A Roadmap to the State of Electric Vehicles in Panama

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Fifteen days spent on the project
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Executive summary: A Roadmap to the State of Electric Vehicles in Panama

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Introduction

Like many other countries, Panama is working to diminish its reliance on fossil fuels and cut country's greenhouse gas (GHG) emissions, effectively increasing the overall sustainability of its energy network while working towards the goal of energy independence. To accomplish this goal, the federal government has laid out a roadmap in the *Plan Energetico Nacional,* specifically targeting the emissions of the transportation sector which is responsible for a large percentage of the GHG emissions. There is a global trend in countries around the world to focus on electric vehicles (EVs) as a possible measure to cut GHG emissions. This report aims examine the current state of the EV industry in the Panama Metropolitan Area (PMA), investigating the barriers and the incentives mediating the diffusion of electric transportation in the country and to subsequently propose strategies to implement this technology.

Methods

Over the course of the past four months we conducted research into the state of electric vehicles in Panama. It quickly became apparent that with such a novel technology it would be vital to examine the incentives and barriers mediating the widespread adoption of EV technology in other countries, information we would then be able to use to structure our investigation to answer the same question here in Panama. Thus, we split our investigation to focus on two factors, the global state of EVs and the Panamanian state of EVs. We further divided our research to examine public electric transport initiatives, private electric transport and the auto industry's shift to more sustainable technology.

Results

It quickly became obvious from our research that there is a very limited presence of EV technology in the country of Panama. The only significant legislative effort taken to promote this technology over the past decade was the sunset clause in Law 69 which eliminated any import tax on EVs. However, this law was allowed to laps at the end of 2017, meaning that the import tax on EVs is now back up to five percent. Although the Ministry of Energy is considering taking action to reestablish this tax break, we could not identify any other legislative action being considered by the Panamanian government to promote EVs.

Resulting from the combination of this void of incentivizing legislation and lack in consumer interest, there are only two vehicle distributors in Panama that carry EV; BMW and BYD. Despite taking various approaches to promote EV technology such as building charging stations and conducting EV pilot projects, the efforts of these two companies is unlikely to have a very large impact on the market share of EVs in the short term.

Importantly, when comparing EVs and conventional vehicles, EVs register higher upfront costs and lower autonomy. However EVs can demonstrate lower maintenance costs and lower operational costs. It is also notable that EV prices have drastically decreased over the past decades as battery technology has improved and will likely continue decreasing in the future.

Conclusion

The future of the Panamanian transportation sector will likely be characterized by a shift from combustion engine vehicles to electric battery powered vehicles. However, it will likely take some time before market forces converge to facilitate the widespread viability of EVs. While Panama is not at the forefront of this global transition, the Panamanian government should take measures to ensure that an environment favorable to this technology exists in the country to facilitate the diffusion of EV technology when it becomes economically competitive with combustion vehicle technology.

Resumen executivo: Una investigación sobre el estado de los vehículos eléctricos en Panamá

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Introdución

Como muchos otros países, Panamá está trabajando para disminuir su dependencia de los combustibles fósiles y reducir las emisiones de gases de efecto invernadero (GEI) del país, aumentando la sostenibilidad general de su red de energía mientras se trabaja para lograr la independencia energética. Para lograr este objetivo, el gobierno federal ha establecido una trayectoria en el Plan Energetico Nacional, específicamente dirigida a las emisiones del sector del transporte que es responsable de un gran porcentaje de las emisiones de GEI. Existe una tendencia mundial a centrarse en los vehículos eléctricos (VEs) como una posible medida para reducir las emisiones de GEI. Este informe tiene como objetivo examinar el estado actual de la industria de VE en el Área Metropolitana de Panamá (AMP), investigando las barreras y los incentivos que afectan la difusión del transporte eléctrico en el país y posteriormente propone estrategias para implementar esta tecnología.

Methodos

En el transcurso de los últimos cuatro meses, realizamos una investigación sobre el estado de los vehículos eléctricos en Panamá. Rápidamente se hizo evidente que con una tecnología tan nueva, sería vital examinar los incentivos y las barreras que afectan la adopción generalizada de la tecnología VE en otros países, información que luego podríamos utilizar para estructurar nuestra investigación para responder a la misma pregunta aquí en Panamá. Por lo tanto, dividimos nuestra investigación para centrarnos en dos factores, el estado global de los vehículos eléctricos y el estado panameño de vehículos eléctricos. Además dividimos nuestra investigación para examinar las iniciativas de transporte eléctrico público y el transporte eléctrico privado y el cambio de la industria automotriz a una tecnología más sostenible.

Resultados

Rápidamente se hizo obvio por nuestra investigación que hay una presencia muy limitada de tecnología EV en el país de Panamá. El único esfuerzo legislativo significativo tomado para promover esta tecnología en la última década fue la cláusula de caducidad de la Ley 69 que eliminó cualquier impuesto a la importación de vehículos eléctricos. Sin embargo, esta ley se permitió a las vueltas al final de 2017, lo que significa que el impuesto a la importación de vehículos eléctricos ahora está de vuelta hasta el cinco por ciento. Si bien el Ministerio de Energía está considerando adoptar medidas para restablecer esta desgravación fiscal, no pudimos identificar ninguna otra medida legislativa que el gobierno panameño esté considerando para promover los EV.

Como resultado de la combinación de este vacío de incentivar la legislación y la falta de interés del consumidor, solo hay dos distribuidores de vehículos en Panamá que llevan EV; BMW y BYD. A pesar de tomar varios enfoques para promover la tecnología EV, como la construcción de estaciones de carga y la realización de proyectos piloto de EV, es poco probable que los esfuerzos de estas dos compañías tengan un gran impacto en la cuota de mercado de los vehículos eléctricos en el corto plazo.

Es importante destacar que, cuando se comparan vehículos eléctricos y vehículos convencionales, los vehículos eléctricos registran mayores costos iniciales y una menor autonomía. sin embargo, los vehículos eléctricos pueden mostrar menores costos de mantenimiento y menores costos operacionales. También es notable que los precios de los vehículos eléctricos hayan disminuido drásticamente en las últimas décadas, ya que la tecnología de la batería ha mejorado y es probable que continúe disminuyendo en el futuro.

Conclusión

El futuro del sector del transporte panameño probablemente se caracterizará por un cambio de los vehículos del motor de combustión a los vehículos con batería eléctrica. Sin embargo, es probable que tarde un poco antes de que las fuerzas del mercado converjan para facilitar la viabilidad

generalizada de los EV. Si bien Panamá no está a la vanguardia de esta transición global, el gobierno panameño debe tomar medidas para asegurar que exista un ambiente favorable a esta tecnología en el país para facilitar la difusión de la tecnología EV cuando sea económicamente competitiva con la tecnología de vehículos de combustión.

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I) INTRODUCTION

1.1) Purpose of this research

Panama, like many other countries around the world, is working towards decreasing its reliance on fossil fuels and increasing the overall sustainability of its energy network, hoping to achieve energy independence by 2050. In the *Plan Energetico Nacional,* the federal government lays out a roadmap to accomplish this goal, specifically targeting the emissions of the transportation sector which is responsible for a large percentage of the country's greenhouse gas (GHG) emissions [1].

Over the past ten years, various efforts have been made to increase the presence of electric transports in the Greater Metropolitan Area of Panama City (PMA), however, with the exception of the metro system, there has been very little progress towards creating a viable and efficient electric transport system for the city. The role of this research is to identify the current barriers and incentives mediating the diffusion of electric transportation in the PMA and to subsequently propose strategies to implement this technology.

1.2) General context and Literature review

1.2.1. Global State of EVs

In 2016, 196 nations signed the Paris Climate Agreement, a United Nations pledge to maintain global temperatures no more than 2 degrees C above pre-industrial levels [2]. Although this pledge is largely symbolic, as proven when the Trump Administration backed out of the agreement in 2017 with no repercussions, it does demonstrate the global political climate which largely acknowledges and is facing mounting concern over climate change as a serious threat to international economic and political stability.

As has been clearly documented in the scientific literature, climate change is inextricably linked with greenhouse gas (GHG) emissions [3]. According to the Environmental Protection Agency (EPA), the transportation sector is responsible for roughly 14% of all greenhouse gas emissions on a global scale [4]. However, the transportation sector is the economic sector with the largest anticipated growth over the next several decades as population growth corresponds with economic growth and the number of vehicles on the road globally is projected to skyrocket. Thus, the transportation sector could be responsible for the largest increase of GHG emissions by sector [5,6].

While it is largely acknowledged that the transportation industry will gradually shift from one based in fossil fuel consumption to be made up of electric battery powered vehicles, there are two main avenues by which the sector could arrive at this destination [7]. First, national governments could institute legislative change imposing stricter emissions regulations, simultaneously applying pressure to consumers and manufacturers alike, incentivizing the shift from hydrocarbon to electric battery powered vehicles. Secondly, there will be a gradual, free market shift towards EV's. Research suggests that this transition will largely depend on gradual improvement of public perception of this technology [8].

In recent years, some national governments have sought to enact policies to promote the growth of the electric vehicle industry in order to offset fossil fuel emissions of the transportation sector and thus combat the effects of climate change. For example, Great Britain passed a law in July 2017 banning the sale of any new vehicles with internal combustion engines by the year 2040, setting the goal to have zero emissions from the transportation sector by the year 2050 [7,9]. India has expressed similar objectives, demonstrating that this shift from petroleum consuming vehicles to electric vehicles is not a phenomenon confined to Western developed nations, but is also considered an effective way of lowering local pollution by drastically decreasing tailpipe emissions and meeting national emissions targets [10].

