Comparative evaluation between electric vehicles and conventional vehicles in the context of climate change mitigation

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Abstract

Currently, electric vehicles (EV) have been identified as a future trend in the automotive industry. Among the motivations of the countries for this are: reducing dependence on oil and its derivatives, promoting the more efficient use of energy and causing less environmental impacts, especially those related to the emission of Greenhouse Gases (GHG). Hybrid and electric cars do not represent a recent technological innovation, despite that they have had a marginal participation in the history of the automobile since the 1930s. Incidentally, it is worth mentioning that EVs are not exempt from environmental impacts, especially in the production stage of the same. In this article, we hope to contribute with information about the characteristics of the environmental performance of EVs in relation to conventional vehicles powered by internal combustion (ICE), analyzing what are their advantages and disadvantages, what are the environmental impacts caused throughout the life cycle and how this technology could contribute to the mitigation of climate change. In addition, the impacts of EV expansion on final energy demand are also discussed. To this end, a review of the systemic literature was undertaken based on recent research and on basic ones focused on EV. One of the main results indicated that, the greater the share of renewable energies in the supply of electricity, the greater the reduction in GHG emissions by EVs, and in some cases there may be an increase in emissions in the total balance of the life cycle of this energy. technology compared to conventional.

Keywords: Electric vehicles. Climate changes. Environmental impacts. Life cycle. Energy.

1. Introduction

The stimulus for electric cars, together with the policy of transforming an economy based on oil (or fossil fuels) to a sustainable economy, based on renewable energy sources, has become a trend for the future of the automotive industry [1]. We can exemplify this statement by citing the historical situation of the United States of America (USA) in relation to this topic.

The USA is the country that consumes the most oil in the world, particularly in the transport sector and, in 2009, more than 95% of the energy consumed came from oil [2]. Much of the oil consumed by the US is imported from other countries such as Canada and Mexico, and gasoline is the petroleum product most consumed by the transport sector in the US, comprising 64% of the energy consumed. In response to this strong dependence on oil, the US government, more incisively since the end of the 2000s, has been stimulating the production of electric and hybrid cars [2].

The history of electric cars is not recent and is linked to the emergence of batteries. The first lead-acid battery was developed in 1859 by the Belgian Planté. This battery came to be used later, from 1880, by several electric vehicles in France, USA and United Kingdom [2]. In the year 1881, Trouvé allowed the first electric car to be powered by a secondary battery. Only four years later, Benz demonstrated the first vehicle with an internal combustion engine [3].

Therefore, electric vehicles (EV) do not represent a recent technological invention, and appeared before fossil fuel-based vehicles [4]. However, the explosion vehicle (internal combustion) ended up predominating as a transport option due to some reasons, such as: its greater autonomy in kilometers per liter of fuel; the lack of concern with atmospheric emissions from urban vehicles at the time (early 20th century, in this case); low price of fossil fuels; the fact that batteries have low efficiency and charge density; the productive system of cars developed by Henry Ford, which allowed the final price of gasoline cars to be equivalent to half the price paid for electric cars. In addition, in the 1920s, US highways already connected several cities, which demanded vehicles capable of covering long distances, in addition to the ease of commercialization of fuels with the network of gasoline distribution [5-6].

Over time, technologies were developed that improved the performance of EVs, for example: a nickel-iron battery with 40% more capacity than lead. Other advances were regenerative braking, equipment capable of transforming the car's kinetic energy into electrical energy during braking, and the hybrid system, powered by gasoline and electricity. The regenerative braking system is capable of recovering up to 30% of the vehicle's energy [3-6].

In the early 19th century, there was competition between steam-powered, electric, and gasoline-powered automobiles. It was also easy to find professionals capable of carrying out the maintenance and repair of gasoline vehicles due to their simplicity. On the other hand, there were few mechanics who understood how electric motors and batteries in electric and hybrid cars work. Due to these aforementioned factors, EV and hybrid production started to decline from the 1930s onwards in the US and UK. It is interesting to note that there were production peaks in these countries only during the two world wars, when there was fuel rationing [3].

