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CHARGING AHEAD

The Growth of Electric Car and Bus Markets in Latin American Cities

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Foreword

I am pleased to present "Charging Ahead: The Growth of Electric Car and Bus Markets in Latin American Cities," a report by Guy Edwards, Research Fellow and Co-Director of the Climate and Development Lab at Brown University; Lisa Viscidi, Director of the Energy, Climate Change and Extractive Industries Program at the Inter-American Dialogue; and Carlos Mojica, Urban Transport Senior Specialist at the Inter-American Development Bank.

Expanding the use of electric vehicles, including cars and buses, is a critical component to advancing a sustainable transport agenda. This report analyzes the key policies that have been effective in promoting electric mobility in Latin America. The report focuses on case studies covering six urban electric car and bus markets in the region, as cities have the most favorable conditions for electric vehicle adoption due to the concentration of drivers and widespread availability of public transportation. The three electric car markets (Bogotá, Mexico City, and Santiago) and three electric bus markets (Santiago, São Paulo, and Campinas) have seen among the fastest growth in electric vehicle adoption in Latin America. The case studies focus on battery electric and plug-in electric vehicles as well as battery electric buses, which have greater potential to reduce emissions than conventional hybrid vehicles.

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This effort is a product of the Energy, Climate Change & Extractive Industries Program, which informs and shapes policies that promote investment while encouraging climate change mitigation and the socially, economically and environmentally responsible development of natural resources. The report is part of the program's ongoing Clean Transport Initiative, which has produced numerous publications and conferences throughout Latin America.

We are grateful to BMW Group for their generous support of this report. The views expressed in this report are those of the authors and do not necessarily reflect the perspectives of the Inter-American Dialogue or its board, partners or sponsors. The Dialogue is committed to intellectual independence, transparency, and accountability and our donors have no control over the analysis or findings of our research efforts.

MICHAEL SHIFTER
President

The report focuses on case studies covering six urban electric car and bus markets in the region, as cities have the most favorable conditions for electric vehicle adoption due to the concentration of drivers and widespread availability of public transportation.

Introduction

The electrification of the transportation sector promises far-reaching benefits for urban areas and the world. Electric mobility is critical to tackling climate change, reducing air pollution, and improving energy security. To achieve the goal set by the Paris Agreement on climate change of limiting global warming to well below 2° Celsius, the transport sector—which accounts for 20%[1] of global CO_2 emissions—will need to shift rapidly towards zero-emission options. This will only be possible through mass electrification of the transport sector coupled with decarbonization of the electricity grid. Moreover, even when run on electricity generated partly from fossil fuels, electric vehicles (EVs) emit significantly less greenhouse gas over their lifetimes than conventional vehicles due to their far greater efficiency.[2] Decisions made today will determine whether the Paris goals can be met, as 70% of the forecast increase in emissions from developing countries is based on infrastructure that has not yet been built.[3] With zero tailpipe emissions, EVs also make a huge contribution to improving air quality in areas where they are driven.

In addition, electric mobility improves energy security by cutting fuel imports and diversifying the energy sources used for transportation. Electric cars and buses will add just 6% to global electricity demand by 2040, while the switch from conventional to electric vehicles will displace 7.3 million barrels per day of transport fuel, according to Bloomberg New Energy Finance.[4]

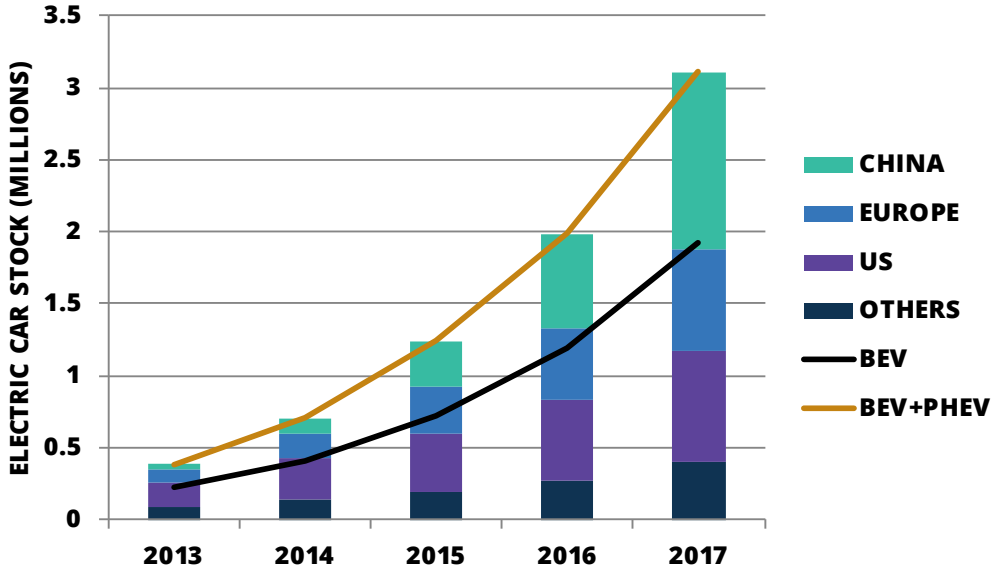
Even in markets that are small today, governments should start to prepare for an industry that is expected to grow rapidly. Local supply chains and service providers, such as auto maintenance shops, as well as transport-related businesses, like long haul trucking, urban distribution, and public transportation companies, will have to adapt to the new technology to remain competitive.

Electric mobility has taken off in recent years, with global sales of electric cars, buses, motorcycles, and other vehicles steadily rising. The global stock of electric cars surpassed 3 million in 2017 after reaching 1 million in 2015 and 2 million in 2016[5] (see Figure 1). While demonstrating an impressive growth rate, EVs still represented only 0.2% of the total number of passenger light-duty vehicles in circulation in 2016.[6] The stock of electric buses, meanwhile, increased to 370,000 in 2017, driven mostly by developments in China, which accounts for over 99% of the global electric bus market.[7]

Various forecasts predict rapid expansion (see Figure 2). The International Energy Agency estimates that by 2020 the global EV fleet will reach 13 million,[8] while Bloomberg sees the global electric car fleet surging to 530 million by 2040.[9] China will lead this transition, followed by Europe and the United States. Electric bus markets could advance even faster. By 2030, Bloomberg expects that 84% of global municipal bus sales will be electric.

FIGURE 1: GLOBAL ELECTRIC CAR STOCK

Source: International Energy Agency (IEA), *Global EV Outlook 2018.* Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle



Latin America's car fleet is responsible for some 37% of total transport emissions while public transport, including buses, accounts for close to 10%.

The fast growth in EV uptake has been due largely to policies adopted in a select group of countries as well as market developments. Policies to implement stronger fuel economy standards (which give car manufacturers incentives to invest in EV technology), tax incentives, and national electric mobility strategies have boosted sales. A significant drop in the cost and increase in the range of batteries is also driving growth. Meanwhile, new business models such as car sharing have made it easier for consumers to access electric cars. Various automakers are also stepping up with pledges to increase investments in EVs and develop new models, providing consumers with more options.

Cities are the focal point for EV adoption, and many are setting ambitious goals to tackle climate change and promote clean transport. Fourteen cities, including Oslo, Shanghai, Shenzhen, Amsterdam, and San Jose, California, accounted for 32% of new EVs in 2015.[10] Drivers in cities travel shorter distances and generally use smaller cars, making EVs more viable. Public transportation is more widely used, creating opportunities for electrification of larger vehicles that run throughout the day. And municipal governments have specific policy instruments at their disposal, such as building codes that mandate charging points, exemptions from road access and parking restrictions for EVs, and municipal public procurement strategies to introduce electric car and bus fleets. The mayors of 50 cities, including Buenos Aires, Mexico City, Rio de Janeiro, and Santiago, have pledged to reach net zero emissions by 2050. Since 2017, 14 cities, including Quito and Mexico City, have pledged to procure only zero-emission buses starting in 2025 and ensure that major areas of their cities are zero-emission by 2030.

