion will change urban areas. . In Brazil, the manufacturing and fuel industries, and the electricity sector must make significant changes to accommodate this new reality. Among the technological alternatives competing are fully electric vehicles (BEV), plug-in hybrids (PHEV), and fuel cell electric vehicles (FCEV). Most likely, each region will gradually adopt solutions that balance advantages and constraints imposed by cultural, economic, transportation, environmental, and industrial contexts.

The solution that will prevail in Brazil must adapt to factors intrinsic to the country, among them: (1) its size, and consequent (2) disparity between large metropolitan markets versus small, remote cities, (3) high income concentration, in addition to (4) existence of a established biofuel production chain for flex fuel and ethanol vehicles.

Business models have been subject to tests to evaluate their economic viability, as well as the expected adoption curve and potential side effects on road and electricity networks. Large Brazilian cities need to adapt to this scenario and several have already created their pilot projects in partnerships between city governments and private initiatives. The following are examples of tests carried out or in progress in Brazil.

SEVERAL BRAZILIAN CITIES ALREADY HAVE ELECTROMOBILITY PILOT PROJECTS IN PLACE THROUGH PARTNERSHIPS BETWEEN MUNICIPALITIES AND THE PRIVATE SECTOR



ELECTRIC CAR SHARING FROM NORTH TO SOUTH

Electric car sharing projects were recently started in Fortaleza and Porto Alegre, both seeking to encourage the car-sharing model, a growing need in large metropolitan areas, and to promote greater interaction with electric vehicles in order to demystify their use.

Starting in September 2016, the Veículos Alternativos para Mobilidade (VAMO) project is part of an initiative made possible by a partnership between Fortaleza City Hall, Enel (formerly COELCE, a utility concessionaire in the state of Ceará) and a health care plan provider (Hapvida), with the goal of "stimulating the logic of sharing and integration between modes [of transportation]," according to the Secretary of Conservation and

Public Services, Luiz Alberto Sabóia. VAMO, which began with five stations and eight cars, extended its charging points in five months to 11 locations and its fleet to 15 two-seater vehicles - all 100% electric. Fees, which are incentivized for public transportation card users in the capital of Ceará, are cost competitive with taxis' rates, but require a minimum monthly subscription fee. Registration and reservations are made through an app developed for the project.

In the capital of the state of Rio Grande do Sul, the model began in March 2017, similar to what happened in Fortaleza, using electric vehicles that have a range of up to 300 kilometers. The initiative began with a partnership with Porto Alegre City Hall, involving public transportation and data processing, and will last 20 days.

ELECTRIC TAXIS IN SÃO PAULO AND RIO DE JANEIRO

In 2016, after four years of operation, Nissan completed its pilot program, which provided its 100% electric vehicles from the Leaf line to taxi drivers in partnership with the municipal governments and taxi associations in Rio de Janeiro and São Paulo. Throughout the campaign, the 40 cars in circulation, 25 cars in the city of São Paulo and 15 in Rio, traveled about 2.2 million kilometers, and according to Nissan, reduced CO_2 emissions into the atmosphere by 13.6 tons for each vehicle in the program.

PUBLIC SERVICE TO THE POPULATION IN CURITIBA

In Curitiba, incentive to use electric cars is structured in phases. The Eco-electric project is part of a strategy to meet environmental commitments assumed by the municipality under the C40 - a network involving large cities interested in creating initiatives to mitigate climate change. In the first phase, started in 2014, ten cars and three mini buses were provided by Renault and Itaipu Binational under a loan agreement, as well as ten charging stations installed in seven locations to meet the demands of the Municipal Guard, the Secretary of Municipal Traffic, and the Curitiba Institute of Tourism. In the second phase, the focus is to make charging stations multifunctional. In the next stages, a car-sharing model is planned for the 2018-2020 triennium.