From the 1960s onwards, when there was greater public awareness about environmental problems and the limits of exploiting natural resources, especially non-renewable ones, electric cars once again gained the attention of industries such as Ford and General Motors. During this period, conventional automobiles came to be seen as the main source of air pollution in cities. Electric cars, on the other hand, do not generate local emissions and allow the use of renewable energy sources, which led to US government incentives for research related to EV and hybrid technology. Other countries have also started to invest in this technology. In 1997, Toyota's Prius hybrid vehicle was launched in Japan, and Audi in Europe also created the Duo hybrid. However, it is worth mentioning here that in the 1990s the large oil companies, such as Exxon, Shell and Texaco, contributed financially for campaigns of politicians against EVs and financed advertisements against this type of vehicle [3].

Bringing the question of transport to the Brazilian reality, according to the projection made by [7], in 2030, the national fleet would be the fifth largest in the world, reaching 83.7 million cars. In 2015, Brazil had 49.8 million cars [8]. As a result, the high concentration of vehicles can cause traffic jams, especially in large Brazilian cities (which already occurs in megalopolises such as São Paulo and Rio de Janeiro). In addition, the growth in the number of cars in Brazil will certainly demand a proportional increase in energy demand in the coming years1, which makes the use of electricity in the transport sector attractive as an alternative to the fossil fuels currently used, especially gasoline [3]. A greater adoption of EVs, however, can generate an increase in load demand on the electrical system and transmission networks, which, eventually, will require investments for their readjustment [9].

Given this scenario, it is questionable under what circumstances the entry of light electrified vehicles is strategic both from the point of view of energy planning and in the context of the transition to a low-carbon economy [10]. Regarding the mitigation of climate change, technological transitions offer the main possibility of reducing greenhouse gas (GHG) emissions [11]. However, it is unlikely that atmospheric GHG stabilization can be achieved through the adoption of only one type of technology, requiring a portfolio of technologies, suitable for different economic sectors, to achieve the desired mitigation goals [11-12].

In this context, some questions addressed in this article are: To what extent can EVs be considered sustain able? Do these vehicles actually contribute to climate change mitigation? What are the impacts generated in the useful life of an EV and a conventional vehicle? What are the results when comparing EVs and conventional vehicles? There is sufficient and adequate infrastructure to EV mobility? Finally, this article discusses whether the expansion of EV production and use is, in fact, a less energy-intensive and carbon-intensive strategy compared to conventional vehicles. To support this discussion, a comparison was made in relation to the productive life cycle of these two groups of vehicles, namely: electric and conventional vehicles.

2. Discussion

2.1 Types of vehicles

Vehicles can be divided into the following [4,13,14]:

- **Conventional vehicle:** Conventionally marketed vehicle, with an Otto cycle internal combustion engine (ICE). It covers vehicles that run only on gasoline or only on ethanol and vehicles equipped with flex fuel technology that run on gasoline and ethanol.
- **Vehicle converted to vehicular natural gas (CNG):** Vehicle of any technology that has been converted to use vehicular natural gas.
- **Hybrid Electric Vehicle (HEV):** Vehicle with two engines, one electric motor, powered by an electric battery, and one internal combustion engine. The HEV battery is rechargeable exclusively through the regenerative braking system (it is not connected to the mains). A vehicle is only classified as fully hybrid if it can be powered, at least part of the time, by the electric motor alone. A device capable of accumulating energy that has been applied in hybrid commercial vehicles is the ultracapacitor, capable of very quickly accumulating a large amount of the electrical charge recovered when braking, for example, to release it instantly later. It has greater autonomy than the battery electric vehicle.
- **Plug-in Hybrid Electric Vehicle (PHEV):** A hybrid vehicle, which also has a liquid-fuelled MCI and an electric motor. Its battery, however, is rechargeable both via regenerative braking and via connection to an electrical system. Combined with smart grids, it allows electric cars to function as buffers in the distribution network, charging their batteries during low demand hours and discharging them during peak hours.
- **Battery Electric Vehicle (BEV):** Vehicle based on an electric motor only. The vehicle is powered by a battery, which can be recharged from the local electricity grid and also through the regenerative braking system, which takes advantage of the energy released during braking.

