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Electric mobility in Panama: A review

Jessica Guevara-Cedeño
Facultad de Ingeniería Eléctrica
Universidad Tecnologica de Panamá
Panamá, Republica de Panamá
jessica.guevara@utp.ac.pa

Jairo Aguilar
Facultad de Ingeniería Eléctrica
Universidad Tecnológica de Panamá
Panamá, República de Panamá
jairo.aguilar@utp.ac.pa

Roham Torabi
Madeira Interactive Technology Institute
Universidade da Madeira
Funchal, Madeira, Portugal
roham.torabi@m-iti.org

Aranzazu Berbey-Alvarez
Facultad de Ingeniería Eléctrica
Universidad Tecnológica de Panamá
Panamá, República de Panamá
Aranzazu.berbey@utp.ac.pa

***Abstract*—Global initiatives against climate change have recommended that the world must make a change in its mobility technologies, as the transport sector is responsible for 21% of global emissions, this concern has accelerated in promoting the various options for more transport efficient and cleaner fuels. One of the approaches that the major international organizations have had is to promote electric mobility, which has evolved in recent years, in which the capacities and energy densities of the batteries have been improved, reducing their manufacturing costs. The objective of this work is to conduct a review of the state of the art about electric vehicles in Panama and identify the potential impact of high electric vehicle penetration in reducing CO2 emissions and electricity consumption, which must be adapted to produce the required energy in a sustainable and efficient way. Finally, country of energy policies are identified expected to encourage renewable generation such as solar and wind energy that are planned to be built in Panama, promoting the generation of clean energy to contribute to sustainable development.**

***Keywords*— mobility, urban transport, railway engineering, electricity emission, batteries**

I. INTRODUCTION

The emissions of pollutants from fossil fuel combustion have increased from the period of the industrial revolution. The development of internal combustion engines and boiler systems combined with the improvement of oil extraction technologies facilitated the increase of the use of fossil fuel derivatives. The burning of fossil fuels cause emissions of gases like CO_2, among others, which are the cause of climate change and global warming.

In addition to global warming, these gases cause other consequences which are known as local pollution and the problem of air quality. The problems of air quality and global warming are very worrisome worldwide situation. Many initiatives have been created over the years to try to curb the damage that the planet is receiving for these emissions. For example, only by 2015, they exceeded 400 Ppm of carbon dioxide concentration in the atmosphere [1], limiting to that never reached in 400 000 years [2]. The concentration for February 2017 increased to 405.61 ppm, which indicates that the actions to be taken to stop this growth must be accelerated to comply with the Paris agreement [3], which indicated a limit on the increase of the global average temperature in 2 ° C from pre-industrial times.

The poor air quality is a local pollution that affects the health of neighboring populations. According to WHO [4] in 2012, there were more than 3 million premature deaths in rural and urban areas worldwide, due to exposure to suspended material below 10 microns, which causes cardiovascular problems, respiratory problems and cancer. Problems like these should be addressed immediately.

Greenhouse gas emissions come from various sectors of energy consumption, such as the industrial, commercial, service, transport and residential sectors.

This study will focus on one of the sectors, it is transport sector. The transport is one of the sectors that is attributed a large part of the increase of concentrations of greenhouse gases in the atmosphere. The transport sector is responsible for 21% of global emissions, so electric vehicles could be seen as one of the solutions to stop climate change, since they do not produce such gases, although electricity generation uses technology that emits CO_2. In the Panamá City, 90% of the emissions correspond to the transport sector [5-7].

EVs are not a current technology. This technology is presented since the 1800s [8]. This technology was even created earlier than the current internal combustion vehicles. Its diffusion low and slow, in the world, is due to the different limitations that these technologies present such as the range of travel, number of charging systems, cost of acquisition, battery life, and charge time of the battery, among others aspects. According to the History of the Electric Car [8], there are 3 electrical technologies in the world (missing quote):

1. 100% electric vehicles (EV).

2. Plug-in electric vehicles (PEV) which is composed of an internal combustion engine and electric motor, the MCI internal combustion engine starts to operate once the capacity of the battery that moves the electric motor is exhausted.

3. Extended Range Electric Vehicles (EREV) is powered by an electric motor, it also has an MCI that is used to move a generator which charges the EV battery.