Many private companies have recognized the budding consumer demand for electric vehicles (EV's) and the past decade has seen car manufacturing giants such as General Motors, BMW and Audi begin to shift resources into research and development of EV technology [7,9]. In fact, Volvo has pledged to stop making traditional gas-powered cars in 2019, instead shifting its entire production to plug-in hybrids and battery powered EVs. While Volvo is the only major car manufacturer eliminating gas and diesel powered cars from their 2019 fleet, many other industry leaders have projected introducing record numbers of hybrid and electric battery powered cars in the coming years [7].

Slowly but surely, electric vehicles are entering the transportation market. According to the Interamerican Development bank, an institution dedicated to promoting Latin American progress, personal electric car sales have accelerated over the past decade globally. It estimates that in 2010, only 20,000 electric cars were sold on the global market. By 2014 this number had grown to over 700,000 and by June of 2017 gross sales of electric cars worldwide had surpassed 2 million [11]. Up until this point, the adoption of EV technology has been a very localized phenomenon as roughly three quarters of these sales occurred in the United States and Japan, only accounting for a small percentage of global car sales [11]. However, in recent years, EV distributors have been piercing markets in China, India and Latin America. [11].

1.2.2. Electric vehicles in Latin America

The transition towards electric vehicles is also happening in Latin American countries, albeit more slowly than in the US or Japan. With the transport sector being responsible for approximately 30% of GHG emissions in Latin America, many countries in the region target this sector as a priority to reach their emission reduction commitments pledged in recent international climate change agreements [12]. Since an important part of regional electricity generation relies

on hydropower, it is cleaner than the global average and the transition towards electric transport could therefore be an effective way to reduce carbon emissions [13].

Argentina, Brazil, Chile, Colombia, Mexico and Peru are the countries leading the implementation of electric vehicles on the continent. It is expected that between 52,000 and 220,000 electric vehicles per year will be sold together in those six countries by 2023 [11]. Most of the EV's currently used in Latin America function as taxis, public transportation, corporate or government vehicles. In recent years, cities like Bogota, Mexico City, Montevideo and Santiago de Chile, introduced pilot programs designed to introduce electric vehicles to the public transportation system, generally in the form of electric taxis and electric buses [12]. Other Latin American countries have taken different approaches, choosing to promote personal electric vehicles. For example, in 2017, six charging stations were installed in Uruguay connecting some of the nation's major touristic cities. The plan is to extend the network over the coming years, both in Uruguay and across the border in Brazil, adding an additional 42 charging points [14].

1.2.3. Electrification of transports in Panama

Although in the literature Panama is not portrayed as a leader in the transition towards the implementation of widespread electric transportation, the country is currently making efforts to ensure a more sustainable transportation sector for the future. As presented in the *Plan Energetico National 2015-2050*, the Panamanian government has established the long-term goal to shift away from fossil fuel dependence, both in terms of electricity production and with regards to combustion engine vehicles. The report cites both the desire to distance the Panamanian economy from volatile oil prices and the ripple effect these fluctuations can have on the national economy as well as the desire to cut GHG emissions [1].

In Panama, the transport sector is responsible for over 60% of the fossil fuel consumption while roughly 60% of the country's electricity is generated through renewable energy production

(mostly hydroelectric). Thus, electrification of the transportation sector has the potential to significantly reduce the country's GHG emissions and dependence on oil imports [1].

With over 65% of the country's vehicles found within the PMA, many of the projects to develop a less fossil-fuel dependent transport system focus on this geographic area of the country [1]. However, given the current congestion problems caused by a continuously increasing car fleet, projects to transform the PMA's transport system should also aim at improving the mobility throughout the metropolitan area [15]. The document responsible for outlining the future goals for the transport sector in the PMA, *El Plan Integral de Movilidad Urbana Sostenible* (PIMUS), therefore prioritizes promoting pedestrians, cyclists and public transports while reducing the number of motorized private vehicles in the city [15].

PMA's need to decrease the environmental impact of its transportation system and to improve its efficiency could be a real opportunity for the metropolitan area to follow the path already taken by many other metropoles worldwide to electrify their transport system. The new metro system and the various electric transport pilote projects going on in the PMA, demonstrate that some steps are being taken towards the electrification of the transport sector. However, standing alone, these projects are simply not enough to initiate a large scale transition towards the new technology.

Barriers to the innovation, transfer and diffusion of clean energy technologies are technology-specific but also country-specific [16']. If there is to be the successful development of the electric transportation sector in PMA, it is necessary to understand the barriers and incentives specific to the industry in this city.

1.3) Goals of this research

The goal of this research will therefore aim at answering the following question: What are the incentives and barriers at the governmental, production and consumption level for the

diffusion and the use of electric transport technology in the Greater Metropolitan Area of Panama City and what measures can be taken to address those barriers?

For the purpose of this research we will consider the two main veins of the transportation sector; public transportation, encompassing electric busses, electric subway, and electric taxis, and private transportation, which will be limited to personal electric cars.

We have organized this report into two major subsets. First we discuss the global state of the electric vehicle industry. Because electric battery-powered vehicle technology has the potential to instigate a massive overhaul transportation grid at a global scale, revolutionizing vehicular transportation both in Panama and Norway alike, we examine how wealthy Western nations have begun adopting to and preparing for impending new technology. This approach provides the reader with insight into how the industry is developing and what measures can be taken to effectively facilitate the eventual transition.

Subsequently, we shift our focus to PMA. In this part of the report we outline the current state of the electric transport sector in Panama, investigating the barriers impeding further development of this sector and the incentives with the potential to benefit the introduction and promote the eventually wider adoption of EV's by the country. Finally, this section ends with a series of recommendations regarding the next steps that should be taken to promote the use of electric transports in Panama.

II) METHODS

We first addressed our research question by understanding the context to the diffusion of electric transport technology in PMA. For this, various techniques were used:

- **Literature review**: Review of the scientific and grey literature was used to:
    - Identify the barriers faced by cities or countries who developed electric transport systems and the incentives and measures put in place to overcome them.

- Identify the resources required for the implementation of various electric transport systems.
- Understand the organization of the electric transport systems that already exists in Panama.

A review of the laws of Panama also helped us understand the legal and regulatory context mediating the diffusion of electric transportation technology in PMA.

- **Interviews**: Interviews with various government institutions, companies and individuals from civil society were conducted[1]. These helped us understand the legal and regulatory context mediating the diffusion of EV's and the market conditions of this new technology. Here is a list of the persons that were interviewed and the institutions they represent:
  - Rubilu Rodriguez - Dirección de Políticas Públicas al Ministerio de Economía y Finanza
  - Eduardo Lopez – Country Manager for BYD /ventas de autos eléctricos
  - Enrique Vargas – Subdirector de Cambio Climático y Vulnerabilidad a la Dirección de Gestión Ambiental del Municipio de Panamá
  - Hector Rodríguez – Secretaria Nacional de Energía
  - Nini Johanna Carillo & Luis Pinzon – Tranporte Massivo/ MiBus
  - Alexis Rodriguez - Especialista en Protección Ambiental de la Autoridad del Canal de Panamá
  - Ameth Guevara – jefe del Centro de Control de Tráfico de la Autoridad del Tránsito y Transporte Terrestre (ATTT)
  - Amarilis Uloa – Coordinadora de la Unidad de Mobilidad Dirección de Planificación Urbana Alcadía de Panamá
  - Esteban Bermudez - Especialista en Movilidad Eléctrica de ONU Medio Ambiante

[1] The questions asked during these interviews can be found in Appendix A.

The information collected during those interviews will be used to identify the incentives and barriers at the governmental, production and consumption level for the diffusion and the use of electric transport technology in the PMA.

Measures/solutions will then be proposed to overcome the identified barriers. These will be developed by taking into consideration the Panamanian context previously identified. We will also incorporate at case studies of the diffusion of electric transports in other regions of the world found in the literature.

Furtherefore, this research was conducted following the *Code of Ethics* of McGill University.

III) RESULTS

3.1 Analysis of EV's at the international scale

3.1.1. Pros of EV's

There are many environmental benefits in transitioning to a transportation sector based on electric power, both in terms of large scale, national targets and more localized benefits.

Most notably, EV's produce zero tailpipe emissions. Unlike traditional gas-burning cars that carry their energy source with them in the fuel tank, EV's rely on an external energy source, generally the main power grid, to charge their battery prior to any given trip [16']. In other words, EVs offset their emissions to the power generation source from which they charge. Thus, EV's can only be considered as clean as their energy source. They have the potential to demonstrate strong lifecycle emissions benefits when compared to conventional gas or diesel powered vehicles as long as they are charged using electricity generated by clean, renewable sources [16']. Some experts go on to claim that the operating cost of an EV is 70% cheaper than that of a conventional car [14].

It is estimated that while combustion vehicles take advantage of only 40% of their fuel's energy potential as a large percentage of the energy conversion is lost in the form of dissipated heat. In comparison, EV's utilize up to 90% of their fuel's energy potential [14].

Not only can EV's cut GHG emissions at a national scale, the implementation of this technology in cities has the potential to drastically lower local pollution levels, effectively improving urban air quality. Independent of energy charging source, the fact that EVs boast zero tailpipe emissions has far reaching implications for urban air quality. By offsetting all pollution to the source of energy generation, EVs offer a method of transportation with no local emissions of NOx or CO2, the primary contributors to urban smog [17].

Additionally, it is worth noting that EVs operate virtually silently. Viewed in conjunction, these two facts offer urban planners the potential to to drastically alter the way cities are designed, encouraging open concept buildings at the street level [18].