PROGRESS IN LATIN AMERICAN CITIES

Latin America has a great need to move toward cleaner forms of transportation. The transport sector is the largest and fastest-growing source of energy-related emissions in the region. Latin America's car fleet is responsible for some 37% of total transport emissions while public transport, including buses, accounts for close to 10%.[11] If electric mobility expands in Latin America to an extent sufficient to meet the 2° Celsius scenario, the region would see an approximate reduction of more than 1.5 billion tons of CO_2 and fuel savings of almost $85

FIGURE 2: PROJECTED GLOBAL EV STOCK UNDER EXISTING OR ANNOUNCED POLICIES

Source: IEA, *Global EV Outlook 2018.* Notes: PLDV = passenger light duty vehicle; LCV = light commercial vehicle

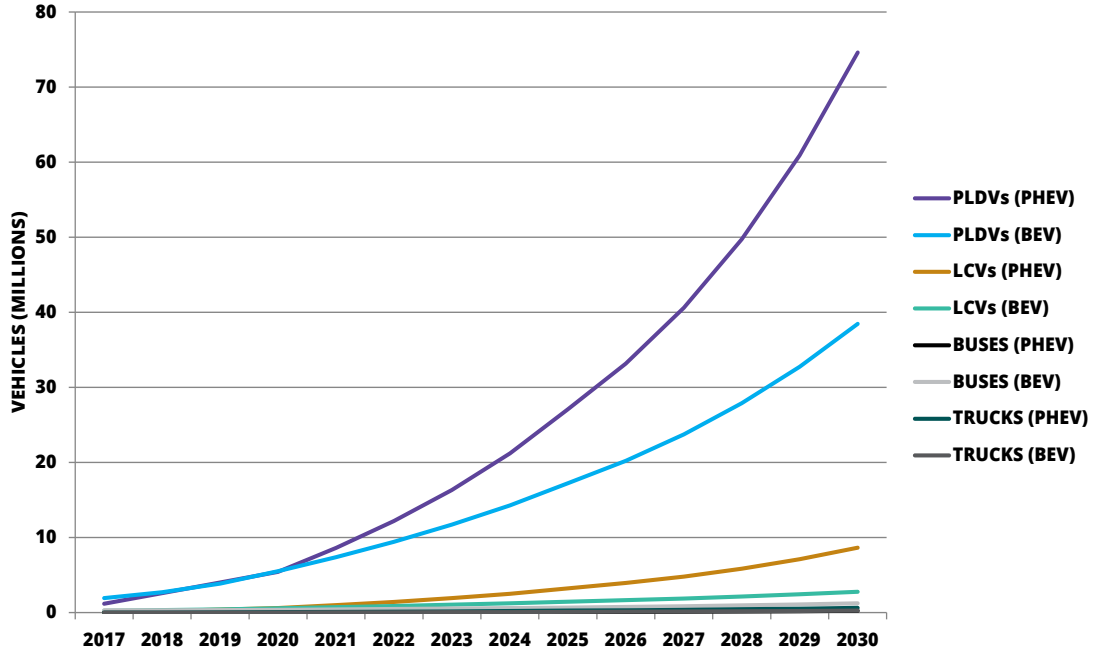
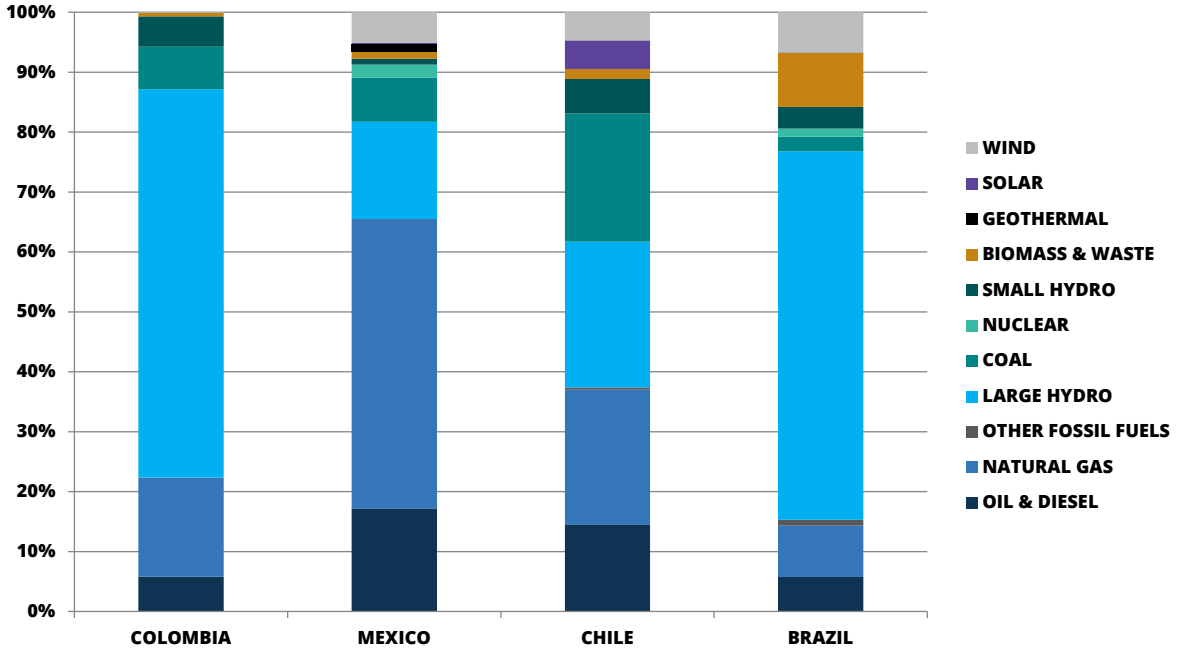


FIGURE 3: INSTALLED CAPACITY BY GENERATION SOURCE, 2016

Source: Climatescope



billion from 2016 to 2050, according to the United Nations Environment Programme ("$" indicates USD throughout this report).[12]

Latin American cities are also plagued by severe air pollution due to the large numbers of vehicles and poor fuel quality. Many cities exceed World Health Organization (WHO) thresholds for the concentration of airborne pollutants including particulate matter (PM10 and PM2.5). Conservative estimates suggest that every year 50,000 people die prematurely in the region due to air pollution caused mainly by transport.[13]

The region has a critical window of opportunity for electrifying its transport sector. Latin America enjoys one of the cleanest electricity matrices in the world—roughly 50% of installed power capacity comes from renewable energy compared to a global average of about 15%[14] (see Figure 3). It has the fastest growing car fleet in the world, with the number of vehicles set to triple in the next 25 years, reaching over 200 million units by 2050.[15] Latin America also boasts the highest use of buses per person globally, and bus rapid transit systems (BRTs) across 62 cities provide a lower-cost alternative to metro and rail systems.[16] Buses run many hours each day, meaning that the fuel savings and lower maintenance costs generated by electrification produce a fast return on investment. The fixed routes and defined distances also make it easier to install charging systems.

Electric mobility policy is evolving rapidly in Latin America, though the market remains incipient. Numerous countries have incentives for EVs, such as exemptions or reductions in sales, environmental, and import taxes, revenue-neutral "feebates" that tax polluting cars and reward clean ones, exceptions from traffic permits and vehicle restrictions, and differentiated electricity tariffs. In January 2018, the region's first route for electric vehicles opened in Uruguay, allowing EVs to travel the entire coastal strip between Colonia del Sacramento and Punta del Este with access to several charging points. This year, a new EV incentives law came into effect in Costa Rica, followed by an announcement by President Carlos Alvarado that by 2021 the country will launch a plan to establish a fossil fuel-free transport system. Colombia is also debating a draft law to incentivize EV adoption. In Argentina, a recent presidential decree slashed import duties on EVs for local car makers. More electric car models are being brought to the region,

Roughly 50% of Latin American installed power capacity comes from renewable energy compared to a global average of about 15%.

providing more choice to consumers. Meanwhile, the creation of national EV industry associations is playing an important role in promoting the new technology in various countries.

However, there remain significant challenges for expanding the use of electric vehicles. While the cost of batteries has fallen considerably over the last decade, a 2016 IDB study indicated that in Latin American countries, privately owned electric vehicles remain more expensive than conventional vehicles over the lifetime of the car, even when accounting for lower fuel and maintenance costs.[17] Steep upfront costs for both electric cars and buses are a major deterrent. Fossil fuel subsidies—which consumed 1% of GDP from 2011 to 2013—discourage EV sales by lowering the costs of gasoline and diesel at the pump.[18] In addition, the region has made little progress on improving fuel efficiency in automotive markets, which would help level the playing field for EVs. The lack of specialized financial instruments or business models to incentivize EVs has slowed their deployment. Many Latin American countries have inadequate charging infrastructure, and consumers are concerned about how far they can drive, especially between cities and towns, without recharging. Latin America's public transport systems have tended to contract using open bidding processes that prioritize least-cost options, which disqualifies technologies with high upfront costs such as electric buses.

Some projections for EV markets in Latin America remain quite conservative. Within the next decade, Argentina, Brazil, Chile, Colombia, Mexico, and Peru will have the largest markets for plug-in hybrid electric vehicles and pure electric vehicles in the region, according to one analysis.[19] Annual EV sales in these six countries could range from 52,000 to 220,000 units in 2023, depending on regulatory changes, consumer acceptance, and technology development. This would represent a market penetration of only 0.3% to 2.5%.

The greatest potential to expand electric mobility clearly lies in the region's cities. Latin America is the most urbanized region in the world, with 80% of its citizens residing in cities, and that figure is expected to reach 90% by 2050. The high urbanization rate provides advantages for policymakers looking to promote electric transportation, as cities have numerous policy tools available to promote the use of electric cars and buses. While EV adoption in Latin America has lagged behind other regions, a number of its cities demonstrate how the right policy mix can accelerate this trend.