In addition, an opportunity that Brazil should consider when developing its electric car industry is which vehicular electrical technology would be more appropriate for the country, since the biofuels industry and flex-fuel technology is already nationally widespread.

Another business opportunity, which may inspire Brazilian electricity utilities, is one developed by Spanish electricity distributor Endesa, a subsidiary of Enel, on the island of Mallorca. Through Ecar (Endesa Club de Auto-Recarga), electric car drivers have access to fast charging stations throughout the Island, using a prepaid card to pay for charging, as well as an app that informs when and where charging stations are available. Endesa also offers different plans for charging electric car batteries - a mechanism similar to cellphone operator plans, as well as a service for installing home charging points.[158]

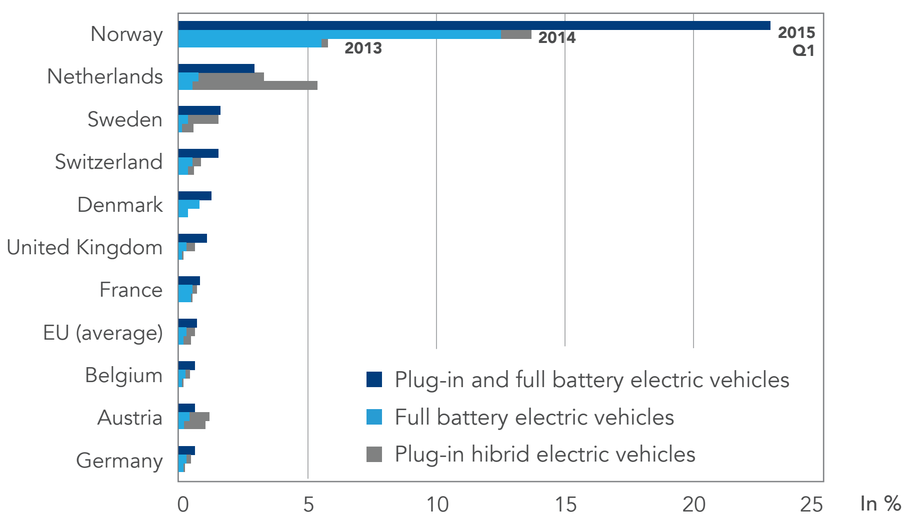
In addition, an opportunity that Brazil should consider when developing its electric car industry is which vehicular electrical technology would be more appropriate for the country, since the biofuels industry and flex-fuel technology is already nationally widespread. Several variables influence adoption of different electric vehicle technologies in several countries (see BOX). It is up to the policy maker to consider the national comparative advantages when developing Brazilian electric mobility.

158. For more information, see: https://www.endesavehiculoelectrico.com/

Which factors determine the EV technology to be adopted in a country?

Electric vehicle technology predominance varies considerably from country to country. In the European Union, PHEV and BEV accounted for 0.7%[159] of total vehicle registrations in 2014, but, considering each country separately, these technologies' proportions in market share are quite different. In the Netherlands, for example, in 2014, PHEV accounted for 3.1% of new vehicle sales, while BEV accounted for 0.9% of sales[160]. In Norway, where electric vehicles account for 22.9% of the total market share, 18% are BEV.[161]

FIGURE 24: NEW BEV AND PHEV MARKET SHARE IN SELECTED EUROPEAN COUNTRIES



Source: The International Council on Clean Transportation (ICCT), 2014.