- **Electric Vehicle with Fuel Cells:** uses the energy generated by a cell from Hydrogen to drive the vehicle or charge the battery.

There are basically three types of charging for electric vehicles: slow, in which the charging time is 6 to 8 hours (recommended for use in homes and businesses); semi-fast, in which the charging time is between 1 and 2 hours (recommended for use in public spaces, shopping centers, parking lots, etc.); and fast, in which the charging time is 30 minutes to reach 80% charge and 1 hour to 100% charge (recommended for use in public places, such as: highways). Figure 1 illustrates some of the models in circulation in Brazil.

Figure 1- Some models of electric cars that are in circulation in Brazil.

An example of use in Brazil for cargo transport are electric vehicles powered by pulling, which are used to collect recyclable urban solid waste by collectors [15].

2.2 Comparison of the life cycle of electric vehicles and conventional vehicles

The Life Cycle Assessment (LCA) is a tool that allows quantifying the environmental impacts throughout the entire life cycle of a product, from the extraction of raw materials to its final destination [16], as illustrated in Figure 2. However, performing this estimation is a challenging task. In this context, this subsection presents and compares the results of studies that used this instrument to comparatively assess different types of LV and ICM.

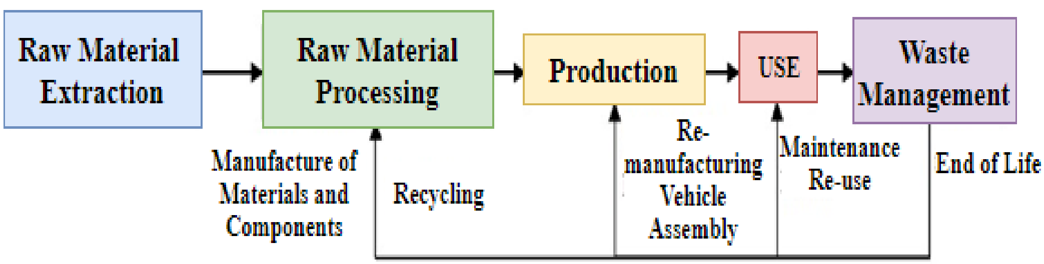

Figure 2- Life Cycle Assessment Stages

The environmental impacts of EVs can be influenced by several factors. Analysis from the perspective of Cradle-to-grave and Well-to-wheel (WTW) considers the entire life cycle and can be useful to assess the contribution of EVs to the reduction of GHG emissions [1, 17]. Gasoline and diesel vehicles in operation pollute the atmosphere [1]. The EV, on the other hand, allows for zero emissions during the use phase. In the Brazilian case, where hydroelectric generation predominates in the national interconnected system (SIN), EV allows for very significant reductions in total GHG emissions (from electricity generation to vehicle use and other processes that require energy), when compares the BEV with its conventional equivalent MCI.

However, EVs are not free of GHG emissions in their life cycle, for example: they require energy to recharge the vehicles, and in electricity generation there is a higher or lower emission level, depending on the country's electrical matrix.

An LCA study developed by the [18] analyzed the emissions of polluting gases inherent to the different stages of production, operation and disposal of BEV and compared them with the emissions of vehicles powered by gasoline. This study found that, on average, an electric vehicle generates half the GHG emissions of a regular car (powered by gasoline) over its lifetime, even when emissions caused by the battery manufacturing process are included. Expanded EV use has the potential to reduce GHG emissions, especially when recharged by electricity generated from renewable sources. A comparison was made from the raw materials to manufacture a car, its production, use, disposal and/or recycling. The study considered the most popular models for sales in the US: Nissan LEAF and the Tesla Model S. Considering where these cars are currently sold (in the US), emissions from the production process are offset within 6 to 16 months of use of electric vehicles. GHG emissions associated with the use of electric vehicles are not insignificant and will depend on the energy sources used to recharge the vehicle's battery and its efficiency. The results showed that driving an electric car generates less GHG emissions than driving a gasoline car that manages to do 12.3 km/l [18].