Electric Car Case Studies

The following sections examine developments in the electric car markets of Bogotá, Colombia; Mexico City, Mexico; and Santiago, Chile, and analyze the policies that have had the greatest impact on EV uptake (see Figure 8). "EVs" in these case studies refers only to battery electric and plug-in hybrid electric vehicles (BEVs and PHEVs, respectively). "Hybrids" refers to non-plug-in gasoline or diesel-electric hybrids.

BOGOTÁ, COLOMBIA

On a national level, Colombia has been an early adopter of electric mobility within Latin America, recognizing the dire need to reduce emissions and improve air quality. Its carbon emissions are set to double by 2040 if no action is taken,[20] and the transport sector will be responsible for the majority of the increase.[21] Colombia's Nationally Determined Contribution (NDC), its commitment under the Paris Agreement (see Figure 9), does not mention electric mobility specifically but notes the importance of reducing transport sector emissions.

Air pollution, which causes some 6,000 deaths annually, is another key driver of Colombia's electric mobility efforts. An aging fleet is partly responsible—the average is 16 years, and older vehicles contribute disproportionately to air pollution.[22] By increasing incentives to drive, generous subsidies to gasoline and diesel (costing up to 1.6% of GDP since 1983) are exacerbating pollution. Colombia currently has only 148 vehicles per 1,000 inhabitants, compared to 230 in Chile and 275 in Mexico.[23] However, private light duty vehicles are set to increase more than any other class of vehicle, from 16% of the vehicle fleet in 2009 to 36% by 2040.[24] Thus, swift action to incentivize uptake of electric cars could have a major impact on the future composition of Colombia's fleet and therefore on air quality.

Furthermore, Colombia's clean electricity matrix could complement fleet electrification and allow for full decarbonization of transport. In 2015, electricity generation was dominated by hydropower, which accounted for 70%, followed by natural gas, oil, and coal.[25]

The Colombian government has recognized the potential benefits of electrifying transport and incorporated EV promotion into national decarbonization planning. Its 2012 Low Emission Development Strategy identifies electrification of the country's public transport fleet as a priority[26] and led to the launch of Latin America's first EV taxi fleets. In 2016, the Ministry of Mines and Energy

published a roadmap for smart grid investment through 2030 with a focus on rolling out EV adoption in addition to smart metering and distributed energy integration.

Most recently, in June 2018, Colombia's Green Growth Commission launched its new roadmap, "Colombia towards Green Growth." Led by the National Planning Department, the initiative seeks to guide the transition towards green growth by 2030.[27] It is hoped that the new government of President Iván Duque, who took office on August 7, will incorporate the roadmap into its national development plan and budget. One of its main objectives is to advance electric mobility, with the goal of reaching 600,000 EVs in circulation by 2030. The plan also calls for electric buses to make up 100% of purchases in bus tenders and aims for 45% of the population to use public transport. Before taking office, President Duque announced that he would like to see the private vehicle fleet made up primarily of EVs by 2030.

A series of fiscal incentives at the national level have helped incentivize the purchase of EVs. In 2012, a series of tax incentives granted the exclusion of value-added tax (VAT) for electric and hybrid vehicles as well as for public transport systems for passengers or cargo. These incentives have already been requested by important transport organizations in various Colombian cities, with benefits that exceed $47 million of VAT exclusion (across all clean technologies).[28] In August 2017, Colombia's Ministry of Commerce, Industry, and Tourism established an import tariff of 0% for electric vehicles and 5% for hybrid vehicles. The tariff will be applied from 2017 through 2027 for the annual importation of 500 EVs through 2019, rising to 3,000 by 2023. This decree will complement the already approved 5% VAT exemption for this segment.[29]

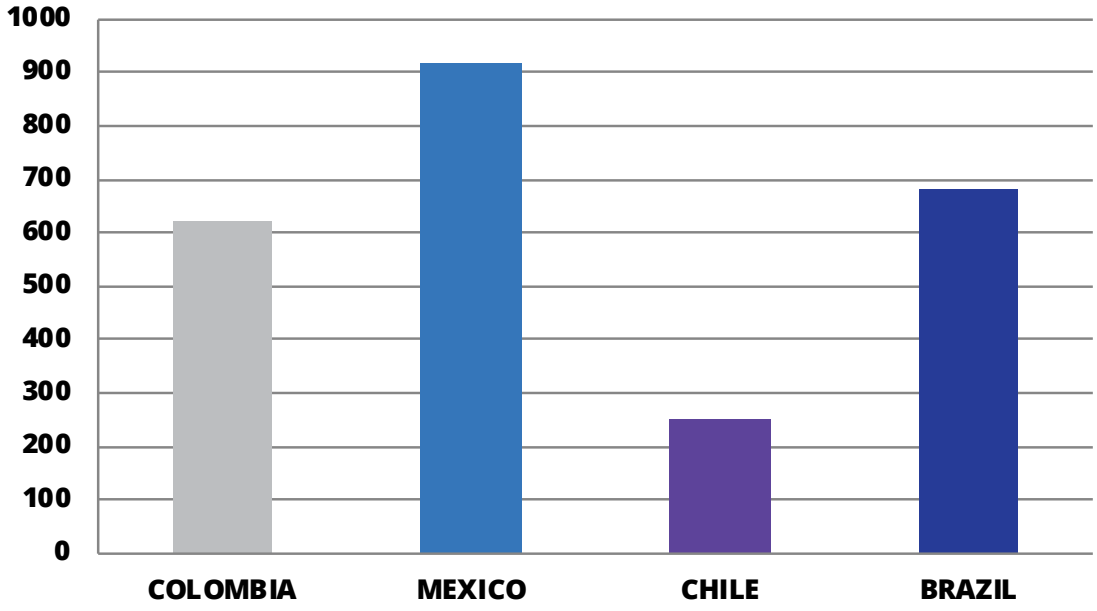
There have also been efforts to pass an overarching law to incentivize EVs, including a draft law proposed in 2017[30] with expected approval in 2018.

Colombia has also striven to provide disincentives to emitting carbon, which implicitly incentivizes clean technologies like EVs. As part of a 2016 tax reform, an economy-wide carbon tax was imposed on all liquid and gaseous fossil fuels used for combustion to encourage compliance with emission reduction goals. The tax, which entered into effect in June of 2017, includes an initial tax rate of $5 per ton of CO_2. The provisions of the law are intended to stimulate implementation of mitigation activities that generate emissions reductions/removals, since these can be used in exchange for payment of the tax.[31]

With a population of 11 million in the metropolitan area, Bogotá is Colombia's largest EV market. About half of the 241 EVs sold in Colombia between January and June of 2018 were purchased in Bogotá.[32] The market for BEVs is outperforming the PHEV market. By mid-2018, 754

FIGURE 4: EV STOCK BY COUNTRY, 2017

Source: IEA and Asociación Colombiana de Vehículos Automotores (ANDEMOS)



The adoption of electric taxis and public car fleets in Bogotá and the rest of Colombia has boosted sales.

BEVs had been sold compared to 206 PHEVs. Unlike in Mexico and Chile, in Colombia, sales of EVs have markedly outperformed those of conventional hybrids. In 2017, there were 193 pure EVs and PHEVs sold compared with only three hybrids. This likely reflects not only the more attractive incentives in place for EVs compared to hybrids but also the wide range of EV models available for purchase. The pace of EV sales has increased dramatically since 2012 (see Figure 5) even though sales dropped between 2016 and 2017 when preferential tariffs for EVs and hybrids expired in December 2016 (they were not renewed via a new decree until June 2017 because of government delays). One prediction suggests that 650 EVs will be sold in 2018.[33] Still, electric vehicles make up only a small share of the roughly 5 million vehicles in Colombia's total fleet.[34]