3.1.2 Global barriers to EV's

Despite the many environmental and anthropocentric benefits of EVs, the electric transportation sector currently is faced with (at least) three major technical roadblocks impeding the widespread adoption of this new technology. First, even state of the art electric car batteries today have a significantly lower roaming range than conventional gas or diesel burning equivalents. Second, recharging the battery of an electric vehicle is a process that is considerably more time consuming than filling up a tank of gas, often requiring several hours for a full recharge. Lastly, and possibly most importantly, electric vehicles will only really be viable for the mass markets once a comprehensive recharging grid has been established. This presents a certain Catch 22 as no company will be willing to invest the massive amounts of capital required to create such a grid without having a fleet of electric vehicles already on the roads. At the same time, few consumers will be willing to buy electric vehicles before a recharging grid has been

established [26, 27]. It is this lack of charging infrastructure that creates a negative feedback between consumers and producers which is crippling the large-scale rollout of EV technology at both a global and regional level.

a. Roaming range/ autonomy

When considering vehicle autonomy of all the personal electric vehicles currently on the market, Tesla Motors dominates the top three positions. The personal EV with the greatest autonomy is the Model S which boasts a maximum of 535 km range on a single charge. It is notable that the Tesla Model S with the supplementary battery upgrade costs $123,000, putting it well within the range of what is considered a luxury car [19]. Chevrolet is the company marketing the model with the second highest autonomy as the Chevy Volt, a $34,000 model, can travel as much as 380 kilometers on a charge [20]. The comparison with the Chevrolet Cruze, a model similar to the Chevy Volt in size, but less than half its price and that runs on diesel or gas with an autonomy of 730 km, reveals how the lower roaming range of electric vehicles is a barrier to their wider adoption. [21]

As a rule of thumb, an EV battery generally accounts for about one third of an electric vehicle's total price [22]. Thus, the bigger the battery the higher the autonomy of the vehicle but also the higher the price tag. For example, the Tesla Model S without the supplementary battery which has a roaming range of only 415 km per charge has a price of $68,000, considerably lower than the price mentioned above [19]. The majority of this price discrepancy can be accounted for by the cost of the additional battery capacity.

b. Recharging process

Secondly, car owners are accustomed to rapid refueling at a gas station. In contrast, recharging the battery of an EV is currently a slow process. Charging speed can vary by orders of magnitude across charging points and electric vehicles. Indeed, charging infrastructures differ in

their amperage and voltage and the maximum charging power that electric vehicles can accept varies[2] [23].

In comparison, a small household charger may charge as slowly as 1.2kW while advanced rapid charging stations may be capable of charging up to 350kW, using liquid cooling technology to maintain low temperatures at the contact points [23]. A full recharge can take anywhere from 30 minutes to over 15 hours, depending on the size of the battery and the speed of the charging point. For example, using the standard 120V charging station, the Chevy Volt will take about 16 hours to regain a full charge. Using higher amperage, such as a 240V charging station, this time can be reduced to four hours [20]. Tesla's super-fast charging technology can only charge 50 km of range per hour connected to an energy source, meaning that a full 480 km charge takes just over nine hours [19].

These lengthy battery charging times present an inconvenience to car owners who have the ability to charge their EV overnight at their home. However, for those car owners relying on public charging points, this slow charging process is one of the largest impediments to this technology, effectively limiting the EV market and keeping these electric battery powered vehicles from replacing vehicles with combustion engines on a large scale.

Gasoline pumps in the US deliver fuel at a rate of ten gallons per minute. The average car in the US has a gasoline tank between 13-17 gallons, meaning that the actual fueling process for the average car lasts no longer than two minutes [24]. This allows a single gas station to service many customers in a very small area of land without the large upfront investment of installing many pumping stations. At present, there is no EV technology that can compare to a gas pump charging speed meaning that charging stations for EVs need more land and more actual charging stations, representing a significantly higher front end investment when compared to gasoline or diesel pumping technology.

[2] See Appendix B: 3 types of electric vehicles charging levels

c. Comprehensive charging grid

This brings our analysis to the largest impediment hanging over the electric vehicle industry; the lack of a widespread, efficient and comprehensive charging network for EV's. The rise of the personal EV could signify the death of the centralized gas station and reliance on fueling-in-transit that has defined the personal car since the release of the Ford Model T. Adoption of this technology will require a cultural and technical paradigm shift, completely changing how and when cars are re-fueled. Instead of relying on gas stations as the loci of personal transportation, consumers and planners alike will have to entirely reorganize, transitioning from a system relying on centralized fueling to a system depending on dispersed charging stations. Instead of being situated on transit routes like gas stations, these charging stations will have to be placed at locations where cars are already stationary for long periods of time, such as parking lots [25].

This layout begets the question, which stakeholders should be responsible for building such a charging network? Should it be centrally planned? How will a local grid cope with such a large surge in energy demand? How can private companies benefit from supplying EV's with energy?

d. Fighting public perception

For decades, personal cars have embodied the freedom to go anywhere at any time, always confidant that a fueling station will be nearby and readily accessible. Consumers have been trained to rely on the hydrocarbon approach to personal transport and polls show their wariness to embrace EV technology. Much of this reluctance to change stems from genuine concerns regarding autonomy and charging availability, but there is also a large component mediated by confusion and lack of understanding this new tech [8].

Notably, this is not a death sentence for the personal EV industry, but rather an indication that despite government policy and industry measures to promote the technology, adoption of a new product is still determined by the consumers.

3.1.3 Global incentives for EV's

At a global scale, it is not a question of *if* electric battery powered vehicles will replace combustion engines, but rather *when* this massive transition will occur and *which* automobile companies will be at the forefront of the movement [7]. The debate intensifies when considering what the roll of the government should play in this transition phase; passive supporter allowing the consumers to choose the technology that meets their needs or active legislator, instituting official mandates and incentives to accelerate the arrival of large-scale consumer EV infrastructure.

Many governments have taken concrete action to promote electric mobility on their territory. These measures can be divided depending on which component of the electric mobility they target: the electric vehicle value chain or the charging infrastructure value chain. As showed in figure 1, each chain is further composed of four elements: research and development, production, services and customers. Table 1 presents the measures that can be taken at those different steps of the vehicle and infrastructure chain [29].

Figure 1: Components of the vehicle and the charging infrastructure value chains [29]

Table 1: Components of the vehicle and the charging infrastructure value chains and associated actions [29]

	Electric vehicle value chain	Charging infrastructure value chain
Research & development	Influence the research and design of EVs	Influence the research and design of the charging infrastructure
Production	Influence the production of EVs and their components	Influence the production of charging stations as well as the electricity production and network needed to supply them
Services	Influence the service providers of EVs (car dealerships, mechanics, insurance companies, etc)	Influence service providers for charging stations (energy suppliers, power plant, grid managers, etc)
Customers	Influence customers of EV's (individual consumer's, fleet owners, governmental agencies, etc.)	Influence customers of charging stations, both users and owners (EV owners, EV companies, public authorities and government)

Governments actions can also promote electric mobility using 4 different frameworks: Legal, financial, communication and organization framework [29].

Table 2: Examples of actions that governments can take to promote electric vehicles under the legal, financial, communication and organisation framework [29].

Legal	Legal requirements, local parking legislation, standards for charging stations, limited access to road and urban areas
Financial	Purchase grants, tax benefits for consumers of EVs, funding for battery research, subsidies on home chargers or free electricity for charging stations
Communication	Education if schools, information campaigns
Organisation	Government or public authorities acting as a launching customer, being an own fleet of EVs, government installing public chargers

In its article Martijn and al. summarizes the EV policies put forward by seven European countries, namely the Netherlands, Belgium, Germany, Denmark, Sweden, Norway and the UK. It reveals the following [29]:

- Most policies are conducted by the National government, are financial and target consumers in the vehicle value chain. They consist of tax incentives, rebates and specific local benefits like free parking.
- Measures focused on the charging infrastructure mainly consist in government paying for this infrastructure or subsidizing at the consumer level.

- Many local and regional organization, as well as public-private partnerships are created to ensure the dynamism of electric mobility projects and to encourage their development and success at the regional and local level.
- Although providing financial incentives to consumers does bring down the upfront cost of electric vehicles and private chargers therefore helping the penetration of EV in the market, this strategy is not sustainable in the long term. Indeed, as the early market phase of EVs comes to an end and the sells of EVs rise, countries cannot afford this financial support anymore. At this point, other policies must be adopted to create a self-enforcing loop in the sales of EV.

Finally, other more symbolic measures can still have an impact on the transition towards more electric vehicles. Many countries, have recently set the goal to have a 100% car fleet in the coming years. While Norway is aiming to have strictly electric car sales by 2025, other European nations like France and Great Britain have followed its example and pledged to ban the sale of gasoline and diesel burning cars by 2040 [7]. This approach is not unique to Western Europe. First India and later China, the two countries with the largest populations in the world (potential for most cars) pledged similar bans, although they seem to be more symbolic as both governments neglected to set strict timelines or concrete repercussions for failure to meet the national goals [7].

It is notable that this 20-year timeline corresponds to roughly four generations of car technology, enough time for innovation to radically alter the current status of the global car industry. For this reason, it is debatable whether goals set for two decades in the future are anything more than symbolic, regardless of established repercussions. However, automobile makers tend to structure business models considering long-term plans, and thus can be incredibly sensitive to how government targets influence consumer preferences, regardless of whether these targets are legally binding and actually directly affect the car industry [28].

It's also important to note that these symbolic commitments can also be the first step to a series of more concrete actions to promote electric transports. This is the case of Norway who took several measures to incentivize the radical goal of having strictly electric car sells by 2025. The country will waive high vehicle taxes for EVs, allow EVs to travel in bus lanes and on toll roads free of charge, and overhaul the vehicle fueling grid, building charging stations along highways and providing free charging in urban parking lots [30].