EV emissions are still tending to decrease, given that, in the USA, the share of coal in electricity generation decreased from 49% in 2006 to 30% in 2016, to the detriment of renewable sources, especially wind and solar energy (EIA, 2017). In Brazil, 83% of electricity generation came from renewable sources in 2016. On a grid comprised of 80% renewable electricity, manufacturing an electric car will result in a 25% reduction in production-related emissions and an 84% reduction in usage-related emissions [18].

The manufacturing stage of electric vehicles generates more emissions than the manufacture of gasoline powered vehicles due to the materials used. About 85 to 90% of emissions in the life cycle of gasoline-powered vehicles are in the operation stage, with the manufacturing stage having a smaller portion of emissions [18]. An EV, on the other hand, generates a greater amount of emissions (about 70%) in its manufacturing stage than the gasoline vehicle, considering a vehicle that travels 426 km per charge. This varies depending on the model. However, if we consider the total balance (manufacturing + operation), the electric vehicle will generate 53% less GHG emissions than the vehicle equivalent to gasoline (Figure 3). An electric vehicle of medium size (midsize) causes an emission reduction of about 29 tons of CO2 equivalent (tCO2e) compared to a similar vehicle powered by gasoline.

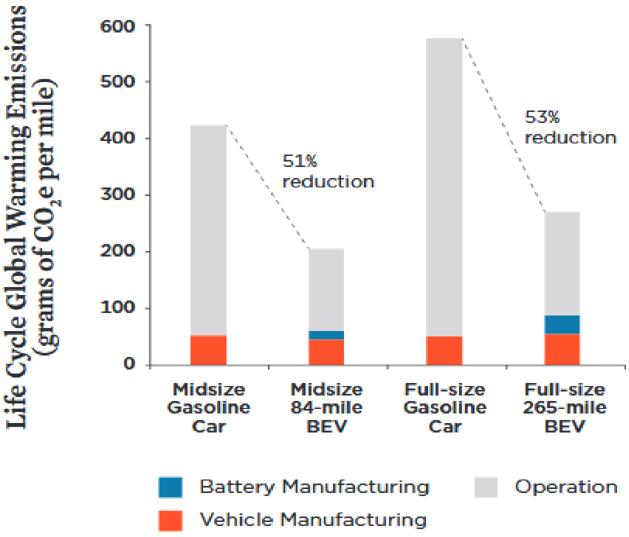

Figure 3- Life cycle of GHG emissions from the manufacturing and operating phases of gasoline and electric vehicles

Note: Midsize model equals 135 km per charge and Full-size model 426 km per charge. It was considered that a consumer who bought an electric vehicle would drive the same mileage as a consumer who bought a gasoline vehicle.

Considering an average vehicle and comparing it with a similar gasoline vehicle, it would take around 7,884 km driving the electric vehicle to reach payback (compensate for the extra emissions from the electric vehicle manufacturing process). These emissions can also be reduced with actions such as: recycling lithium ion batteries in the manufacturing process and using renewable energy sources.

An important factor is that the greater the autonomy of the EV, the greater the weight of its battery. Still with regard to the vehicle manufacturing stage, the weight and composition of materials (such as copper) will determine the GHG emissions that will be generated [18]. Currently, many scientists are researching models of batteries and electrodes with greater stability. cycle for electric vehicles through nanotechnology. Li-ion batteries and aluminum batteries are being used for testing [1].