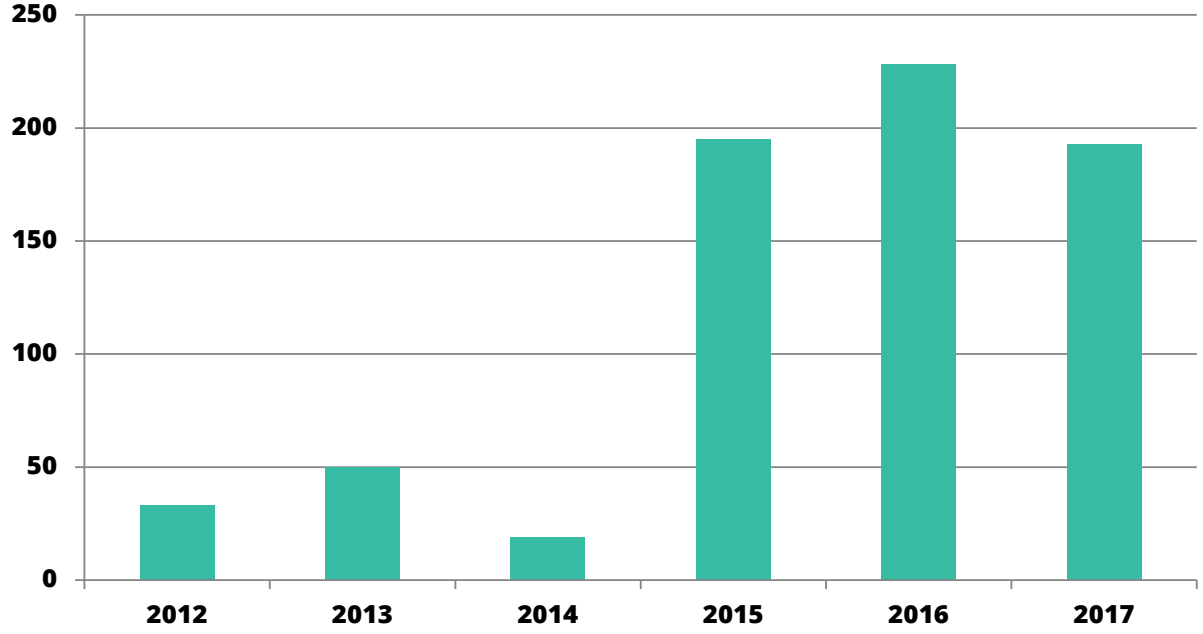
A growing number of EV models are available in Colombia (see Figure 6) and in 2018 alone several new EV models arrived in the country, including new versions of the Renault ZOE, the Chevrolet Bolt, and the Hyundai Ioniq.[35] The new Nissan LEAF will go on sale in Colombia later this year.

The adoption of electric taxis and public car fleets in Bogotá and the rest of the country has boosted sales. In 2012, Bogotá launched an electric taxi pilot project in partnership with Colombian utilities Codensa and Emgesa, civil society groups, and local taxi companies. The pilot project began by testing Mitsubishi i-MiEV and BYD e6 vehicles. The BYD e6 won the final concession for the 43 electric taxis currently operating in the city. The operational results of these taxis have been positive: recharging infrastructure was created for 350 EVs and owners can use a mobile app to facilitate the recharging.[36] Bogotá has pledged to convert 50% of its taxi fleet (1,000 taxis) to EVs in the next 10 years.[37]

In October 2017, Colombia's first EV pilot program for the public sector was launched by the Ministry of Mines and Energy and the Mining and Energy Planning Unit. The government will help formulate projections using different vehicle brands such as BYD, Nissan, Renault, BMW, and Kia, and will provide financial models that demonstrate the

FIGURE 5: EV SALES IN COLOMBIA

Source: ANDEMOS



benefits of electric mobility over conventional technology. In total, the Ministry of Mines and Energy foresees 400,000 EVs coming into the market during the next decade.[38]

The city of Bogotá has also granted nonfinancial benefits to EV drivers. EVs are exempt from vehicle restriction measures in the city such as "pico y placa," which limits the number of days a vehicle can circulate. Electric cars also have special parking permission.

Finally, the growth in charging infrastructure, though still inadequate, has helped facilitate the use of EVs. Although EVs have been in circulation since 2012, the first public charging station opened in Bogotá in March 2015. Installing the necessary infrastructure for home charging is expensive, costing around $1,000. Today, there are 10 public charging stations and 238 charging points in Bogotá, with 150 of these located in private homes.[39]

Although national and city governments have made progress in promoting the adoption of EVs, obstacles remain, including the high upfront costs of EVs compared to conventional vehicles and insufficient public charging infrastructure. Colombia's Green Growth Commission also identifies the lack of specific electric mobility policies, effective allocation of incentives, coordination between national and local policies, regulations and standards for charging stations, and equipment certification schemes as barriers.[40]

Conclusions

After a relatively slow yet pioneering start in 2012, Colombia's market for EVs is now growing steadily. In 2012 just 33 EVs were sold while in 2018 sales will surpass 600 units.

Colombia provides a good example of how local and central governments, alongside private actors, can work together to provide incentives to promote EVs. Financial incentives have played an important role in helping to reduce upfront costs. In particular, the 2017 launch of a 0% import tariff for electric vehicles for the next decade sent a robust signal to EV car manufacturers and consumers that Colombia is backing electric mobility. The adoption of the Low Emission Development Strategy led to the launch of Latin America's first electric vehicle taxi fleets and an important demonstration of the new technology in action. This year, the expected passage of a new law to incentivize EVs in Colombia could help boost their adoption. Colombia's Green Growth Commission goal of reaching 600,000 EVs on the streets is ambitious yet captures this growing effort. There is significant potential for further expansion as new policies are implemented. The commission has called for the government to generate exclusive quotas for electric taxis and issue technical regulations for private charging points, as well as additional financial and nonfinancial incentives for consumers, which could kick EV adoption into a higher gear.

MEXICO CITY, MEXICO

Mexico has introduced a variety of policies in recent years to promote renewable energy and clean transport. In 2014, the country implemented a carbon tax set at approximately at $3.5 per ton of CO_2 equivalent, differentiated by fuel type. A voluntary emissions trading scheme is set to formally begin in 2021.[41] In 2015, Mexico passed the Energy Transition Law, which includes specific targets for renewable energy generation and creates a wholesale market where bidders can compete for renewable energy supply contracts. Despite extremely rapid growth in recent years, renewable energy still represents only a quarter of installed power capacity, with the remainder coming from coal, oil, and natural gas.[42]

Transport is a critical sector for Mexico to achieve its climate change mitigation goals. The country's largest source of CO_2 emissions is transport, followed by power generation. While Mexico's NDC does not directly make reference to electric transportation, it includes targets to reduce black carbon, of which transport is one of the main sources. Vehicle ownership in Mexico doubled from 2000 to 2010,[43] largely due to subsidized gasoline and increasing purchasing power among the middle class.[44] At the national and state level, Mexico has some important incentives for EVs. Since 2015, EVs have not paid the federal tax on new vehicles. This exemption also applies to hybrids and fuel cell electric vehicles. However, any type of car that costs less than 229,360 pesos (roughly $12,100) is also exempt, meaning that cheaper, less fuel-

Vehicle ownership in Mexico doubled from 2000 to 2010, largely due to subsidized gasoline and increasing purchasing power among the middle class.

efficient vehicles also receive this benefit.[45] In Mexico City, EVs are exempt from the yearly circulation fee for the first five years and pay 50% of the fee for the next five.

In March 2016, an initiative was launched to generate additional tax incentives for EVs. Initially, EVs enjoy exemptions from VAT payments, among other benefits, with a preference for vehicles assembled in Mexico. To avoid deterring potential purchasers of EVs due to the country's high electricity costs, Mexico's Federal Electricity Commission (CFE) has introduced a free scheme to install separate residential electric meters for slow EV chargers. In Mexico, electricity tariffs are calculated on a sliding scale, with higher users paying a higher rate for their power. Under the scheme, use of an EV charger will not push a user into a higher rate bracket, which would create a disincentive to EVs through higher electricity costs.

Spurred by these incentives, Mexico's EV market is gradually progressing. The country's electric car stock was 920 in 2017, a market share of 0.02%.[46] The Mexican Automobile Industry Association reports that from January through April of 2018, 4,946 hybrid and electric vehicles were sold, with roughly 35% of sales occurring in Mexico City. However, only 68 EVs were sold compared to 4,878 conventional hybrids.[47] In comparison, during the same period, over 350,000 vehicles were sold nationally. In a recent development that is helping to boost market penetration, a wide variety of EVs have recently come to Mexico (see Figure 6), including the Nissan LEAF, Renault Twizy, BMW i3 and i8, and the Chevrolet Bolt and Volt. Mexico is currently the only country in Latin America in which Tesla distributes both its Model S and Model X. In May 2018, Zacua became the first 100% Mexican-owned company to manufacture electric cars in Mexico after opening a plant in Puebla.[48]

By far the most relevant region in the discussion about EVs in Mexico is the nation's capital. With a population of over 21 million, the metropolitan area of Mexico City faces acute transport challnges. Mexico City has experienced a significant increase in motorization[49] and is one of

FIGURE 6: SAMPLE OF EV MODELS AVAILABLE BY COUNTRY

Source: Automakers' websites as of August 2018

	COLOMBIA	MEXICO	CHILE
HYUNDAI IONIQ EV			✓
NISSAN LEAF	✓	✓	
BMW i3	✓	✓	✓
BMW i8	✓	✓	✓
RENAULT ZOE	✓		
RENAULT KANGOO ZE	✓		
RENAULT TWIZY	✓	✓	
CITROËN E-BERLINGO			✓
MITSUBISHI i-MiEV	✓		
MITSUBISHI OUTLANDER PHEV	✓		✓
TESLA MODEL S		✓	
TESLA MODEL X		✓	
CHEVROLET VOLT		✓	
CHEVROLET BOLT EV		✓	
ZACUA M2		✓	
ZACUA M3		✓	
KIA SOUL EV	✓		

the most congested cities in the world.[50] An estimated 4.5 million people commute daily into the city from the metropolitan area. This daily influx increases the demand on public transport, which carries over 10 million people per day.[51]

While air quality is improving, Mexico City experiences regular episodes of dangerous pollution.[52] It is estimated that if the WHO recommendations for air quality were achieved, more than 1,400 deaths could be avoided in the city each year.[53]

To actively tackle air pollution and climate change, Mexico City is working to expand low emission transport options. The city's ProAire program, launched in 1990, aims to reduce industrial and automobile emissions and contain urban sprawl.[54] Its 2013-2018 Comprehensive Mobility Program calls for the first "Green Corridor" in the city through the deployment of 100 new electric buses and 22 kilometers of new bicycle lanes.[55] The 2014-2020 Mexico City Climate Action Program pledged to reduce emissions from transport by 3.9% by 2020.[56] In March 2015, Mexico City joined other cities in signing the C40 Clean Bus Declaration, which aims to incorporate low- and zero-emission buses into their fleets.[57] Mexico City also signed the C40 Fossil-Fuel-Free Streets Declaration, pledging to procure only zero-emission buses from 2025 onwards.[58] In 2016, Mexico City and Paris were the first cities to announce restrictions for diesel vehicles as soon as 2025.