This study takes into account 100% electric vehicles in Panamá, which will provide a better mitigation of greenhouse gases. EVs have great potential if their fuel (electricity) is supplied from renewable generation sources, thereby reducing the carbon footprint. The EV would be of great help in

Panamá, since the country has a hydroelectric generation system with 59% share of the installed capacity, and a participation percentage in the generation of 62% by 2015 [9].

II. Current Situation

In Panamá, the transport sector (TS) is the largest consumer of energy with a consumption that represents 43.2% of the total consumption of the country. This is also the sector that consumes 46.75% of the total of oil derivatives imported in Panamá [10-13]. Among the energy consumed by the transportat sector are gasoline, diesel, kerosene, liquefied gas, and in recent years Electricity (See the figure 1). The gasoline is the most consumed energy followed by diesel in the Panamanian transport sector. Jet Fuel is used for air travel (internal demand travel). The fuel consumption generated at Tocumen International Airport and ships transiting the Panamá Canal is not included in Panama's energy balances because these belong to a free zone of fuels, taking these consumption into account would double the demand for these energy sources.

At present, the statistics regarding the transport system is not precise, so the data with which this report has been made is an approximation to the current situation, the data consulted come from the INEC [10-13], which collects the vehicle information of the different municipalities throughout the country. When using the information collected by the INEC [10-13], it should be taken into account that there are a large number of vehicles that do not remove the plates or circulate without them so the data are not accurate. The analysis of this report will be made taking into account only private vehicles, according to the requirements of the National Energy Plan of the Authorities of the National Secretary of Energy.

A. *Mobility in Panamá*

According the review of Berbey *et al*., [14] by Panamá, there are several studies, scientific papers, literature information about the Panamá City Transport System. Among them are: ESTAMPA I [15], ESTAMPA II [16], ESTAMPA III [17], Bermúdez [18], Dames & Moore [19], INECO [20], Renardet[21], BCEOM [22], ESTUI [23], Bocarejo [24], Banco Mundial [25], Solis *et al*:,[26], Nikoei [27], SMP[28-31] Berbey *et al.*,[32-42].

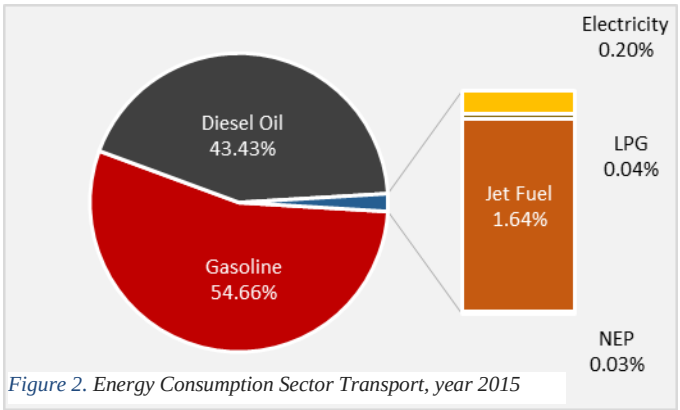

Figure 2. Energy Consumption Sector Transport, year 2015

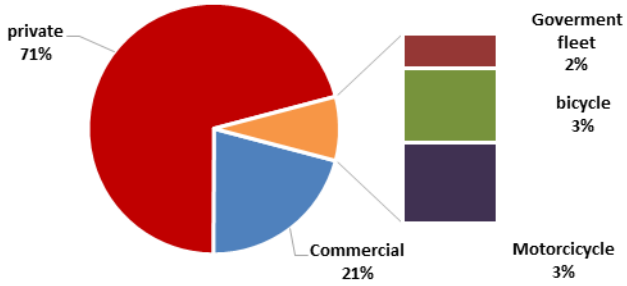

Figure 1. Composition of the Vehicle Fleet in Panamá - 2015 (preliminary)

Panamá has a vehicle fleet of 782 883 vehicles [10], which are distributed in 70.8% of private vehicles, 21.0% of commercial vehicles (See figure 2). It is important to mention that 74.78% of these vehicles are concentrated in Panamá City [11], the Panamá City concentrated the 50.3% of the national population.

Car sales in Panamá have been growing steadily since 2009, reaching 64,735 new cars by 2015 [12], which gives a motorization rate of 196.93veh / 1000 inhabitants and it is expected to grow at 213veh / 1000hab. This Panamanian rate is a bit high if it is compared to countries in the region such as Venezuela, Peru and Colombia with 142, 105, 104 veh / 1000 inhabitants respectively [43].