Also depending on the extraction process of the natural resource, there will be more or less emissions. [19], performed a comparison between PHEV and the conventional vehicle (considering a life cycle of 240,000 km driven), and concluded that the PHEV generates a 32% reduction in GHG emissions compared to the conventional vehicle throughout the cycle of life.

There are also impacts that occur after the useful life of the electric vehicle. Dismantling the vehicle, recycling its materials and disposing of the battery can generate emissions. GHG emissions related to vehicle maintenance and disposal represent less than 10% of total emissions [17]. In this respect, it is worth mentioning that most of the materials that make up the electric vehicle can be recycled, as is the case for the gasoline vehicle. Reuse, recycling or landfills are the available options for disposal of the lithium battery. In reuse, the battery can be used to store energy from other renewable sources, such as wind and solar, since it has about 75% of its original capacity, and can postpone the recycling phase, reducing costs and waste [20]. In recycling, some components, such as metals, can be used to produce new batteries. It is worth noting that recycling requires energy and produces emissions, which can be reduced compared to using new materials. Lithium-ion battery recycling processes must be studied and improved in order to reduce energy consumption, s olid waste generation and pollutant emissions. The last option (landfill disposal) is the worst of the three, and can generate pollution [19].

Another study [21] demonstrates that CO_2 emissions from electric vehicles are 4.6 times lower than diesel vehicles. Silva (2014) estimated that, if the Brazilian fleet of MCI vehicles were completely replaced by an EV fleet, it would reduce GHG emissions (tCO_2e) from passenger cars in Brazil by 7.34 times.

In Brazil, there is a Research and Development (R&D) Project called "Emotive" that studies the impacts of using electric vehicles. This project is financed with resources from the R&D program of the National Energy Agency

(Aneel) and involves the CCR Institute, the Electric Mobility Program of CPFL Energia, and has a partnership with the State University of Campinas (Unicamp) and other institutions. The research started in 2013 and in the current phase (2018) the project has expanded the fleet of electric vehicles to 16 cars and installed 10 public charging stations. Regarding costs, data collected by this project show that the value of a kilometer driven by a combustion car is approximately R$ 0.30, while this cost in an electric vehicle is R$ 0.10, that is, a third of the cost of a conventional car =.

Another survey, carried out using initial projections by CPFL Energia, points out that the use of electric vehicle technology would increase energy consumption by between 0.6% and 1.6% on the SIN in 2030, when forecasts indicate that the fleet of cars electric vehicles can reach between 4 million and 10.1 million units. That is, the expansion of EVs would have little influence on energy demand (CPFL, 2016). It should be noted that, if the charging cycles adopted by users of electric vehicles are carried out in an uncontrolled or unplanned way, this could have negative impacts on the distribution system of the energy concessionaire, increasing the demand for energy at peak hours.

In this context, the study by [14] simulated the impact of the electric vehicle on the distribution system, considering the time horizon between 2013 and 2020, and concluded that the horizon for the grid stress to be reached is distant. If the arrival of EVs grows at the planned pace, utilities will have reasonable time to adapt to the introduction of this new load. As for the impact of EVs on the national energy matrix, results from the same study indicate that if EV penetration reaches 50 or 100% of the national car fleet, energy demand would represent respectively 3.89% and 7.77% of the planned power for 2020. It should be noted that, currently (2018), some important Brazilian cities, whether experimental or not, already have fleets (for the time being, of a small amount) of buses entirely powered by electricity; one could mention, in particular, in this context, Santos, Curitiba, Rio de Janeiro and São Paulo.