Partnerships between the local government and companies to introduce EV fleets and build public charging infrastructure have helped to boost Mexico City's EV market. In October 2009, Nissan reached an agreement with the Mexico City government for the purchase of 500 LEAFs to be used by government and corporate fleets. In exchange, recharging infrastructure was to be deployed by city authorities.[59] After delays, in July 2015 the Zero-Emissions Taxi pilot program was launched, introducing 20 Nissan LEAF electric taxis. These have carried more than 70,000 users in over 36,000 trips, avoiding the emission of 22.48 tons of CO_2 equivalent.[60] In January 2015, the first public EV charging stations were opened at four Walmart stores in Mexico City and the surrounding State of Mexico through an alliance between BMW Group, Schneider Electric, Walmart, and the CFE. Public charging points are currently free as automakers and businesses attempt to encourage EV adoption until services can be commercialized.

Charging infrastructure is now fairly extensive—the country had 1,528 publicly accessible chargers in 2017, including 42 fast chargers.[61] To date, Tesla has installed the vast majority of public chargers. One out of three of these chargers is compatible with other EV models. Tesla has struck deals with shopping centers and hotels by offering free charger installation with the condition of allowing two out of three chargers to be exclusively for Tesla drivers.[62]

Mexico City has also encouraged EV uptake through nonfinancial incentives like exempting hybrids and EVs for eight years from "Hoy No Circula," a program that includes restrictions on driving. Studies show that the program largely failed to deter congestion because many people bought second cars, but the impact of these incentives on EV ownership is still unclear. As of 2017, hybrid and EV owners are also eligible for a permanent 20% discount on three urban toll roads in Mexico City.[63]

Though all these programs may help encourage EV purchases, the principal challenge to greater adoption of EVs in Mexico City is hefty price tags. EVs compete in the Mexican luxury car segment, meaning most drivers are priced out. The financial incentives to support EV adoption remain insufficient when considering high upfront costs.

The lack of incentives for EVs is compounded by the slow modernization of the vehicle fleet and large market for secondhand vehicles imported from the United States and Canada. The relatively low price of gasoline and lofty electricity rates (especially for high users, despite separate metering for EVs) may also deter consumers from purchasing EVs. Mexico's effective tax rates on diesel and gasoline use remain among the lowest in the OECD.[64] Gasoline prices in Mexico recently rose after domestic prices were liberalized under the energy reform and global oil prices increased. This may have helped to increase the sale of hybrid vehicles but it was

Partnerships between the local government and companies to introduce EV fleets and build public charging infrastructure have helped to boost Mexico City's EV market.

Mexico City, a market which represents around one third of national hybrid and EV sales, is a good place to start expanding clean transport policies.

likely insufficient to persuade consumers to opt for EVs, especially when factoring in their high cost.

In addition to incentives for consumers, stronger fuel-efficiency and vehicle emissions standards will also be necessary to obligate carmakers to produce more efficient vehicles. Mexico's EV market has great potential but may continue to grow slowly if fuel taxes and efficiency standards remain low or incoming president Andrés Manuel López Obrador follows through on his plans to freeze fuel prices.

Conclusions

At the end of 2017, Mexico was Latin America's largest EV market. However, given the size of its vehicle fleet, Mexico still has tremendous potential—and need—to further increase the use of EVs and other clean transportation options. Although its total vehicle fleet is eight times larger than that of Colombia, the two countries have EV fleets of roughly the same size. And despite the availability of various EV models in Mexico, sales of hybrid vehicles are much larger than those of EVs. This reflects the fact that most of the incentives for EVs also apply to hybrid vehicles, which are cheaper.

Mexico City, a market which represents around one third of national hybrid and EV sales, is a good place to start expanding clean transport policies. In Mexico City, financial and nonfinancial incentives have been combined with various government and taxi fleet programs to encourage EV adoption. In addition, the number of charging points has increased thanks mainly to efforts by automakers and other private companies.

Going forward, Mexico could consider the introduction of further incentives to expand the EV market. As the overall environmental benefits of hybrids are weaker than those of EVs, the government could further increase incentives for EVs. The federal tax on new vehicles could be differentiated on the basis of the vehicle's emissions characteristics rather than its price.[65] Increasing nonfinancial incentives, such as EV access to preferential vehicle lanes and parking, could also support further adoption. The Hoy No Circula system could be complemented, and potentially replaced, by a city-wide low-emissions zone using the existing vehicle inspection, classification, and identification system. This approach could have a greater potential for reducing emissions since the incentives for using cleaner vehicles and switching to other modes of transport would apply every day.[66]

Advancing EV adoption could be part of Mexico's strategy to modernize its vehicle fleet and ensure that its large auto industry remains competitive.[67] Mexico's position as both a large vehicle market and a global vehicle manufacturing hub gives automakers a strong incentive to bring a wider range of EV models to the country. For example, Audi plans to make an electric version of its Q5 midsize SUV at its new plant in Mexico while a new BMW plant in San Luis Potosí will also be able to produce EVs.[68] As companies increasingly focus on electric mobility, Mexico is well-positioned to capitalize on this transition.

SANTIAGO, CHILE

Chile boasts one of the region's largest electric car markets, having promoted electric mobility for nearly a decade. Yet transport sector emissions have increased rapidly in recent years amid a boom in the number of cars and other vehicles on the road. This year, vehicle sales could reach around 400,000, making Chile one of the most motorized countries in the region at 3.8 people per vehicle.[69] Chile's transport sector makes up 22% of the country's total GHG emissions, which are projected to have grown by 40% between 2010 and 2020 under a business-as-usual scenario.[70] The country is aiming to increase renewable energy generation in order to cut emissions and reduce its reliance on oil, 95% of which is imported. Chile aims to source 60% of its electricity from renewable energy by 2035 and 70% by 2050, up from 40% today.[71] In addition, air pollution has been identified as a major environmental concern, annually costing the health sector at least $670 million and causing more than 4,000 premature deaths.[72] In winter months air pollution in Santiago is almost three times higher than the safe level of exposure to particulate matter recommended by the WHO.[73]

To address these concerns, the national government has promoted electric mobility. In 2011, President Sebastián Piñera inaugurated Latin America's first public EV charging station in Santiago. Part of a Nationally Appropriate Mitigation Action (NAMA) designed to support Chile's goal of reducing emissions by 20% by 2020 focuses on sustainable transport. The Chilean government has reduced pollution by imposing more stringent vehicle standards and tax incentives for lower-emission vehicles. Chile is the only country in Latin America that has adopted the Euro VI emissions standard, the highest of the European standards. In December 2014, a tax on new vehicles was imposed based on performance and NO_x, SO_x, and PM emissions. It taxes the sale of lightweight vehicles according to vehicle performance and fuel efficiency, with lower taxes for more efficient cars. This "green vehicle" tax does not apply to EVs, replacing that revenue by placing a higher tax on diesel vehicles and the SUV segment, which has seen a sharp drop in sales.