The accelerated growth in vehicle sales in Panamá has been a natural consequence of various factors like: the inefficient public transport system, low interest rates on vehicle purchases, and per capita GDP growth, among others factors. This increase of the motorization in the last years has caused the collapse of the transit systems creating great vehicular congestion in the center of the Panamá City in peak hours diminishing the quality of life of the citizens.

Improving the transport system in Panamá is a challenge that the government system has to face in order to meet the goals agreed at COP21 and ratification at COP22 in Marrakech. Panamá as a country has begun to take its first steps towards an improvement of the mass transport system, implementing in December 2011 the metrobuses system in Panamá City, by 2014 the Panamá Metro Line 1 enters into operation, improving the movement of the people.

B. *Panamá Subway.*

The analysis of electromobility also involves rail transport systems, such as the "Metro of Panamá". Panamá Metro line 1 began its operations in April 6, 2014 [44][45]. According to the national oldest newspaper *La Estrella de Panamá* [46], the Panamá Metro Line 1 surpassed the expected limit of travels with more of 273000 daily travels during the Black Friday in November, 2015. [47] The Metro System of Panamá has been of great help to the resident population in the areas of San

Isidro, Los Andes and San Miguelito in the north of the Panamá City. This system has reduced the travel time significantly, thus increasing efficiency compared to the previous system called "Diablos Rojos". Today, Panamá City has a metro line "Line 1", which initially had a length of 13.2 km in its phase 1 from *"Los Ande*s" Station to the *"Albrook*" Station, have a length of 16 km. Time after time, the Panamá Metro line 1 was extended with until the San Isidro Station a total of 16 km, thanks to the Phase 2 Project. The *Albrook* station also connects with the National Buses Terminal of Transport of *Albroo*k. This first metro line was inaugurated on April 4, 2014, it has managed to transport an average of 5 479 233 Travelers / month in 2015 [44-45], with working days being the most booming days [47-48].

The Panamá Metro line 2, which has a planned length of 32 km, is currently under construction and it has a direction of San Miguelito Station (north of Panamá City) and Nuevo Tocumen (East of the Panamá City). By August 2017, according to the national newspaper *La Estrella de Panamá* [49], the authorities of Secretary of Panamá Metro commented that Panamá Metro line 2 current has a 50% of advance after 22 months of construction.

As the Panamá Metro line 1, the line 2 will be a viable and clean alternative to public transport [50]. Both lines are part of the plans that Panamá Metro Authorities has called "The Panamá Master Network", which will help reduce the number of private vehicles in circulation in the province of Panamá. For the National Energy Plan 2015-2050, four lines have been proposed by the Panamá Metro Authorities [51]. They would be completed during the study period between 2015-2050 (See table 1).

Table 1: Panamá Metro Network according PEN 2015-2050 [51]

Line	General Description
1	Inaugurated on April 4, 2014, the same part from the National Terminal of transport of Albrook to the station of San Isidro.
2	Line 2 will be inaugurated in 2020, will have an extension from San Miguelito to Nuevo Tocumen.
3	This will be done from the National Terminal of transport from Albrook to Futuro city (Arraiján), it will start operations from 2025.
4	The same will be built from the 5 de Mayo station to the Pedregal station.

According to the Energy Matrix of Panamá for 2015, published by the Secretariat of Energy [52], the energy consumption corresponds to 26 Kbep, or thousands of equivalent barrels of petroleum. This is equivalent to 41.9 GWh/year. It is important to mention here, that the 26 Kbep is electric energy required to power the subway system and that no other public transport system in Panamá is electrically driven. According to Vivapolis [53] for Panamá, the relationship of emissions of CO_2/KWh is 0.298 $KgCO_2$/KWh. According Berbey *et a*l.,[14] the Metro of Panamá generated 12,504 tons of CO_2/year in 2015.

Table 2. Experimental estimation about CO2 emissions 2015-2016 and Energy Consumption 2015-2016.