The LCA is used to compare various types of vehicles including: MCI vehicle powered by diesel, MCI vehicle powered by gasoline, PHEV, BEV, MCI vehicle powered by ethanol, and flexfuel vehicle. According to their results, the vehicle that has the least impact on GHG emissions is the one powered by ethanol. this is due mainly to the benefits of capturing CO_2 during sugarcane production. In addition, electricity used for ethanol production is produced from sugarcane bagasse. It is worth noting that the use of data referring to the Brazilian electricity matrix, which has a renewable energy base and consequently lower GHG emissions in the energy production stage, influenced the result. The production stage of the BEV's lithium ion battery accounted for 35% of CO_2e emissions. Car production (BEV) is responsible for around 50% of the total CO_2e emission, while car recycling is responsible for around -5.5% and battery recycling for -3.5%. Figure 4 presents the general comparison of the results of this LCA. The high human toxicity impact values of BEV and PHEV related to the production of the lithium ion battery are highlighted. In [23], in their LCA mentioned that EV toxicity can also be associated with the disposal of sulphide residues and residues from coal mining.

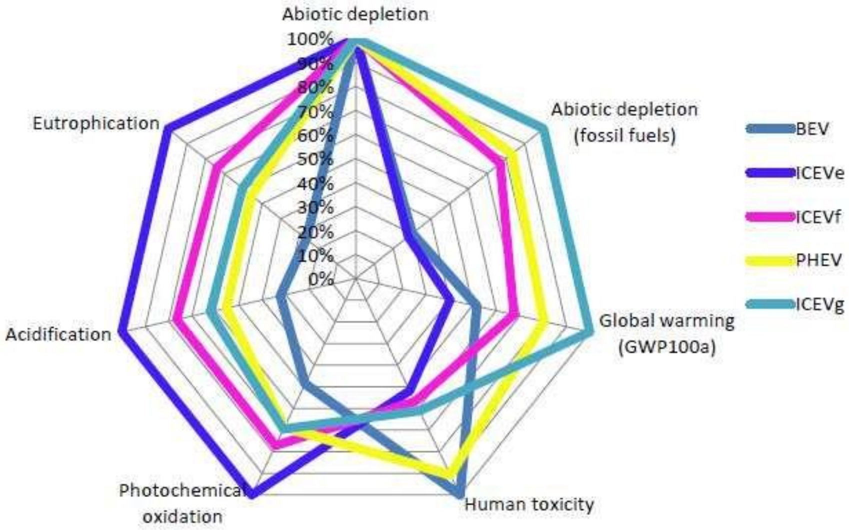

Figure 4- General Comparison of LCA results for various vehicle categories

Note: Internal combustion vehicles powered by ethanol (ICEVe), flexfuel (ICVEf) and gasoline (ICEVg).

One of the advantages of EVs is that they are silent, that is, they do not generate noise pollution, in addition, they do not consume energy when stopped in traffic, unlike conventional vehicles (Silva, 2014). Also, the fact that trams circulate at a lower speed than conventional cars can help reduce the number and severity of traffic accidents.

The use of EV also contributes to increasing energy efficiency, since the electric motor has an efficiency of around 90%, against 40% of the combustion engine [14].

The WTW analysis has been used by some studies and analyzes the EV from the point of view of producing the vehicle's propulsion energy source (which feeds the battery). This is interesting since the electricity generation technology influences its energy and environmental impacts. [22] performed the WTW analysis for Beijing (a city with a serious air pollution problem) and, based on road tests and data reported by BEV drivers, estimated that BEV caused a significant reduction in CO2 emissions by 32% for the year 2015 compared to a conventional gasoline vehicle. HEV and PHEV could annually reduce oil consumption by 43 and 56% respectively, and BEV could eliminate oil consumption.

In [10] analyzed how the electric, sugar-alcohol and energy sectors in Brazil would react to the expansion of the introduction of electric vehicles in the country and concluded that the greater penetration of EV in the fleet of light vehicles provides a lower consumption of primary energy by the energy system. However, in a scenario where parallel mitigation policies are not adopted, this greater penetration would cause an increase in coal consumption and a reduction in bagasse consumption, which would consequently cause an increase in national GHG emissions.