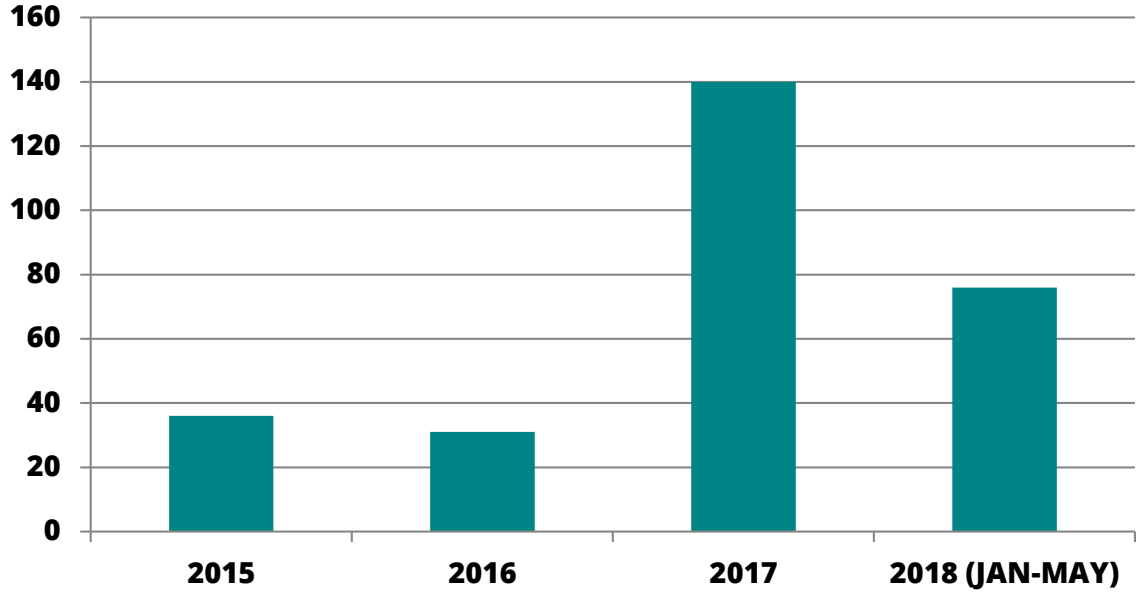
In 2017, Chile launched a groundbreaking National Electric Mobility Strategy, which aims to spur EVs in order to reduce emissions, save energy, and make the transportation sector more competitive. The strategy seeks to transition to a 100% electric public transport fleet and a private vehicle fleet made up of 40% electric vehicles by 2050. Chile expects its public, private, and commercial fleet of EVs to reach 5 million units by midcentury. It is projected that the deployment of electric vehicles will avoid 11 million tons of CO_2 per year and reduce energy expenditure by more than $3.3 billion per year, equivalent to about 1.5% of GDP in 2016.[74] While it may be premature to quantify the strategy's impact on Chile's EV adoption, the initial signs are promising, with various actors pledging to support its implementation. For example, BancoEstado has committed to providing preferential finance to support electric mobility and the Centro Mario Molina, an environmental organization, will create an innovation platform focusing on electric mobility to facilitate access to the best technical information.

Chile's "green vehicle" tax does not apply to EVs, replacing that revenue by placing a higher tax on diesel vehicles and the SUV segment, which has seen a sharp drop in sales.

The Metropolitan Region of Santiago, with a population of 6.5 million inhabitants, represents the epicenter of electric mobility in Chile. There are approximately 300 EVs and PHEVs in Chile out of a total fleet of over 4 million cars

FIGURE 7: BEV AND PHEV SALES IN CHILE

Source: Asociación Nacional Automotriz de Chile (ANAC)



Enel Chile's corporate fleet program included a financing plan for the purchase of electric cars, free charging in the corporate building, installation of a home charger, and maintenance.

as of 2018.[75] Over the last couple of years sales of EVs have jumped (see Figure 7). According to Chile's National Automobile Association, from January to June of 2018, 76 electric vehicles (62 pure EVs and 14 PHEVs) were sold in Chile compared with 428 hybrid vehicles out of roughly 200,000 new vehicles in total.[76]

The introduction of electric taxi, corporate, and government fleets has significantly increased the number of EVs in Santiago. For example, Chile's Ministry of Transport and Telecommunications has enacted a program to subsidize the renovation of the taxi fleet. The level of subsidy is proportional to the energy efficiency of the replacement vehicle. The subsidy is funded by taxes on polluting vehicles under the green vehicle tax scheme. By August 2018, Santiago had 60 additional electric taxis on the streets.[77] In 2017, Enel Chile bought 30 EVs for its corporate fleet. Its program included a financing plan for the purchase of electric cars, free charging at the corporate building, installation of a charger at home, and maintenance throughout the term of the plan.

Financial incentives, though limited, have also spurred sales. Electric cars are exempt from green vehicle taxes and an annual vehicle registration fee for a period of 4 years. EVs are also exempt from Santiago's circulation restriction, which prevents vehicles from circulating two days per week. Enel Distribution, which is Santiago's electricity utility, has a 30% discount for owners of EVs who are able to charge their vehicles at night.
City-level plans have further promoted EV markets within Santiago. The Santiago Transportation Green Zone NAMA aims to promote low-carbon transport. As of 2016, progress included the addition of three electric taxis and the implementation of a public bicycle system. The NAMA

FIGURE 8: BENCHMARKING EV CONDITIONS BY COUNTRY

Source: Authors' calculations. *Fossil fuels account for <50% of energy matrix †Refers to charging infrastructure in capital cities

	COLOMBIA	MEXICO	CHILE	BRAZIL
LOW-CARBON POWER GENERATION*	✓			✓
NATIONAL ELECTRIC MOBILITY STRATEGY			✓	
LACK OF FUEL SUBSIDIES			✓	✓
ROAD ACCESS INCENTIVES	✓	✓	✓	✓
FINANCIAL & TAXATION SUPPORT POLICIES	✓	✓	✓	
ADEQUATE PUBLIC CHARGING INFRASTRUCTURE†		✓	✓	
ELECTRICITY INCENTIVES		✓		
VEHICLE FUEL ECONOMY/CO_2 EMISSIONS REGULATION		✓	✓	

is expected to be scaled up to Greater Santiago and completed by 2022. This date is contingent on the renewal of Transantiago contracts to incorporate low-emission buses (discussed in a subsequent section). In May 2018, the Metropolitan Region of Santiago's Atmospheric Decontamination and Prevention Plan entered into force with the aim to reduce PM emissions by 60%.[78] The plan calls for the Ministry of Finance to establish by May 2019 a strategy to generate incentives for the purchase of zero- or low-emission vehicles.[79] It also requires the construction of 60 kilometers of exclusive bus lines in areas covered by Transantiago, South America's largest integrated public transport system.

Finally, widespread availability of charging infrastructure has also encouraged EV adoption. In Santiago, there are 25 free public chargers which include half a dozen direct current (DC) fast chargers. The chargers were installed by a variety of energy companies and private sector actors including BMW. Enel Distribution has installed 27 charging points across 14 municipalities in Chile.[80] Within the city there are a sufficient number of chargers, since most vehicles are driven daily distances easily serviceable by EVs on a single charge. EV owners also have the option to charge their vehicles at home, facilitated in Chile by the residential availability of 220 volt single-phase power.

All of these efforts considered, one of the biggest obstacles to broader EV adoption in Chile is the vehicles' prohibitive price. An electric car in Chile costs approximately $15,000 more than a similar-sized internal combustion engine vehicle. In an encouraging move, Renault decided to reduce the price of its Fluence ZE by 50% from 26 million pesos (around $40,000) to 13 million pesos (around $20,000).[81]

Still, the incentive structure in Chile is not attractive enough to shift most consumers away from conventional vehicles. The number of electric models available in Chile is also quite low, a feature of the market that is hampering EV adoption. In 2017, the Hyundai Ioniq was Chile's best-selling EV. The Nissan LEAF is currently available only for purchasing fleets, while the Chevrolet Volt and Bolt are currently not available for retail in Chile. The absence of the Chevrolet Bolt and Nissan LEAF is notable given their popularity in other markets.

Conclusions

The adoption of EVs in Santiago is advancing rapidly, as demonstrated by the impressive sales so far in 2018. The creation of a taxi pilot program and purchasing of government and corporate fleets, the introduction of financial and nonfinancial incentives, and the widespread availability of public and private charging infrastructure in the capital all appear to play a role.

Chile's approach to financial incentives focuses more on improving fuel-efficiency standards and taxing dirty vehicles than on directly incentivizing EVs, with the exception of the program to support electric taxis, which is partly funded by the green vehicle tax. The introduction of the tax in 2014 has played a key role in reducing pollution and leveling the playing field for EVs. Chile's progress on developing a policy framework for greater EV adoption, primarily through the National Strategy on Electric Mobility, is also bearing fruit.

Going forward, Chile could build on the policies that have worked by strengthening green vehicle taxes to modernize the overall vehicle fleet, expanding public-private partnerships to build charging infrastructure, and prioritizing the electrification of taxis, corporate, and public fleets. Financial incentives would likely be most effective in promoting EV adoption by lowering upfront costs. There is also an expectation that the market will continue to help bring down EV costs, as has been the case with the remarkable drop in the price of renewable energy.

Finally, the adoption of EVs in Chile has the potential to be part of a broader ecosystem of electric mobility, drawing support from renewable energy and the development of international supply chains for batteries (underpinned by the development of Chile's lithium, copper, and cobalt reserves). Chile is well-positioned to establish itself as a regional and global hub of electric mobility innovation if it capitalizes on these advantages.