159. ICCT, 2014.
160. Ibid.
161. Ibid.

Among the factors explaining the major differences between BEV and PHEV in market share, we highlight incentives' design, which, in Norway, were more targeted on pure electric vehicles. First, BEV and hydrogen-cell vehicles are exempt from vehicle registration tax, which is not the case for hybrids - although the latter benefit from fee reductions based on CO_2 and NOx emissions. Another BEV advantage is value added tax (VAT) exemption, which is currently 25% in Norway. Both exemptions help to explain these vehicles' reduced costs, as well as the considerable effect on their sales. It should also be considered that BEV and hydrogen cell vehicles pay lower licensing fees, and that BEV are exempt from toll payments in much of the Norwegian territory, just as they enjoy access to exclusive bus lanes.[162]

In the Netherlands, in addition to BEV, hybrids enjoy a reduced vehicle registration fee as well as a 50% exemption on ownership tax, which is zero for owners of zero emissions vehicles. Gradual changes in these incentives are expected by 2020, which for hybrids should be reduced considerably, matching their rates to those paid by internal combustion vehicles, so that ZEV are prioritized.[163]

What is not yet known are the factors that initially led these governments to direct incentives that favor certain technologies over others. The environmental agenda is one of the main determinants of electric vehicle technology adoption, and also determines the pace with which these technologies are adopted in each country. But other factors, such as consumer profiles and where they live, may also influence greater dissemination of one EV type over another.

162. Bjerkan et al., 2016.
163. EAFO – European Alternative Fuels Observatory (http://www.eafo.eu/content/netherlands).

The Brazilian case, for example, is very particular: flex-fuel technology has been a reality since 2003, just as since the end of the 1990s, mandatory percentages of anhydrous ethanol mixed in gasoline must be respected. The percentage of anhydrous ethanol blended in gasoline has been around 20% to 25% since 2000, and in 2015 was raised to 27%, one of the largest possible without causing damage to the engine.[164]

This way, flex-fuel vehicles have already contributed heavily to reducing emissions in the Brazilian transportation sector for almost two decades. Unlike other countries, it is not as necessary to "hurry" to adopt EV in order to comply with the climate emissions reduction agenda. According to the Automotive Vehicles Manufacturers National Association (ANFAVEA), ethanol use reduces the effect of carbon dioxide in nature through the sugarcane farming cycle in Brazil, which compensates for this gas' emission. Therefore, it may be said that there are "negative emissions"[165] associated with ethanol hybrid or ethanol cell (SOFC) vehicles, since emissions compensation occurs on two fronts.

Thus, Brazil benefits from this comparative advantage from using electric vehicles to reduce emissions, since ethanol is already used as a renewable fuel and flex hybrids or ethanol cell (SOFC) vehicles can be used in the transition toward electrifying the fleet.[166] Another advantage of the increased adoption of flex hybrid or ethanol cell vehicles is using an existing supply infrastructure as well as a biofuel production chain.

164. FGV Energia, March/2017.
165. This is a vague term, as emissions from the vehicle production process are not taken into account.
166. Vehicular natural gas (VNG) is also already used in Brazil as a transitional fuel, with fewer emissions than traditional fossil fuels.

Final Remarks

The recent dawn of the electric car is linked to policies to mitigate greenhouse gas emissions in the transportation sector in several countries around the world. However, it is also worth considering that electric cars are the natural evolution of vehicular technology, which will lead to more efficient and better performing vehicles in the future. In addition, with the advent of information-sharing technologies, consumers are becoming more proactive in their way of consuming goods and services. This evolution of consumer behavior - which can already be seen in the electricity sector, with the growth of distributed generation, more widespread use of energy efficiency, and demand-side management - is also occurring in the mobility sector with the increased sharing of the services it provides.

In this mobility as a service scenario, the technological characteristics inherent in electric cars make them suitable to meet these new requirements. In addition, it is worth noting that besides climate issues and mitigation policies, developing the electric car industry creates new business models, new economic opportunities, and practically a whole new production chain.

Despite these transformative variables, the electric car is still a few years away from massification - which should occur in the coming decades. Before the electric car becomes common, it must become less expensive, have greater range, and the initial resistance to its use needs to be overcome. To address the first two issues, lithium-ion batteries – the reason electric cars are still high priced - are expected to become substantially less expensive and have a greater capacity to store energy in the coming years.[167] Until this occurs, incentives are needed for electric mobility to continue to develop.