3.2 The State of EV's in Panama

3.2.1 Presentation of the Panamanian context

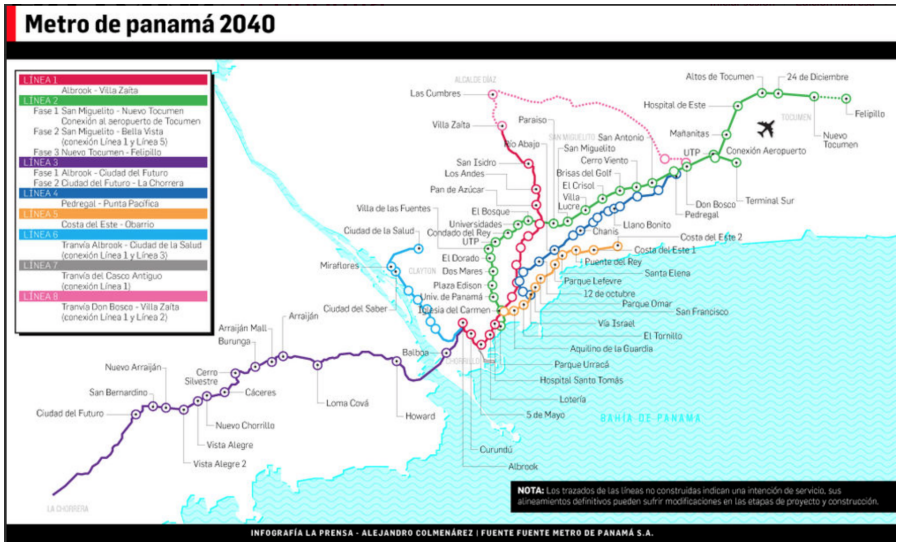
a. The Metro

The expansion of the metro system in Panama City is the most ambitious and costly domestic transport project currently under consideration in the entire country. The whole metro system is under the authority of Metro de Panamá, S.A., a public limited company that has been fully under state control since 2015 [31]. Opened in April 2014, line 1 of the metro covers 16 kilometers and is comprised of 14 stations, linking Albrook, the city's largest transport hub, to San Isidro, one of the city's most densely populated neighborhoods [32]. Initially projected to service 120,000 riders each day, there are currently between 240,000 and 280,000 passengers using the line on a daily basis. In July 2015, Metro de Panama approved the purchase of 70 additional wagons to meet the unexpected demand [32,33].

The construction of line 2 started in July 2015 and and is projected to be completed by 2019. Linea 2 will span 21 km comprised with 16 stations linking San Miguelito to Felipillo [32].

Those projects have important associated costs: 2.9 billion dollars were invested in the construction of line 1 and the second line is estimated to cost an additional 2.62 billion. However, those 2 lines are just the start of the ambitious 8-line metro-system that the Metro de Panama

aims to build by 2040, in an effort to greatly improve the mobility for the areas of San Miguelito, Arraiján and La Chorrera by decreasing reliance on the highway system (see map 1) [33].



Map 1: Projected metro grid of the PMA for 2040 [33]

In an early assessment of the metro proposal, it was projected that the first 4 metro lines would result in a 10% reduction of vehicles on the road on the main routes connecting the macro zones where these lines operate [1]. However, given that the actual usage of Line One has proven to be more than double the projected usage, the benefits of this 8-line metro system in terms of both commuting time and CO2 emission reductions, could be even higher than initially expected.

Despite being a very costly project, it is also one that transcends the different administrations in power and that should not be impeded on by the change in governments [33, 34].

Looking the the future of the metro system, which is projected to have eight lines in total, a new electricity generating plant is currently being designed specifically to secure the electricity provisioning of the metro [35].

b. Governmental institutions and legislation

Although there seems to be no governmental institution currently investigating a possible transition towards a Panamanian transport sector that relies more heavily on EV's, some

legislative action has been taken to promote EV technology in the past. On October 12th 2012, law 69 was passed in an effort to incentivize the buying of non-combustion engine cars. With a sunset clause, this law stipulated that electric and hybrid vehicles destined for human transport would be exempt from import duties until December 31st 2017 and then subsequently subjected to a low 5% import tax rate as of January 1st 2018 [36]. Nearly six years after its implementation, this tax exemption has had very little impact as there are very few hybrid vehicles and virtually no electric vehicles on the streets in Panama. The Secretaria de Energia is contemplating renewing this law to re-establish duty free imports on clean vehicle technology, hoping that as the technology progresses and becomes more affordable, this tax incentive will more be more effective in promoting EV's [34].

c. Demand

Both in terms of the personal vehicle market and public mass transport market, the demand for EVs in Panama remains virtually nonexistent as there are thought to be only twenty electric cars present in the entire country [34].

Becasue of these limited numbers, it was simply not feasible for us to interview any private citizens owning an electric car.

To our knowledge, the only company owning electric cars is the Autoridad del Canal de Panamá (ACP). The company possesses two Ford Focus electric models, each with their own charging station, as part of a pilot project to test out the functionality and profitability of converting a portion of their vehicle fleet from combustion engine to electric battery technology. The ACP operate several hydro-electric dams and thus are able to recharge the EV's using a combination of green electricity produced via hydro and thermic energy produced by burning natural gas. Considering the main objective of becoming carbon neutral in the coming years, the company aims at transitioning 200 of its aging 1200 vehicle fleet from conventional gas and

diesel powered vehicles to EVs. However, the ACP has not yet began this transition as they are struggling to find EV suppliers in Panama that carry models that fit the company's needs. [37]

d. Supply: BYD and BMW

The only two suppliers of electric cars in Panama are BYD and BMW. While BMW offers its best selling electric model the BMWi3 starting at $54,000, BYD offers more affordable electric cars with prices ranging between $34,000 and $46,000. Furthermore, in 2019 BYD plans to introduce a new subcompact electric car model to the Panamanian market with a price of $25,000 and a 260km autonomy [38,22]. The following tables summarize the electric cars available on the Panamanian market and present the different charging systems proposed by BMW and BYD.

Table 3: Electric cars available on the Panamanian market and their characteristics

Car model	Supplying company	Price ($US)	Autonomy (km)[3]
BMWi3 (subcompact car)	BMW	54,000 [38]	183-289 [39]
BYD E5 (compact car)	BYD	34,000-36,000 [22]	250 [22]
BYD E6 (compact car)	BYD	44,000-46,000 [22]	205 [40]
BYD New 2019 model (subcompact car)	BYD	25,000 [22]	260 [22]

Table 4: BMW's and BYD's charging systems and their characteristics

	Name	Type of outlet	Charging time	Usage	Additional information
BMW Charging systems [39]	TurboCord/OUC Level 1	120v	18-28 h	Home charging	Up to 4.8-6.4 km per hour of charging
	TurboCord Level 2	240v & 20 amps	5-8 h	Home charging and public stations	Up to 41.8 km per hour of charging
	Connected charging Station	240v & 32 amps	3-4h	Public stations only	Up to 80% of range in 30 minutes of

[3] The autonomy values provided by BYD for the E5 and the new 2019 model should be considered critically. We suspect that these numbers are overestimated and or apply to the higher price range models.

					charging
BYD Charging systems [22]	System 1	200 V	9-12h	Home charging and public stations	
	System 2	480 V	30 min – 1h for a car	Public stations	Can charge both BYD buses and cars

Although BMW and BYD both sell electric vehicles, they focus on two different markets. BMW is working on developing the niche market for upscale private electric cars in Panama, already having built three level 1 public charging stations in the PMA: one at the Multiplaza, one on Calle 53 and one on Costa el Este. Anyone can use these chargers for free as long as their EV charging port is compatible with the BMW charging systems [38].

In contrast, BYD has largely focused on entering the public transit sector. Indeed, the company manufactures and markets several electric bus models with prices ranging from $180,000 to $240,000, depending on size and autonomy of the vehicle [22]. Given the need for improved mobility and the high levels of pollution in the metropolitan area, the company believes that focusing on public transportation is an effective strategy to address both these issues and presents the best way to pierce the Panamanian vehicle market. This strategy also allows the company to introduce electric vehicles into the system, encouraging consumers to interact with the budding technology and experience the benefits firsthand without having to purchase a brand new EV. It is generally agreed that once consumers are habituated to electric buses and taxis, they will be more inclined to gain confidence in the technology, potentially shifting their preferences from combustion engines to electric battery powered vehicles [22].

According to Eduardo López de Victoria, BYD's country manager for Panama, the company's 2021 vision for the country can be summarized in 3 main points [22]:

- Develop an electric taxi fleet for the PMA:

On March 12th 2018, the Secretaria de Energia announced the initiation of a pilot project testing the feasibility and profitability of a taxi fleet comprised entirely of electric vehicles [41]. Thirty BYD EVs will be introduced into the PMA in order to assess the potential for electric taxis in the market. The data from this project will be recorded and analyzed in an effort to break down the benefits and drawbacks of EV taxis, serving as a benchmark to inform future investors and policymakers alike. This project is realized in partnership with the company Eumerica Taxi and Uber [42, 22].

- Introduce electric buses throughout the City in partnership with MiBus:

  In september of 2015, the Alcadia de Panama announced the inception of an electric bus pilot project in Casco Antiguo. Using an eight-meter 2013 BYD prototype electric bus, the goal of this project is to test the feasibility of introducing a bus onto the streets of Casco Antiguo while verifying the actual lifetime benefits of electric buses before implementing them on a larger scale [22,42]. The bus takes 2.5 hours to recharge on a 480v station and can transport up to 40 passengers with a 200 km range on a full charge. As this bus is a 2013 prototype and has been used as a test subject in several cities around the world, a new, more efficient BYD bus is scheduled to replace it in April 2018. In a complicated arrangement between the city and BYD to initiate this endeavor, the bus and the charging station were provided by BYD, the bus drivers are provided by MiBus and the electricity is paid for by the Alcadia de Panama [22,42,43].