Widespread availability of charging infrastructure has encouraged EV adoption. In Santiago there are 25 free public chargers, including half a dozen direct current (DC) fast chargers.

Electric Bus Case Studies

The following sections examine developments in the electric bus markets of Santiago, Chile, and of São Paulo and Campinas, Brazil, and analyze the policies that have had the greatest impact on market expansion.

SANTIAGO, CHILE

Although Santiago's current electric bus fleet is tiny, with only two e-buses in circulation, this figure is set to expand drastically in 2018 thanks to two key developments: a major tender process being carried out by national authorities and a groundbreaking partnership between Enel, a global energy company, and BYD, a Chinese maker of electric cars and buses.

In September 2017, the government of President Michelle Bachelet announced a tender for the renewal of 3,000 buses, nearly 50% of the Transantiago fleet. In a decision informed by Chile's National Electric Mobility Strategy,[82] the government stated that the tender should include 90 electric buses with the remainder of the new buses held to Euro VI emissions standards.[83] In March 2018, Chile's new Minister of Transport and Telecommunications, Gloria Hutt, cancelled the Transantiago tender due to perceived increases in the costs of the system and announced that the process would restart under the new administration of President Sebastián Piñera.[84] Critics of the move countered that the decision would cause delays to the entry of new buses and incur additional costs from starting the process anew. However, the new version will likely be even more favorable to electric buses.[83]

Under the revised rules, expected to be published in late 2018, bus maintenance and operations will be awarded under separate contracts from the ownership of buses, which will mean the tendering of smaller units and shorter contracts that are solely for maintenance and operation. In the event that an operator cannot comply with its contract terms, the operator can be replaced and the contract transferred to another operator, since the buses will be located in the central system.[86] Under the new bidding process, bus companies will receive most of their payments based on the number of passengers transported rather than how far the bus travels, which could give an edge to electric buses.[87]

Although Santiago currently has only two electric buses in circulation, this figure is set to expand drastically in 2018.

There is also a separate process underway to procure an additional 100 electric buses by the end of 2018 and possibly early 2019. Several companies are negotiating the contract, including Vule and Yutong.

While the initial tender was being developed, an important market breakthrough was taking shape. In 2016, a global framework cooperation agreement was signed between Enel and BYD to explore the development of joint projects in electric mobility and energy storage. The agreement paved the way for cooperation projects to jointly offer electric buses and other transport services to interested municipalities. In November 2017, a pilot program was started which sought to test the suitability and performance of two battery electric buses in the Transantiago system. The buses were purchased by Enel Distribution from BYD and leased to Metbus, which provides regular bus services for Transantiago. The K9FE 81-passenger buses are equipped with air conditioning, Wi-Fi, USB charging outlets and a secure separate cabin for drivers.

The pilot program successfully demonstrated to bus operators and city authorities that electric bus technology lowers operating costs. The buses are said to cut operating costs by roughly 70%, consuming around 70 pesos (around $0.11) per kilometer driven, compared to 300 pesos (around $0.47) for diesel vehicles. The buses can cover up to 250 kilometers on a charge that takes less than three hours. A survey found that passengers spoke favorably of the electric buses due to the quieter and smoother ride and the contribution to improving air quality.[88] The buses were kept clean and fare evasion, which has plagued the Transantiago system, was reduced.

Following the successful pilot program, the bus operator, Metbus, partnered with Enel Distribution and Sonda (a company that operates bus payment system technology) to replace 100 of its old buses with electric buses from BYD. Enel Distribution is playing a key role in providing the financing. The company will invest $30 million to purchase the buses and lease them to Metbus. The electric buses can cost up to two to three times more than a conventional diesel bus. However, with much lower operating costs and a lifespan of 14 years versus

10 for a conventional bus, the initial investment is seen as justified.[89] Enel is also providing financing to bus operators for electricity and charging infrastructure, as well as upgrading two bus depots to install the charging infrastructure for the new buses. The 100 electric buses are expected to operate along "electric corridors," along which 60% of passengers commute daily, before the end of 2018.

Conclusions

The main drivers behind Santiago's push for electric buses were high levels of pollution, poor quality of service on Transantiago's bus systems, and Chile's NDC and National Strategy on Electric Mobility.

Recent developments in Santiago's e-bus market attest to the value of pilot projects that demonstrate the technical and economic viability of electric bus technologies. The pilot program orchestrated by Enel Distribution, Metbus, and BYD in 2017 helped build confidence in the technology. The new electric buses will serve as an additional trial run on a larger scale, which could inform the design of the city's new bus tender.

The case of Santiago also highlights how private companies can take the lead in encouraging governments to embrace electric mobility. The agreement signed between Enel and BYD in 2016 to explore the development of joint projects in electric mobility played a key role in establishing the pilot program to test the two BYD buses, which led to plans to introduce a further 100 electric buses.

The arrival of the new electric buses is only the start of Chile's ambitious plans to gradually expand electric buses into the transportation system in the next few years. Chile aims to deliver 1,500 electric buses by 2025, which would represent more than 25% of the Transantiago fleet,[90] and to create a 100% electric public transport fleet by 2050. If the bus tender to be announced this year is successful, it will help to ensure that these goals are realized.

SÃO PAULO, BRAZIL

Brazil is one of the world's top vehicle markets and accounts for over half of all vehicles sold in Latin America.[91] The country could greatly benefit from expanding its electric bus fleets as it confronts inadequate public transportation systems, growing transport emissions, and deadly air pollution. After a slump due to an economic downturn, the light duty vehicle fleet is again expanding rapidly[92] and is expected to reach 43.19 million by 2027.[93] Owing to this boom in private car ownership, congestion has become a significant problem, and many cities are looking to improve their public transportation systems. In São Paulo, daily traffic jams reaching more than 350 km are estimated to cost $120 billion (nearly 8% of urban GDP) each year in lost work hours, increased fuel consumption, and traffic accidents.[94]

The inadequacy of Brazil's public transportation system, which is mostly comprised of privately owned bus fleets, is one impetus for the expansion of electric buses. In the last 15 years, Brazilian public transport ridership dropped 15% while the car fleet nearly tripled and the motorcycle fleet grew five-fold.[95] This decrease occurred due to poor service and a preference for private car ownership, among other factors. In June 2013, after the mayor of São Paulo announced bus and metro fare hikes, protests spread across Brazil. Protesters deemed the proposed increases unacceptable given poor and often overcrowded public transport systems.

The inadequacy of Brazil's public transportation system, which is mostly comprised of privately owned bus fleets, is one impetus for the expansion of electric buses.

Brazil has also been motivated to introduce electric buses by the desire to tackle air pollution and climate change. Air pollution in Brazilian cities poses significant risks to human health. In 2015, 52,284 deaths in Brazil were attributable to exposure to PM2.5.[96] In São Paulo, PM2.5 concentrations exceed the guidelines of the WHO by 60%.[97] At the same time, transportation is the largest energy-related emissions source,[98] despite the near ubiquitous use of ethanol in passenger cars (flex-fuel vehicles, which can run on pure ethanol, a gasoline-ethanol blend, or any mixture of both, account for more than 90% of passenger vehicle sales in Brazil). In its NDC the Brazilian government highlights the need to improve public transportation.

São Paulo was one of the first cities in the developing world to implement a plan to fight climate change.

Electrifying the transportation sector would bring particularly significant benefits in greenhouse gas reductions since Brazil's extensive use of hydropower grants it one of the cleanest electricity matrices in the world. Brazil is among the world's largest markets for wind and solar PV.[99] The country plans to achieve a ratio of 45% of renewables in the energy mix by 2030.

Despite their potential advantages, electric passenger cars remain limited in Brazil. In 2017 there were just 680, a market share of 0.02%.[100] One barrier is stiff competition from the powerful ethanol industry. In 2017, Brazil passed a new law to further increase the use of biofuels based on emissions reduction certificates, which is set to begin in 2020.[101] Brazil also faces the typical obstacles to widespread EV adoption such as high costs and insufficient incentives provided by the government. Nevertheless, developments in urban electric bus markets are very promising. Cities like São Paulo and Campinas have introduced climate change policies and specific targets for electric bus expansion. Several electric buses are already on the road in these cities demonstrating the promising technology. In the case of Campinas, the decision by BYD to build a local factory has enhanced the company's ability to compete with diesel-powered and hybrid buses.

With a population of 21.1 million, São Paulo is Brazil's largest city. It has one of the largest bus systems in the region, including a fleet of over 16,000 buses. Nearly all bus lines are operated by concessionaires under the planning and management supervision of the public company São Paulo Transportes (SPTrans).