167. The start of production at Gigafactory, Tesla's super battery factory, will be a milestone for reducing battery prices. Batteries produced at the factory will lead to a considerable increase in the world supply, and with that, their prices are expected to fall considerably in the following years (Lee, 2017). When batteries become less expensive, electric cars will become more advantageous than internal combustion vehicles on all fronts considered.

The issue of resistance to electric vehicles use may be battled on two fronts: first, educating consumers about electric cars, demystifying their real costs and benefits, and second, by investing in (whether public or private) charging station infrastructure. Although electric car batteries are expected to be mostly charged in users' homes in the future, public charging station availability will still be of great importance in this transition phase from combustion to electric mobility.

Another barrier to electric car development is the low price of fossil fuels. For example, studies for the US show that it is only when the price of gasoline exceeds USD 3/gallon that there is a correlation between fuel price and the consumer's vehicle choice.[168] The current scenario of low crude oil prices (about USD 54/bbl at the time of this publication) may become a deterrent to electric car development - another factor justifying the need for incentives while its prices are still higher than those of conventional cars.

As for the sectors affected by the advent of the electric car - environmental, automotive, and energy - impacts are different, as we describe in this publication. For the environmental sector, the electric car brings the good news of decarbonization - if the electricity source that supplies them is renewable, of course. On the other hand, lithium mining for battery production is an activity that needs to have its impacts studied and mitigated. For the automotive sector, the electric car means a whole paradigm shift, a true transformation of the product offered by this industry. In general, cars will still be in demand, whether they are internal combustion or electric. It is up to this sector, therefore, to study the signals of its consumer base and meet its new demands.[169] For the energy sector, the electric car means using electricity as an automotive fuel (with or without the aid of an auxiliary alternative fuel such as ethanol, for flex hybrid or ethanol cell vehicles). The EV technology to be adopted by each country or region will determine how the energy sector in

168. Ayre, 2017. The price of gasoline on 04/18/2017 was USD 2.406/gallon (Source: http://gasprices.aaa.com/).
169. A study by McKinsey & Company (2017) lists 3 horizons of EV adoption, with different consumer profiles in each of them. On the first horizon, pioneer consumers (who are current owners of electric cars) demand this product because it is "new" and "different," motivated by environmental issues or the status that these vehicle provides. In a second wave, there are consumers who will demand electric cars because they have better performance and lower maintenance costs. Current EV prices, however, mean that this portion of the market has not yet been served - which is a potential for the automotive industry when EV price drops. On the last adoption horizon, there are consumers who also want efficiency and lower maintenance costs, but they demand extended range and greater vehicle usefulness (SUV and pick-up consumers, for example). When EV offers these options, it will be another opportunity for the automotive industry. Recently, Tesla announced that it will launch a semitruck in 2017 and is expected to launch a pickup in a few months.

each location will be affected. Another impact of the electric car on this sector is the possibility of its use as a distributed energy resource, which may positively influence planning of an electricity sector increasingly linked to intermittent renewable sources.

As for Brazil, it is expected that electric cars will be disseminated a little later than in other countries due to some factors. First, the country has a well-developed biofuels sector - the Brazilian NDC,[170] in fact, considers that biofuels will help decarbonize the Brazilian economy, while using electric cars for this purpose is not mentioned. Second, the number of conventional vehicles still in stock when EV begin to enter the market may affect adoption speed for this new vehicle technology. Additionally, there is the delicate issue of consumer preferences. At this point, it is worth mentioning that the Brazilian consumer still considers the car an investment good, a factor contributing to the fact that mobility as a service is developing more slowly in the country. But what is expected is that, according to common sense, when the electric car is as inexpensive as conventional cars, it should become more popular in Brazil. Thus, instead of entering the electric car "first wave", which witnessed technology and innovative business models being developed, it is expected that Brazil will participate in a "second wave", of simple adoption.[171] Either way, the electric car will gain strength in the country in the coming years, and it is up to policy makers and the industry to prepare for that moment.