[23] reported that, considering the average emission of the electricity generation matrix, EVs in Europe would help to reduce GHG emissions by 10 to 24% compared to conventional vehicles (considering vehicle life of 150,000 km driven). [24], considered the energy generation matrix of each country, and analyzed the environmental effects of expanding EV use in 70 countries. These authors concluded that BEVs had lower GHG emissions than MCI vehicles in most countries and regions. In Brazil, emissions caused by BEV would be lower

than emissions from vehicles powered by gasoline or diesel. However, in South Africa (where there is 92% fossil fuel use for power generation) GHG emissions would be higher in the use of BEV than in MCI vehicles [24].

On the other hand, it is important to discuss the negative points related to electric vehicles. Critics point to the energy-intensive production process needed to manufacture electric vehicles, as the electric vehicle production step generates more emissions than the production of MCI vehicles, mainly because of the lithium-ion batteries. Much of this impact comes from the mining of metals used in the production of these vehicles and batteries - which can generally be composed of: lithium, iron or aluminum [1]. It is noteworthy that gasoline vehicles also require many of these same metals. Therefore, improving the batteries used in electric vehicles can lessen the impact of their manufacturing process, making cars more sustainable throughout their lives. The production cost of the lithium ion battery is high due to the limited reserve of lithium on the Earth's surface. Therefore, there is research evaluating the replacement of lithium by other metals. Aluminum is a promising substitute, which has more reserves at a lower cost. The current challenge is how to improve the rapid degradation of battery cycle performance, and this is being the focus of research that addresses new types of batteries and electrodes with greater capacity and better cycle performance [1].

An important environmental risk of the electric car is associated with the battery, which must be recycled at the end of its useful life (post-use impact). Few companies now have the technology to recycle the lithium-ion batteries used in electric cars, especially in a cost-effective way, so that needs to be improved as well. The need to replace batteries (high price) and long recharge times can also be pointed out as disadvantages compared to MCI vehicles [3].

Another relevant issue is the high price of EVs compared to conventional vehicles. The cost of an electric vehicle is about 2.5 times higher than that of a diesel vehicle, and the payback of the investment in an electric vehicle compared to a conventional one can take a few years. The purchase of the vehicle and the battery represent most of the costs of an electric vehicle [7]. [13], compared the total costs of electric vehicles (BEV and PHEV) with MCI and found that the costs of electric vehicles were lower due to simpler maintenance and due to the lower cost of electricity in relation to the price of fuel (gasoline or diesel). [14] analyzed in his research, through a projection for the year 2020, that a reduction in the battery price by 50% can occur with a 30-69% probability and the probability of recycling more than 90% of the components of the battery was considered high.

Another aspect is the weight of electric vehicles. Their batteries are still much heavier than a fuel tank and their limited energy storage capacity restricts vehicle autonomy.

Thus, the main efforts in the development of electric vehicles have focused on batteries, in order to improve their performance (autonomy), safety and durability. In addition, it is also necessary to create infrastructure for recharging batteries. [25] conducted research with interviews in companies that sell buses, trolleybuses, bicycles and electric scooters and they reported a lack of incentives from the Brazilian government in this market, and legal barriers with high import taxes.

2.3 Contribution of electric vehicles to GHG mitigation: potential according to the composition of the electrical matrix

The transport sector is a key sector for energy management and of great importance for low-carbon economy strategies in the coming years. Worldwide, annual anthropogenic GHG emissions increased by 10 billion tCO2e between 2000 and 2010, with this increase coming directly from energy supply (475), industry (30), transport (11%) and the construction sector (3%) (IPCC, 2014). In the scenario of GHG emissions, we can highlight the significant contribution of the transport sector, whose emissions are expected to increase by 2021.

In terms of GHG emissions, the transport sector is responsible for about 14% of global emissions (IPCC, 2014). To reverse or stabilize the amount of emissions, some measures such as investments in energy efficiency, greater recycling of materials, and fuels with lower carbon content will be necessary (PBMC, 2014). The 4th Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC, 2014), advocated the use of hybrid and battery electric vehicles to assist in the mitigation of climate change and highlighted that energy efficiency plays an important role in this scenario. Advanced electric and hybrid vehicles with more reliable batteries and energy sources are listed as mitigation technologies in the transport sector.