  Ironically, while this project is designed to mitigate tailpipe emissions by decreasing the traffic that clogs the neighborhood's streets, the biggest impediment to the project is not the implementation of novel EV technology but rather is the number of cars on the road which add to the logistical nightmare of navigating such a large vehicle through the cramped streets of Casco Antiguo. The pilot programs maiden trial was conducted in March of 2018 with the purpose of determining the optimal route for the bus. If the pilot project is successful, the goal is to transform Casco Antiguo into a pedestrian area, where

public transportation such as taxis and buses will be the only form of vehicular transport [22,42].

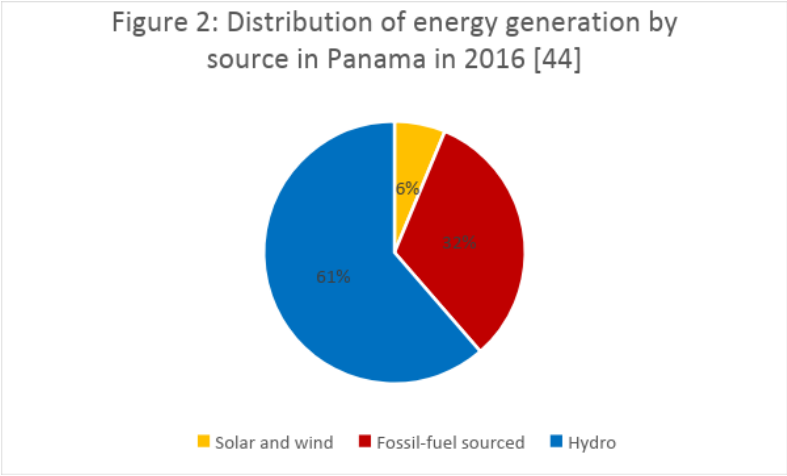
- Implementing a network of charging stations in Panama:

  Given there are only three EV charging station available to the public in Panama, all located at BMW distributors, BYD is considering investing in the development of a network of public charging stations throughout downtown PMA that would be accessible to all EV users. This would be a network of 480v fast-charging stations, each costing of 15,000 to 20,000 dollars. This plan is still in its early stages as the location of these stations has not yet been determined and the paying system for the electricity has not yet been established. BYD is currently looking to forge a partnership with ENSA, the electricity distributing company for the PMA. It is notable that BYD is looking for a third-party contracting company interested in installing the charging stations. BMW is not involved in this project and it is not yet clear if the BYD charging ports will be compatible with BMW charging ports or those of any other EV brand [22].

3.2.2 Barriers identified

a. Increased dependence on fossil fuel for electricity generation

As a country, Panama produces more energy than it consumes, exporting the surplus to neighboring countries [44]. Between 1999 and 2014, the country's average total energy consumption represented only 82% of its total energy generation, indicating that the national energy grid does have to cabability to meet the growing demand that would accompany widespread adoption of EV technology [45]. In 2016, 61.4% of Panama's energy was generated from hydroelectric sources while 32.3% came from thermoelectric plants burning oil or diesel, and the remaining 6.3% can be attributed to solar and wind sources [44].



As indicated by figure 2, nearly 70% of the energy production in Panama comes from renewable sources meaning that the country's energy network is currently suitable to maximize the pollution mitigation effects of implementing EVs. However, hydroelectricity production has plateaued and will likely decrease over the coming decades as a result of controversy surrounding the ethics of flooding river basins, often infringing on indigenous territories, to create energy production plants [44].

As a result, the increase in energy generation over the past fifteen years has largely been due to increased reliance on fossil-fuel based energy production. Out of the 3.525 million kWh/hour capacity increase registered between 2004 and 2014, only 33% came from hydroelectric plants, 41% from oil-based sources and 19% from coal (generation started in 2010). In stark contrast, only 3% of the registered increase in energy production can be attributed to wind generation[4] [45].

Although the contribution of renewable resources such as wind and solar is expected to increase over the coming years, so is the contribution of natural gas. This trend reveals that Panama as a country is increasingly dependant on fossil-fuel imports for electricity generation,

[4] See Appendix C: Evolution of Panama's electricity supply by source between 1999 and 2014

directly contradicting their goal to become energy independent by 2050 laid out it the Plan Energetico [1].

The potential for increased dependence on fossil fuel generated electricity is a barrier to the diffusion of electric transports in Panama, effectively diminishing the practicality of EV technology to decrease the GHG emissions of the transportation sector. As mentioned earlier, EV's are only as sustainable as their energy source, and as such they have limited environmental benefits if the grid that they are powered by generates electricity by burning fossil fuel. Additionally, the increased reliance on imported oil could drive up the price of electricity in Panama which is already among the highest in Latin America: approximately $0.25/kWh [45]. As outlined in the Plan Energetico, relying on an imported fuel source for energy production means that domestic electricity prices are subject to global oil price fluctuations. The high cost of electricity decreases the cost-efficiency/economic incentives causing a shift in private and public investment towards this novel technology [1].

b. The Metro Project

Currently, the vast majority of government funds allocated for the improvement of the Panamanian transportation system are dedicated to the expansion of the metro. While there is no governmental institution specifically mandated to investigate the development of electric transportation, an entire ministry has been established to oversee the metro project. [34] Given the current state of personal EV technology, promoting the metro system rather than the development of any other form of electric transportation, namely electric cars, taxis or buses, is a rational course of action for the city. The metro does not run on high cost electric batteries, instead relying on a constant connection to an energy source, separating it from other forms of electric transportation such as personal and even other forms of public EVs.

Furthermore, the metro has a massive impact on both urban mobility and the reduction of CO2 emissions. In contrast, theoretically, replacing all combustion vehicles in the PMA (whether

buses, taxis or private cars) with EV models would only have an impact on CO2 emissions, doing nothing to impact urban mobility.

For all these reasons, the expansion of the metro is the main focus of Panamanian governmental agencies tasked with improving urban mobility and decreasing the GHG emissions of the transportation sector.

Because the metro expansion is underway and unlikely to be derailed, the remainder of this section will therefore focus on identifying the barriers that exist to the development of an EV network in the PMA.

c. Lack of regulations on combustion vehicles and consumers perception

Another impediment to the modernization of the transportation sector is the lack of national fuel efficiency and vehicle cleanliness standards. In other countries, these standards apply pressure to car manufacturers, encouraging innovation, while also incentivizing consumers to adopt modern technologies [46]. In response to this issue, the Secretaria Nacional de Energia is currently working on defining a set of fuel efficiency standards to govern Panamanian vehicles [34]. It should be noted that this potential legislation will not directly encourage consumers to opt for EVs, but rather could increase the likelihood that they purchase more modern vehicles, which in accordance with global trends, will increasingly be EVs. Interestingly, such legislation could have large effects on the composition of the national vehicle fleet despite the lack of awareness that characterizes the Panamanian consumer in regards to the benefits of shifting towards cleaner vehicles [22].

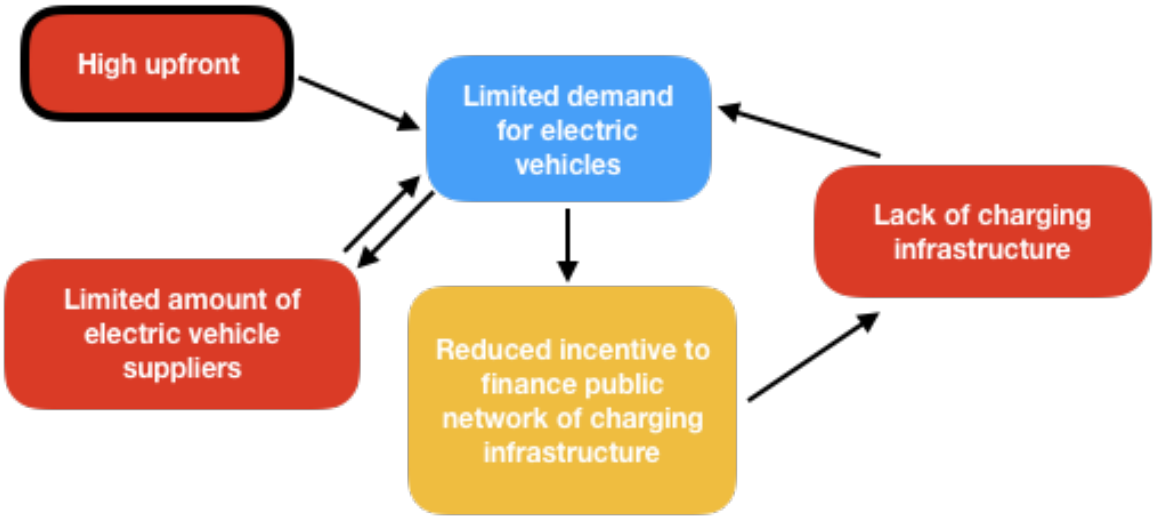
d. High upfront costs, lack of charging infrastructure and limited supply

One of the biggest barriers to the widespread adoption of EVs at a global scale is the high upfront costs of transitioning to this technology. These high costs are impeding the diffusion of

EVs in Panama as well and can be described as follows: With the price of electric buses being at least twice the one of conventional buses, Mibus, the company responsible of the PMA bus system, has little financial incentive to transition towards an electric bus fleet. Similarly, with the cheapest electric car on the Panamanian market being a subcompact model that has the same price as a compact combustion one, the demand for electric cars remains very low. Given this low consumer demand, there is virtually no incentive for the government to finance a comprehensive network of charging stations. This lack of charging stations then feeds back to further decrease the demand: MiBus is even less likely to invest in electric buses if it also has to pay for the charging stations and consumers are less likely to buy an electric car if they don't have access to an extended charging grid [25,47] .