	2015	**2016**	**Variation**
Kbep [52][54]	26	23	-3
GWh_Panamá	41.96	37.12	-4.84
$KgCO_2$/KWh [14]	12504	11061	-1442.87
Ton CO_2 [14]	12.50	11.06	-1.44
Anual Travel demand [14] [55]	65,750,000	78,463,136	12,713,136
Media mensual (Viajeros/mes) [14][55]	5,479,233	6,538,595	1,059,362
0.6196; 0.298 $KgCO_2$/KWh [14]			

According to official statistics from the National Energy Secretariat of Panamá, the energy consumption of the Panamá Metro Line 1 corresponds to 26 Kbep (2015) and 23 Kbep (2016) respectively. The differences of the theses official data give us a negative annual variation of 3 Kbep less per year (2016-2015). For the years 2015 and 2016, the annual energy consumption Panamá Metro Line 1 corresponds to 41.96 and 37.12 GWh respectively. This difference indicates a decrease or negative difference in the energy consumption of 2015 and 2016, in the order of 4.84 GWh. In Berbey *et al.*, [14] the CO2 emissions of Panamá Metro Line 1 are estimated at 12505 tonnes per year (2015). By 2016, the Panamá Railway Engineering Research Group have estimated that Panama's Metro Line 1 mobilized 12,713,136 additional passengers a year compared to the previous year 2015, and the good news is that it did so with an energy consumption less, 37.12 GWh (2016), corresponding to a decrease or negative variation of 4.84 GWh in comparison of the previous year 2015 (See table) This corresponds to a decrease of 1442.87 tons between 2016 and 2015. Finally, for the year 2016, the Panamá Metro line 1 moved approximately 1,059,362 passengers more than in 2015 with a reduction in CO_2 emissions and it was possible with a lower energy consumption compared to the previous year 2015. This is very good news for the environment, because la Panama metro line 1 used the same number of trains circulating in those years 2015 and 2016 respectively. The meaning of this is that more users left their private vehicles to travel using the subway.

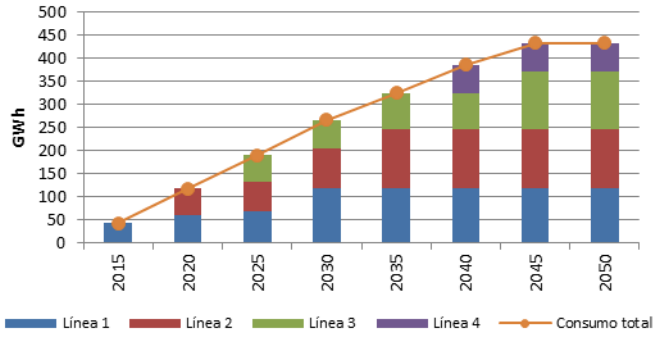

Figure 3. Projection of energy consumption of the Panamá Metro Network.

The Panamá Metro is an electricity-driven transport having a low energy consumption compared with other land transport systems. According Panamá Metro Authorities, the projected consumption of the Panamá Metro network can be observed in the figure 3.

C. Electrification of Private Transport

By 2016, 33707 light vehicles were added to the vehicle fleet in Panamá [13]. The introduction of electrical mobility was modeled based on the penetration of Solar Photovoltaic (SF) technology in the world, since there is no history of this technology. SF technology was chosen due to the fact that it presents just as the EV have presented at the beginning a strong rejection but as time passes the limitations in terms of price and efficiency have been surpassed, creating a large market worldwide that bet greatly in these technologies as an aid to curb global warming and reduce local pollution. The introduction of electrical vehicles was assumed by 2020, a margin that seems reasonable in terms of the implementation of this unconventional technology, the projection of the amount of EV sold can be observed in the figure 4.

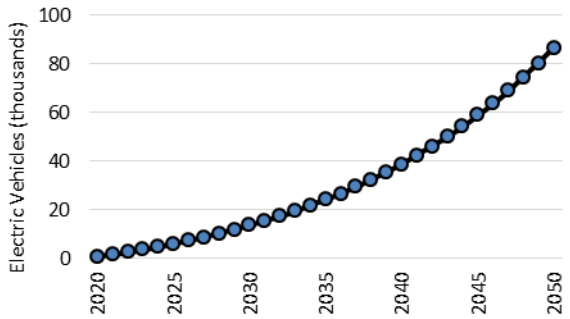

Figure 4. Total of Electric Vehicles.

The EV load curve was modeled based on the travel histogram performed in the PIMUS study [57]. Taking into account the hours in which the Panamanian population stops circulating in the street, as shown in the figure 5, these hours are between 8 pm and 3 am, during which time the loading period of the vehicles, which comprises 7 hours giving the possibility of charging up to 80% of the capacity of the batteries.