In [10] concludes that the entry of electric vehicles is positive from a climate point of view, but it would only be advantageous if accompanied by policies to encourage the production of low-emission electric energy.

[25] carried out simulations for the MCI vehicle and for an EV and found results regarding energy consumption and CO2 emissions. From the point of view of energy consumption, the electric vehicle consumed about eight times less than the MCI vehicle. The results of the simulations were compared to the CO2 emission factors from the generation of electricity in the Brazilian SIN for the year 2014 and showed that an electric vehicle analyzed emits about 14 times less CO2 emissions than a vehicle with an internal combustion engine. . One limitation was that this study analyzed only the vehicle operation phase.

Countries such as: Portugal, Austria, Spain, Sweden and Belgium have a high potential to incorporate electric vehicles due to their low GHG emissions associated with electricity generation [26]. Therefore, the expansion of the use of EVs and hybrids and the replacement of conventional ones can help countries (including Brazil) to reach their national targets for the reduction of foreseen emissions, such as the Nationally Determined Contribution in the Paris Agreement, during the 21st Conference of Parties in 2015.

It should also be noted that, even in cases where electricity is generated from fossil fuels, EV brings the advantage of concentrating both GHG emissions and other pollutants in energy generating sources, which are liable to be regulated, and not at consumption points, which are numerous, dispersed and difficult to control [3]. Thus, EVs can be used in conjunction with technologies such as Carbon Capture and Storage (CCS) in power generation plants. Such technology is unfeasible to be introduced in diffuse emission sources, such as MCI vehicles.

However, even if the consumption of electric vehicles increased, it would take decades for this to result in significant results on the scales national energy. In Brazil, if a policy were implemented to encourage the use of EVs on a large scale, in relation to the conventional car, this would bring effective strategic and environmental benefits only in the long term. However, even with the success of technology innovation, the time required for a new technology to promote a significant global impact on GHG emissions can be considerable [13].

3. Conclusion

It is concluded that HEVs can serve as a bridging technology, facilitating the transition between gasoline and electricity in the transport sector. For electric vehicles to become a sustainable technology option, advances are needed to improve the manufacturing process, with the use of alternative materials, weight reduction, increased battery capacity, cost reduction, and advances in the manufacturing process. recycling.

According to the studies analyzed in this paper, it is stated that, on average, an EV generates less emissions than an ICE vehicle (fueled by gasoline) throughout its useful life. All works consulted that used LCA agree that, if global electricity production has a predominance of renewable sources, EVs can have ample potential with regard to mitigating climate change. It is important to point out that the environmental benefits of developing electric vehicles will depend heavily on the country's energy matrix and the charging conditions of electric vehicles.

Considering the current energy challenges, electric vehicles seem to be the future direction to be explored, mainly in urban centers, because, compared to conventional vehicles, they cause lower emissions considering their entire life cycle. It should be noted that the expansion of electric vehicles must be combined with other initiatives such as vehicles powered by biofuels, hybrid vehicles, encouraging the use of public transport, more efficient vehicles, diversifying the transport matrix, including more significantly other modes other than road (in the case of Brazil, for example, there is an urgent need to expand the capacity of use of the railway modal). The use of renewable energy must be prioritized in order to reduce the amount of emissions associated with the life cycle of electric vehicles.

Another important conclusion is that, contrary to common sense, the expansion of electric vehicles would lead to an increase in the demand for electricity (however, not very significant, according to the projections inherent in the various studies consulted).

Finally, based on previous data, it is concluded that the expansion of electric vehicle production represents an effective strategy in relation to conventional vehicles in terms of mitigating global climate change, however, this depends on the electrical matrix of each country, not possible to generalize the results. For this expansion and effective adoption of electric vehicles by consumers, greater government incentives are needed for the electric sector and for the automobile sector.

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