This lack of consumer interest for electric vehicles discourages new suppliers from entering the market, restricting the supply of electric cars to Panama. As revealed during the interview with Alexis Rodriguez, this lack of diverse supply is another barrier that discourages the consumer from acquiring an electric car, further decreasing the demand for electric vehicles [37]. The situation described here corresponds to a negative feedback loop stemming from the high upfront costs of the technology and that prevents a wider adoption of this technology in Panama.

Figure 3: High upfront cost negative feedback loop



The 3 factors presented in the red boxes are direct barriers to the expansion of the electric vehicles market in Panama.

We believe the high upfront costs barrier could be perceived higher than it really is for two reasons. First, it's currently impossible to actually know if it would be economically interesting to finance the transition towards more electric cars and buses because no study has been done by any Panamanian governmental agency. Subsidized gasoline price and subsidies given to MiBus, currently hide the real cost of combustion vehicles and of the current MiBus bus system. MiBus receives 3 subsidies: one for the import of bus parts, one on gasoline (pays 30-40 cents/L instead of 79 cents/L) and one on the ticket price [34,35]. Other important subsidies on gasoline hide further the real cost of the current combustion vehicle transport system. Depending on the total cost of these subsidies, investing to promote the use of electric vehicles might not be more expansive than subsidizing the current economically and environmentally unsustainable transportation system. Following on this idea, the next part of the report presents the different factors identified as opportunities for developing electric vehicles in Panama.

3.2.3 Opportunities identified

a. Panama: a small country

Geographically, Panama is an ideal country to focus on a shift towards battery powered EVs. Because of its small size, the most populated areas on the isthmus are connected by several main roads. Furthermore, over 60% of the population lives in the PMA, a narrow strip of land roughly 80 km long [48]. Taking these two facts in conjunction, BYD believes that there is a high potential for the diffusion of EV technology as Panama's relatively small size and high population density could facilitate the implementation of a nation-wide charging grid, as relatively few public charging stations have the potential to service a large percentage of vehicle

owners. This is an advantage the PMA has over other cities that are more expansive and less densely populated, thereby requiring a higher front end investment to construct an efficient charging grid [22].

b. Increasing production of green energy in Panama

As mentioned earlier in this report, EVs should be charged with renewable energy sources in order to maximize their potential environmental benefits.

In the Plan Energetico, the panamanian government lays out two potential energy scenarios to describe the development of the country's energy grid of the coming decades. In this report we will only focus on the most optimistic scenario, the 'alternative scenario' that aims at drastically cutting the reliance of the country on fossil fuel sourced energy by 2050. If the country is able to realize this goal, the electricity inputs to the national grid by the mid-century will be as follows: 39% from renewable non-conventional sources, 33 % hydroelectricity, 2% imported and 26% from thermic production (6% coal and 20% natural gas)[5] [1]. With this scenario, 72% of the electricity available to power electric cars would come from non-fossil fuel sources. A transition towards the electrification of transportation in PMA would be an efficient strategy to decrease the country's CO2 emissions from the transport sector while also minimizing Panama's dependence on oil imports.

c. BYD and BMW initiatives

BYD's current interest in developing electric transports in Panama is a real opportunity for the country. First, BYD's previous experience in implementing electric bus and taxi systems in other urban areas could facilitate the creation of similar systems in the PMA[6]. Second, the

[5] See Appendix D: Predicted distribution of energy generation by source in Panama in 2050 according to "optimistic scenario" of the Plan Energético Nacional 2015-2050

[6] Between 2009 and 2017, the company launched a fleet of 15,000 electric buses in the city of Shenzhen, China and in 2017 BYD supplied 29 vehicles for the entirely electric bus fleet in

electric bus and taxi pilot projects pushed forward by the company should provide the data that governmental agencies like the Secretaria Nacional de Energia need to be able to analyze before deciding whether or not they should focus on the promotion of this technology [42]. Furthermore, BYD's efforts to partner with ENSA and other third-party organizations to implement a charging network throughout the PMA could prove invaluable in the promotion of personal EVs in the country.

Similarly, BMW's efforts to implement a network of public charging stations in the city can be interpreted as the first step towards the creation of a larger charging infrastructure, that is necessary to push the adoption of private EVs in Panama. While both BMW and BYD are private companies prioritizing shareholder profit, their actions with regards to EV technology present a great opportunity to the country of Panama.

d. MiBus

The contract regarding the concession of the public bus system in the PMA to the company MiBus will have to be renewed in 2025. Although the government currently has limited power to push MiBus to progressively replace their combustion buses by electric ones, the renegotiation of the terms of the contract in 2025 could be a good opportunity to pressure MiBus to shift towards a more modern bus fleet [34]. As EV battery technology is improving all the time with a new generation of battery being released roughly every six months, it is anticipated that in 2025, EV bus technology will be considerably more cost efficient [22]. Both government mandate and market forces have the potential to incentivize MiBus to transition a percentage of their fleet to electric battery powered alternatives.

Lancaster, England. The company set its sights on the Latin American market roughly 1 year ago, launching a fleet of 33 taxis in Ecuador in April 2017 and subsequently introducing several prototype electric buses in Bogatá, Colombia. BYD is now active in various other latin American countries, namely Columbia, Peru, Chile and Panama [22].

Furthermore, it could be possible to rework the existing three pronged government subsidy program supporting MiBus, designed to offset diesel fuel costs, maintenance costs, and reduce the bus fare. For example, the funds used to subsidized the import of bus parts could also help off-set the maintenance costs of BYD buses. If the subsidy is restricted to the import of parts from a single bus brand, this would be a big roadblock to the introduction of BYD electric buses, but depending on the given brand, it could also incentive to push this electric bus brand into the Panamanian market.

e. Costs of electric vehicles

The cost of a vehicle can be divided in three main categories : the initial cost or the sticker price of the vehicle, the maintenance cost, covering all vehicle repairs, and the operating cost associated to fueling the vehicle [40].

Initial cost

As touched upon earlier in this report, the high initial cost of electric vehicles is a barrier to their mass-adoption [40]. For a similar model, the price of electric vehicles, car or buses, is approximately twice the price of combustion vehicle [22]. However, since the battery cost represents approximately 40% of this initial cost, rapid improvements of electric vehicle batteries in the coming years are expected to significantly decrease the price of this technology [22,40]. Indeed, the price of the batteries that is currently at 300$/kWh is expected to drop to 100$/kWh by 2020-2025 [40].

Maintenance cost

The maintenance cost of electric vehicles is virtually always lower than that of combustion vehicles. Indeed, “they have fewer moving parts, no exhaust system, less need for cooling, less abrasive braking options, and no need to change oil, fan belts, air filters, timing belts, head gaskets, cylinder heads and spark plugs [49]"

Operating cost

The operating cost will depend on the vehicle's electric consumption and on the local price of electricity. In the next section, we estimate the operating costs of electric battery powered vehicles and compare them to combustion engine vehicles in Panama. This exercise serves to demonstrate the lower operating costs of EVs, a major incentive with the potential to promote the diffusion of this technology.

To determine if the operating cost of electric cars in Panama is an incentive or a barrier to the diffusion of electric cars in the country, we chose to compare it to the operating costs of diesel cars. Indeed, the price of diesel is often lower than gasoline and although we were unable to estimate the average fuel consumption of the Panamanian combustion car fleet, we know that it's largely composed of diesel vehicles [1].

We used 25cents/kWh as the national average price of electricity to estimate the operating cost of personal EVs in Panama [45]. The following table presents the estimated operating cost of the BMWi3 and the BYD model e6. It also shows the estimated operating cost of small and medium-large electric vehicles based on the median battery energy content and median range/autonomy of the most common battery powered electric vehicles in the world [40]. Note that the operating costs of the BYD e5 and the new 2019 BYD model were not calculated due to a lack of reliable data regarding the battery energy content and the battery range of these models.

Table 5: Calculated operating costs of different electric cars in Panama

Car model	Battery energy content (kWh) [40]	Autonomy (km) [40]	Energy consumed/ 100km (kWh/100km)	Operating cost ($/100km)
BMWi3 (subcompact car)	22	190	11.58	2.89
BYD E6 (compact car)	61.4	205	30	7.50
Medium-large electric model	24.2	190	12.7	3.20
Small electric model	16.8	150	11.2	2.80

The operating cost of diesel cars was calculated for two scenarios; the first considers the diesel consumption of medium-large vehicles while the second considers the consumption of small, compact vehicles. The estimated diesel consumption of the medium-large vehicles is based on data collected in the US where the majority of the personal vehicle diesel fleet is composed of larger car models. Meanwhile, the corresponding statistics for the compact vehicle's diesel consumption is based on data collected in France where the diesel fleet is composed mostly of smaller vehicles [50]. Both scenarios use the current price of diesel at the pump in Panama: 0.79$/L [34]

Table 6: Calculated operating costs of medium-large and compact diesel cars in Panama

Car model	Diesel consumption (L/100km) [50]	Operating cost ($/100km)
Medium-large diesel vehicle	9.31	7.35
Compact diesel vehicle	5.57	4.40

Our estimates reveal that, despite the high cost of electricity in Panama, the operating costs of small electric cars like the BMWi3 ($2.89/100km-$2.80/100km) are lower than that of small diesel cars ($4.40/100km). The average operating cost of medium-large electric cars ($3.20/100km) is also lower than that of diesel medium-large cars ($4.40/100km). However, the energy efficiency of the BYD e6 is relatively low and its operating cost is therefore higher than its diesel powered counterpart (7.50$/100km). This analysis therefore reveals that certain personal EVs demonstrate a lower operating cost than similar car models that rely on a combustion engine. The lower operating cost of certain EVs could be an incentive for Panamanian consumers to transition from diesel cars to electric ones.