170. Nationally Determined Contribution, document in which Brazil stipulated its targets for compliance with the Paris Agreement. The document may be accessed at: http://www.itamaraty.gov.br/images/ed_desenvsust/BRASIL-iNDC-portugues.pdf

171. Some initiatives may help the country participate in the "first wave." The "first electric car produced with national technology" was recently presented by Serttel, an electric mobility company, in Recife (Ambiente Energia, 2017). In addition, a national charging infrastructure has also been developed in Santa Catarina (Canal Energia, 2017). And the Electric Vehicle Program, by Itaipu Binacional, has been contributing since 2006 to the study of electric mobility in the country (https://www.itaipu.gov.br/tecnologia/veiculos-eletricos).

List of Acronyms

ABVE – Associação Brasileira do Veículo Elétrico

AEV – All Electric Vehicle

ANEEL – Agência Nacional de Energia Elétrica

ANFAVEA – Associação Nacional dos Fabricantes de Veículos Automotores

BEV – Battery Electric Vehicle

BNDES – Banco Nacional de Desenvolvimento Econômico e Social

BNEF – Bloomberg New Energy Finance

BOEV – Battery Only Electric Vehicle

BP – British Petroleum

CCS – Combined Charging System

CHAdeMO - "CHArge de MOve"

COELCE – Companhia Energética do Ceará

CPFL – Companhia Paulista de Força e Luz

EAFO – European Alternative Fuels Observatory

EPE – Empresa de Pesquisa Energética

E-REV ou REX – Extended Range Electric Vehicle

EUROBAT - Association of European Automotive and Industrial Battery Manufacturers

EV – Electric Vehicle

EVCS – Electric Vehicle Charging Station

EVI – Electric Vehicles Initiative

EVSE – Electric Vehicle Supply Equipment

FCEV – Fuel Cell Electric Vehicle

GHG – Greenhouse Gases

GESEL – Grupo de Estudos do Setor Elétrico da Universidade Federal do Rio de Janeiro

GM – General Motors

GNV – Gás Natural Veicular

HEV – Hibrid Electric Vehicle

HOV lane – High-Occupancy Vehicle Lane

ICCT – International Council on Clean Transportation

ICT – Information, Communication, and Technology

ICV – Internal Combustion Vehicle

IEA – International Energy Agency

IEDC – International Economic Development Council

IFA – Institute for Automotive Research

IPI – Imposto sobre Produtos Industrializados

IPVA – Imposto sobre a Propriedade de Veículos Automotores

IVA – Imposto sobre Valor Adicionado

LEZ – Low Emission Zone

MDIC – Ministério do Desenvolvimento, Indústria e Comércio Exterior

NADA – National Automobile Dealers Association

NASA – National Aeronautics and Space Administration

NDC – Nationally Determined Contribution

NEV – Neighborhood Electric Vehicles

Ni-MH - Nickel–Metal Hydride Battery

OECD - Organisation for Economic Co-operation and Development

OPEP – Organização dos Países Exportadores de Petróleo

PEM – Proton Exchange Membrane

PEV – Plug-in Electric Vehicle

PHEV – Plug-in Hybrid Electric Vehicle

RPEV – Road Powered Electric Vehicle

SAE – Society of Automotive Engineers

SEEG - Sistema de Estimativas de Emissões de Gases de Efeito Estufa

SIN – Sistema Interligado Nacional

SOFC – Solid Oxid Fuel Cell

TJLP – Taxa de Juros de Longo Prazo

UCSUSA – Union of Concerned Scientists of United States of America

VAMO – Veículos Alternativos para Mobilidade

VAT – Value Added Tax

VLT – Veículo Leve sobre Trilhos

WPT – Wireless Power Transfer

ZEV – Zero Emission Vehicle

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