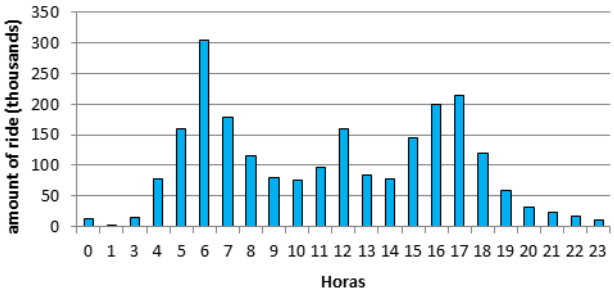

Figure 6. Ride Histogram for the Metropolitan area of Panamá.

III. Results

The penetration of electric vehicles in Panamá evaluated in this report is conservative and is modeled based on the introduction of a photovoltaic panel technology resulting in 9.3% of car sales will be electric by year 2050 resulting in accumulative amount of electric vehicles in circulation in Panamá, the annual distribution of sales are shown in the figure 4. Regarding the electric power consumption due to the penetration of electric vehicles in the country is considerably lower if we compare it with consumption than if the same number of vehicles were gasoline, figure 6 shows the amount of energy that electric vehicles (EV) would require to travel an annual average, in the same graph the consumption is observed if that same Number of vehicles will use gasoline as fuel (MCI) to travel the same average annual distance.

With the implementation of these technologies, Panamá would

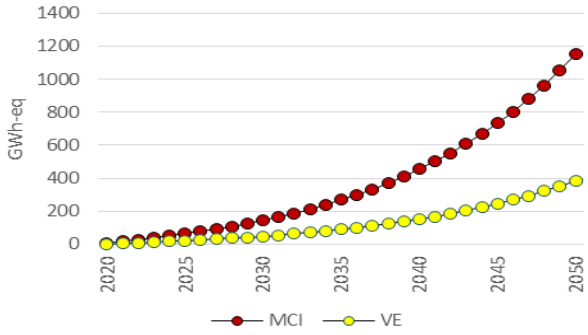

Figure 3. Energy Consumption per technology type.

cease to emit 3800 tons of CO_2, this would have different benefits since the country would be less dependent on the Global Oil Market, reducing the cost of living of the population not only in fuel purchase but also in avoid the increase of cardiovascular diseases caused by emissions of particulate matter and other series of gases that disturb the environment and public health. This situation has been mentioned in [20], thanks to the statistics already indicated by the Ministry of Health of Panamá. The total electricity demand is shown in figure 7

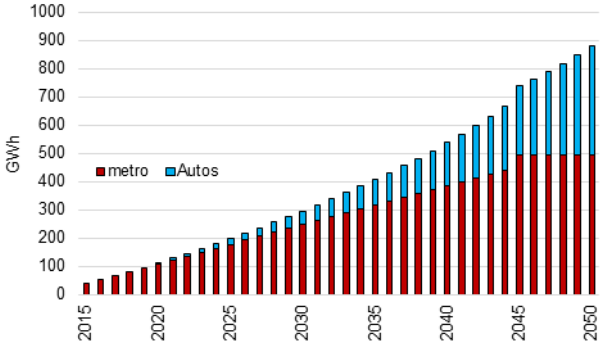

Figure 5. Electricity consumption of Electromobility in Panamá.

The introduction of more than 111 thousand electric vehicles only increases the electricity demand in 2050 by 130 MW, under the same requirements mentioned above. This demand can be supplied through renewable non-conventional generation such as solar and wind power or by cleaner generation sources such as natural gas, thus reducing the carbon footprint and environmental impact caused by the generation of that energy, for this should be oriented to the Generation system to use cleaner forms of energy.

IV. CONCLUSIONS

One of the most important points in energy planning is the quality and reliability of the data used, making it essential for Panamá to improve and unify the data systems managed by the different companies and institutions in the country in reference to the transport sector. Panamá must create regulations and incentives to monitor and facilitate the introduction of more efficient technologies. The high penetration of this type of technology (EV) entails having strict regulations regarding the high penetration of electric vehicles in the distribution networks, while at the same time incentives should be implemented for the easy implementation of the systems necessary for the operation of the electric vehicle.

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APPENDIX

EV: electric vehicles.
PEV: Plug-in electric vehicles.
EREV: Extended Range Electric Vehicles
MCI: internal combustion engine vehicles
INEC: National Institute of Statistics and Census
PEN: National Energy Plan
SNE: National Secretary of Energy
SMP: Secretary of Panama Metro
PIMUS: Integral Plan for Sustainable Urban Mobility.
OMS: World Health Organization