The operating costs of electric buses were compared to those of Euro3 diesel buses, the standard of buses currently servicing the PMA [47]. Like with the personal vehicle comparison, the operating cost of electric buses was estimated using the current price of electricity in Panama (0.25 $/kWh). We first calculated the average operating cost of electric buses using the average

electric consumption of these vehicles in a city setting (1.15kWh/km[7]). We then calculated the operating cost of BYD's 2014 12m long electric bus using the energy consumption value provided by BYD (130kWh/100km)[52]. The operating cost of diesel buses was estimated using the average fuel consumption of Euro3 diesel bus (40L/100km) [53], the subsidized diesel price that MiBus benefits from (0.35$/L) and the unsubsidized diesel price (0.79$/L) [34].

Table 7: Operating cost of different electric buses and Euro3 diesel buses

Type of bus	Operating cost ($/100km)
Electric buses (6 model average)	28.75
BYD K9	32.5
Euro3 diesel bus with the Panamanian diesel subsidy	14.0
Euro3 diesel bus without the Panamanian diesel subsidy	31.6

This analysis reveals that even without diesel subsidies, the operating costs of the BYD K9 bus ($32.5/100km) is higher than that of Euro3 diesel buses ($14/100km - $31.6/100km). However, the average operating cost of electric buses (28.75$/100km) is lower than that Euro3 diesel bus without diesel subsidy ($31,6/100km). This indicates that depending on the type of model, electric buses can have the advantage of having lower operating costs than Euro3 diesel buses. However, the current subsidy on diesel that MiBus benefits from mask the true operating cost of those buses and could prevent one from seeing the cost-benefits of electric buses.

The following table summarizes the barriers and incentives identified in the previous sections

[7] Calculated based on the performances of 6 models of electric buses: Caetano Cobus 2500 EL, Muuli, Ebusco YTP-1, VDL Citea Electric, BYD eBus Green City and Ebusco 2.0) [51]

Table 8: Current barriers and incentives mediating the diffusion of electric transportation in the PMA

Barriers	• High upfront costs • Lack of charging infrastructure • Limited supply of electric vehicles • High price of electricity • All governmental attention going towards the metro project • Lack of regulations regarding the fuel efficiency of vehicles
Opportunities	• Territory on which to implement a network of charging stations is relatively small • Production of energy in Panama could be more than 70% renewable • Projects to encourage electric vehicles in Panama are currently being realized by the two suppliers present on the Panamanian market • The PMA public bus system functions as a concession to a single company: MiBus • Despite the high price of the Panamanian electricity, the operating cost of electric cars and buses can be lower than that of combustion vehicles • The total cost of EVs could become price competitive with combustion vehicles after 2020

IV) CONCLUSION: Addressing the future of EVs in Panama

As identified in this report, the main barrier to the diffusion of electric transports in Panama is the high upfront costs associated with transitioning to this technology. EVs have a higher initial cost when compared to combustion vehicles. Furthermore, not all models avaliable in Panama have lower operating costs when compared to traditional vehicles. The analysis carried out to compare the operating cost of different EV and diesel vehicles revealed that neither the BYD buses are more cost-efficient when compared to diesel vehicles. This is largely attributed to the the high price of electricity in the Panama. The only personal EV currently available on the Panamanian market that has an operating cost that is lower than that of diesel vehicles is the

BMWi3. However, with a price of $54,000, this vehicle is a luxury car marketed to a niche, upscale group of consumers and will not be the EV model to encourage a widespread adoption of electric cars in Panama. Cheaper and more energy efficient EVs do exist on a global market but are currently unavailable in Panama.

Given this context, we believe that the following measures should be taken:

1- Allow time and market forces guide EV adoption: The Panamanian government could follow the example of other North American and European countries and subsidize EVs and charging stations at the consumer level. However, we believe that because of the low cost-effectiveness of EVs currently available on the Panamanian market, this route is not the most effective. As time passes and electric battery technology improves, the price of EVs will decrease, in turn lowering the high upfront cost barriers and increasing the viability for EVs on the panamanian market, encouraging both the supply side and the demand side.

2- Use the EVs pilot projects to assess economic viability of available EV technology: The data points presented in this report are estimates and should probably be verified as they don't take into consideration all the intricacies of the subsidies that influence the price of diesel and electricity in Panama. Reliable data regarding the true cost of the different EV models is necessary to be able to carry out an in depth comparison of EVs and combustion vehicles. Although we believe that taking measure such as renewing Law 69 reestablish a 0% tax on EVs are beneficial, it is clear that governmental institutions should take a more active role in doing this research in order to better inform public policy decisions.

After conducting our research, we believe that the transition from conventional vehicles to EVs in Panama should start with the public transportation sector. This strategy has been shown to be effective in other countries such as England where increased exposure to EVs allowed consumers to gain confidence in the technology. For this reason, the data gathered from the electric bus pilot project in Casco Antiguo as well as the BYD electric taxi fleet initiative will prove invaluable to assessing the economic viability of investing in EV technology in Panama.

3- Taking advantage of existing networks and institutions: Panama isn't the only Latin American nation looking towards promoting electromobility and could therefore benefit from the experience of other countries in this domain. For example, the Panamanian government could coordinate with international organizations such as Mobilidad électrica en Lationoamerica (MOVE), a UN program working to collect data and develop strategies to promote the adoption of electric transports in Latin America. Joining this program could also help obtain international funding to develop electric transport projects in the PMA [54]. Another institution, The World Energy Council could be an ideal actor to further investigate the potential diffusion of EVs in the PMA.

4- Decrease the country's fossil-fuel dependency and promote sustainable green energy: EVs are only an efficient strategy to reduce Panama's GHG emissions dependence on imported fossil fuels if they are powered with green energy. As discussed in this report, Panama has traditionally relied heavily on fossil fuel resources to account for increasing energy demands. For the promotion of EVs to result in a net decrease in GHG emissions from the transportation sector, the Secretaria Nacional de Energia must promote the alternative energy strategy laid out in the Plan Energetico Nacional. Similarly, further investigations should be conducted to ensure that the metro will be powered with renewable electricity.

5- Create standards to improve the energy efficiency of vehicles: Although this legislative measure will not directly facilitate the transition to EVs, it will do so indirectly by creating a climate where both vehicle suppliers and consumers will be forced to comply with modern standards.

6- Education: As identified in this report, public perception of EVs is a non-negligeable barrier impeding the large-scale diffusion of this technology. We therefore encourage the development public outreach campaigns, clearly outlining the pros and cons of both combustion vehicles and EVs, highlighting the future economic and practical viability of the latter technology.

In conclusion, this research reveals that EVs are not currently poised to pierce the Panamanian market. This is mainly due to their high initial cost. However, this doesn't mean that the PMA transport sector should not prepare for the eventual transition away from hydrocarbons and towards electrification. The price of EVs will likely decrease in the next 10 years as battery technology improves, driving up the demand for EVs. The measures presented above should therefore be considered by the Panamanian government in order to ensure that an environment favorable to this technology exists in the PMA when EVs become economically viable in comparison with combustion vehicles.

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VI) APPENDICES

Appendix A: Interview questions

Questions asked to all:

- ¿Cree Ud. que existe un alto potencial para los transportes eléctricos en Panamá?
- ¿Por qué cree que los automóviles eléctricos no tienen mayor presencia en Panamá?
- ¿Cree que se debería promover el transporte eléctrico en Panamá? ¿Como se podría hacer?
- ¿Cuál son las organizaciones o instituciones que podrían impulsar más el transporte eléctrico en Panamá?
- Como consumidor, ¿qué lo incentivaría o no en la compra de un automóvil eléctrico?

Rubilu Rodriguez - Dirección de Políticas Públicas al Ministerio de Economía y Finanza

- ¿El gobierno tiene fondos para el desarrollo de la tecnología sostenible en Panamá?
- ¿Cómo se asignan estos fondos?
- ¿Tiene el gobierno algún interés en financiar el desarrollo de transportes eléctricos (privados y públicos) en Panamá?
- La construcción del metro es un gran proyecto. ¿Cómo se financió y cómo se financiará en el futuro?
- ¿Está el gobierno de Panamá listo para invertir en el desarrollo de transportes eléctricos (públicos y / o privados)? ¿Hay alguna condición para estas inversiones?

Eduardo Lopez – Country Manager for BYD /ventas de autos eléctricos

- *¿Cuáles son los precios de los coches eléctricos BYD? ¿Los buses? ¿Cual vende más?*
- *¿Cómo funciona el sistema de recarga BYD?*
- *¿Qué proporción de las ventas brutas están compuestas de autos eléctricos en Panamá?ù? ¿Ha cambiado el número desde el aprobado del 69 en 2012?*
- *¿Por qué BYD vino a Panamá? ¿Hay un buen mercado para vehículos eléctricos aquí? Como se podría hacer un mejor ambiente por los vehículos electricosÉ*
- *¿Cuáles crees que son las barreras principales para la difusión de los vehículos eléctricos? (transporte público separado: autobuses, taxis y automóviles privados?)*

- *¿Qué se puede hacer para tener más vehículos eléctricos en Panamá?*
- *¿BYD ha intentado asociarse con otras compañías eléctricas o otros negocios para aumentar el número de estaciones de carga disponibles en el país?*

Enrique Vargas – Subdirector de Cambio Climático y Vulnerabilidad a la Dirección de Gestión Ambiental del Municipio de Panamá y Amarilis Uloa – Coordinadora de la Unidad de Mobilidad Dirección de Planificación Urbana Alcadía de Panamá

- ¿Cuál es la opinión de la Ciudad de Panamá sobre el desarrollo de los transportes eléctricos?
- ¿Hay alguna organización investigando las sistemas de transporte eléctrico / concepción o difusión de vehículos eléctricos aquí en la Ciudad de Panamá?
- METRO: Hay un proyecto de metro que es muy grande. Porque el metro funciona con electricidad? Sabe donde viene el electricidad para el metro? ¿Cómo se seleccionan este proyectos? ¿Cuáles son las prioridades?Alguna dificultades para desarrollar este proyecto? ¿Cómo se financian estos proyectos? ¿Algún dinero proveniente del gobierno?
- AUTOBUS: Hay un proyecto piloto de autobuses eléctricos que comenzó recientemente el el casco antiguo. ¿Cómo se seleccionan este proyectos? ¿Cuáles son las prioridades?Alguna dificultades para desarrollar este proyecto? ¿Cómo se financian estos proyectos? ¿Algún dinero proveniente del gobierno?
- Hay otros proyectos de transport electrico que estan passando en este momento en la PMA?
- ¿Que son las dificultades que impiden el desarrollo de los transportes eléctricos en Panamá?
- ¿Podría el PIMUS también considerar favorecer los autos eléctricos a los autos de gasolina normales en el centro de la ciudad?
- ¿ Hay algun plan oficial para hacer esto?
- ¿El municipio de Panamá tiene algún poder para hacer cumplir las regulaciones para incentivar el uso de transportes eléctricos? ¿Qué se puede hacer?
- ¿Cuál son las organizaciones que podrían impulsar más transportes eléctricos en Panamá?

Hector Rodríguez – Secretaria Nacional de Energía

- ¿El gobierno tiene fondos para el desarrollo de la tecnología sostenible en Panamá?
- ¿Cómo se asignan estos fondos?
- La construcción del metro es un gran proyecto. ¿Cómo se financió y cómo se financiará la construcción de las otras líneas en el futuro?

- El sistema de autobuses está altamente subsidiado en Panamá. Cada boleto de autobús cuesta 25 centavos en lugar de 75 centavos. ¿Es lo mismo para los boletos de metro? ¿Cuáles son los números?
- Tiene el gobierno algún interés en financiar el desarrollo de transportes eléctricos (públicos y / o privados) otro que el metro? ¿Hay alguna condición para estas inversiones?
- La empresa BYD tiene un gran proyecto para desarrollar el transporte eléctrico en Panamá para 2021. Quiere introducir taxis eléctricos, buses eléctricos y quiere implementer estaciones de carga a través de la ciudad. ¿Qué piensa el gobierno de Panamá de este plan? ¿Es una prioridad del gobierno central apoyar al sector privado en este objetivo de introducir vehículos eléctricos a Panama?
- ¿Qué medidas está dispuesto a tomar el gobierno para incentivar inversiones en un sector de transporte eléctrico en Panamá?
- Sabemos que existe el proyecto de metro y el proyecto piloto de autobús eléctrico en Casco Viejo. ¿Hay algún otro proyecto de transporte eléctrico en marcha en Panamá?

- A través de nuestras entrevistas, hemos aprendido que las principales barreras para el desarrollo del transporte eléctrico en Panamá son: falta de fondos, falta de estaciones de carga y falta de conocimiento público de esta tecnología. ¿Estás de acuerdo con estas 3 barreras identificadas? ¿Cómo se pueden superar cada una de estas barreras?
- La Ley 69 tiene el objetivo de promover el transporte eléctrico en Panama. ¿Cree que este objetivo esta alcanzado? Porque el CIF para vehículos eléctricos fue aumentado a 5% en 2018?
- ¿Qué se necesita hacer para fomentar el desarrollo del transporte eléctrico en Panamá? ¿Cuál son las organizaciones que podrían impulsar más transportes eléctricos en Panamá?

Nini Johanna Carillo & Luis Pinzon – Tranporte Massivo/ MiBus

- ¿Cómo comenzó el proyecto piloto de autobuses eléctricos en Casco Viejo? ¿Quién está al inicio de esta iniciativa?
- ¿Por qué Casco Viejo? ¿Por qué no comenzar con las rutas de autobús normales?
- ¿Recibió este proyecto algún dinero público? De donde vino?
- ¿A qué compañía compraron los autobuses?
- ¿De que marca son los autobuses? Compraron los autobús de la empresa de esta marca?
- ¿Quién paga la electricidad? ¿A quién se compra la electricidad?
- ¿Vale la pena el dinero invertido?
- ¿Cuáles son los problemas que se han encontrado con el desarrollo de este proyecto de autobús eléctrico?
- Este proyecto es un proyecto piloto. ¿Que son los objetivos futuros de este proyecto?
- ¿Sería interesante / factible reemplazar gradualmente el flotador del autobús por autobuses eléctricos? ¿Cómo se podría hacer eso?
- ¿Ha habido algún otro proyecto de autobuses eléctricos que haya sido avorted? Si es así, ¿por qué?

Alexis Rodriguez - Especialista en Protección Ambiental de la Autoridad del Canal de Panamá

- ¿Cuántos vehículos eléctricos tienen?
- ¿Dónde los recargan? De donde viene la electricidad?
- ¿Por qué decidiste implementar vehículos eléctricos?/ ¿Cuáles fueron los incentivos para cambiar a vehículos eléctricos?
- ¿Por qué decidieron de utilizar vehículos eléctricos en lugar de vehículos híbridos?
- ¿Recibieron algún subsidio del gobierno?
- ¿Fue económicamente rentable hacerlo?
- ¿Cuáles fueron los dificultades en desarrollar esta technologia?

- Conoces algún otra empresa que utiliza vehículos eléctricos?
- Piensa que el modelo de Canal de Panamá funcionara por algún otro empresa?

Ameth Guevara – jefe del Centro de Control de Tráfico de la Autoridad del Tránsito y Transporte Terrestre (ATTT)

- ¿Cómo es el funcionamiento del sistema de taxis en Panamá?
- ¿Sería posible tener un inversionista privado que crea una flota de automóviles eléctricos en Panamá? (El inversionista compra y es dueño de los autos eléctricos y le paga a los conductores por conducir estos autos)
- ¿Hay alguna institución público o privada investigando sobre sistemas de transporte eléctrico / concepción o difusión de vehículos eléctricos en Panamá?

- ¿Como se puede apoyar el desarrollo del transporte público eléctrico y los vehículos eléctricos privado?

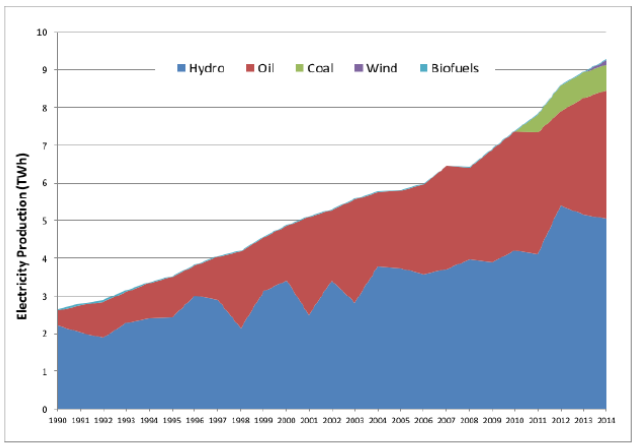
Appendix B: 3 types of electric vehicles charging levels [23]

Charging level	Voltage (V)	Typical power (kW)	Setting
Level 1	120 V AC	1.2–1.8 kW	Primarily residential in North America
Level 2	200–240 V AC	3.6–22 kW	Home, workplace, and public
DC fast	400 V DC	50 kW or more	Public, primarily intercity

V = volt; AC = alternating current; DC = direct current; kW = kilowatt

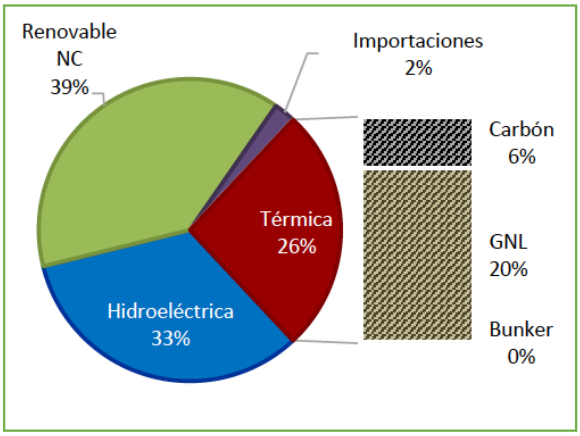
Appendix C: Evolution of Panama's electricity supply by source between 1999 and 2014

Figure 24. Panama: Electricity Supply by Source (1999-2014)



Source: International Energy Agency (IEA).

Appendix D: Predicted distribution of energy generation by source in Panama in 2050 according to "optimistic scenario" of the Plan Energético Nacional 2015-2050 [d]



Appendix E: Ethical certificates

PANEL ON RESEARCH ETHICS

Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Emile Sassone-Lawless

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **18 January, 2018**

Groupe en éthique de la recherche

Piloter l'éthique de la recherche humaine

EPTC 2: FER

Certificat d'accomplissement

Ce document certifie que

Clémentine Mattesco

a complété le cours : l'Énoncé de politique des trois Conseils :
Éthique de la recherche avec des êtres humains :
Formation en éthique de la recherche (EPTC 2 : FER)

18 janvier, 2018