São Paulo was one of the first cities in the developing world to implement a plan to fight climate change. In 2009, the city council unanimously approved Law 14.933, which aimed to reduce São Paulo's emissions by 30% of 2005 levels by 2012 through measures focused on transportation, renewable energy, energy efficiency, waste management, construction, and land use. Measures to implement São Paulo's Climate Change Law, including the introduction of a new generation of 140 electric trolleybuses, are driving an increase in the use of public bus transport by residents.[102]

The city's anti-climate change efforts include a goal to transition the entire municipal bus fleet to renewable fuels and phase out fossil fuel-powered buses. In 2011, SPTrans implemented an "Ecofleet" program to begin testing and incorporating different sustainable technologies, including hybrid and electric vehicles, into its fleet.[103] Two years later, SPTrans conducted a pilot program, which concluded

FIGURE 9: TARGETS OF NATIONALLY DETERMINED CONTRIBUTIONS UNDER PARIS AGREEMENT

Source: United Nations Framework Convention on Climate Change (UNFCCC), Climatescope

	UNCONDITIONAL TARGET	CONDITIONAL TARGET
COLOMBIA	Reduce emissions by 20% relative to the business-as-usual (BAU) scenario by 2030.	Reduce emissions by 30% relative to BAU scenario by 2030. Conditional on the provision of international support.
MEXICO	Reduce combined greenhouse gas (GHG) and black carbon emissions by 25% relative to BAU scenario by 2030.	Reduce combined GHG and black carbon emissions by 40% relative to BAU scenario by 2030. Conditional on access to financial resources and technology transfer.
CHILE	Reduce emission intensity of GDP by 30% relative to 2007 levels by 2030 (excluding land use, land-use change, and forestry (LULUCF)).	Reduce emission intensity of GDP by 35-45% relative to 2007 levels by 2030. Dependent on international financial support.
BRAZIL	Reduce emissions by 37% by 2025 and 43% by 2030 relative to 2005 levels.	No conditional target. Welcomes additional support from developed countries.

that a battery electric bus was effective on roughly 80% of routes currently in operation. With an overnight charge (conducted off-peak), the bus has the autonomy to travel up to 250 kilometers.[104]

São Paulo's early efforts to fight climate change have coincided with efforts to improve public transportation, a top priority when the former Mayor Fernando Haddad took office in January 2013. The "Give Priority to Buses" program was launched early that year to deliver 220 kilometers of bus lines in 4 years. Within 11 months, Haddad's administration had already created more than 291.4 kilometers of exclusive bus lines, improving the average bus operating speed from 13.8 km/h to 20.4 km/h. The new bus lines have already reduced daily diesel consumption by 8.8%.[105]

Electric bus manufacturers have had to prove the performance of their vehicles in a highly competitive environment. In September 2014, BYD Brazil received the InovaCidade award for demonstrating the technical and economic feasibility in terms of lowering the operational costs of bus fleets compared to conventional buses. According to BYD, its GreenCity electric bus is economical in addition to being zero-emission. In order to travel 1 kilometer, a 12m diesel bus consumes over 0.55 liters of diesel, which costs more than one Brazilian real (about $0.25), while just 0.91-1.2 kWh are required to propel BYD's electric bus the same distance. In São Paulo, the cost of this amount of electricity is about 0.35 reais ($0.09), which implies dramatic savings relative to the diesel bus.[106]

Meanwhile, BYD has negotiated a deal with São Paulo bus operator Ambiental to deliver 60 electric battery buses, which are expected to be delivered this year. This would position São Paulo among the cities with the greatest number of electric buses in Latin America. In addition, BYD has two smaller deals to deliver 10 electric buses to two separate operators by the end of 2018, though the delivery will likely be made in 2019.

Despite some important progress on implementing São Paulo's 2009 Climate Change Plan, Article 50 of the law—which called for a 10% annual reduction in the number of city buses running on fossil fuels, with an ultimate target of a 100% non-fossil fuel fleet by 2018—has not been realized. Today less than 2% of Sao Paulo's fleet runs on non-fossil fuels.[107] In response to this lack of compliance, in January 2018 São Paulo passed Law 16.802 to amend Article 50. The amendment sets ambitious goals to reduce pollutant emissions from the transit bus fleet, establishing 10-year and 20-year fossil CO_2 emissions reduction targets of 50% and 100%, respectively. The law also calls for an 80% reduction in NO_x and 90% reduction in particulate matter within ten years.[108]

The law could help to create a huge market for EVs. These legislative advances are already impacting bus tender processes. Under the new tender, bus operators participating in the bidding process will have to demonstrate how their fleets will be aligned with the law's CO_2 and air pollutant emissions reduction targets.[109] Each bus operator would have to provide a plan on how to deliver those reductions 120 days after signing the contract.

Achieving these targets will require a significant transition to biofuel or battery electric buses. Modelling by the International Council on Clean Transportation suggests that from 2020 to 2027 more than 55% of new buses purchased should be fossil fuel free to meet the 10-year CO_2 target, and that all new buses should be fossil fuel free from 2028 onwards to meet the 20-year target.

While the purchase price of electric buses remains high relative to other technologies, this technology is financially competitive when total cost of ownership is considered.[110] Under the "well-to-wheel" framework (which considers both direct tailpipe GHG emissions and upstream emissions from fuel and feedstock production and transport), battery electric buses clearly offer the greatest potential to reduce the emissions of the São Paulo bus fleet because electric drivetrains are more efficient than internal combustion engines and the Brazilian electricity grid has very low carbon intensity. Well-to-wheel GHG emissions would be cut by about 75% if the current bus fleet were replaced with battery electric buses.[111]

Conclusions

São Paulo's impressive legislative advances on climate change and clean transport and the setting of targets have played a central role in driving the city's progress on adopting electric buses. The leadership of São Paulo's mayors and lawmakers in advancing this agenda has created favorable conditions for strong growth in electric buses.

The 2009 Climate Change Law calling for all city fleets to run on renewable fuels by 2018 may have proved overly ambitious but it set in motion important developments that are beginning to yield results. Complementing the 2009 law, the amendment of Article 50 passed in 2018 to

In 2015, BYD opened its first Latin American factory in Campinas to avoid import tariffs. This move introduced some of the first all-electric buses to the region.

reduce CO_2 emissions and pollutants from São Paulo's bus fleet is likely to provide a major boost to electric buses. Crucially, these legislative efforts combine reductions in CO_2 emissions and air pollution, targets which strongly favor electric buses. The steps being taken to align São Paulo's tender process with the city's climate and pollution laws could prove transformative since bus operators participating in the tender will have to bring their fleets into line with these goals.

Running parallel to these legislative advances, the economic recession and slump in passenger numbers due to poor services and high motorization rates have drawn attention to failing bus operators. The pressure on bus operators and city authorities to improve bus services opened a space for electric bus manufacturers to demonstrate the new technology in terms of performance, lower operating costs, and compatibility with the city's climate and pollution goals. BYD's successful completion of an electric bus pilot program in São Paulo demonstrated that the bus manufacturers could deliver. Furthermore, the company's willingness to loan its electric buses to cities for conducting trial runs has lowered the risk associated with the adoption of the new technology.

CAMPINAS, BRAZIL

Campinas, a mid-sized city of roughly 3.7 million people, currently has one of the largest electric bus fleets in Brazil. In 2015, BYD opened its first Latin American factory in Campinas in order to avoid import tariffs. This move allowed the company to introduce some of the first all-electric buses to Brazil and to the entire region. The factory manufactures and assembles long-range electric buses as well as iron phosphate battery packs. The development injected $65 million into the local economy and created 450 jobs.[112]

Campinas currently has some 15 BYD battery electric buses running in the city, one of the largest fleets in Brazil. BYD also has a pre-contract with two operators for 10 electric buses each. These 20 additional electric buses are expected to take to the streets in early 2019 pending the conclusion of a bus tender which was suspended this year by the State Attorney.[113]

BYD's initial success came after it demonstrated to Campinas bus operators and city authorities the performance of its electric buses during a one-year pilot program. In 2017, the mayor of Campinas, Jonas Donizette, announced that 10% of the city's 1,500 buses must be electric by 2022. In downtown Campinas, an area was designated as the "White Zone," in which it will be mandatory to have electric buses by 2022. This initiative will be incorporated into the bus tender to be completed by the end of 2018.

BYD has been able to break into the local bus industry because of its ability to contain costs and meet local content requirements by centering its production in Brazil. Expanding its presence in Campinas, in 2017, BYD opened a plant for the production of solar modules and chassis for its electric buses. BYD also announced plans to open its first overseas PV research and development center via a partnership with Brazil's Universidade Estadual de Campinas. This development positions BYD to become the first company in Brazil to offer comprehensive zero-emission energy ecosystem technology, integrating solar generation and research, storage, and transportation.

In 2018, the beginning of BYD's chassis production in Campinas coincided with the launch of a new electric bus. The new model was designed in partnership with Brazilian bus and coach manufacturer Marcopolo and utilizes a BYD rolling chassis with a Marcopolo Torino body. The partnership with Marcopolo allows BYD to contribute with its strongest technologies—the powertrain and batteries from its factory in Campinas—without having to construct a local factory to build the entire vehicle. BYD plans to sell its buses at local prices and lease batteries in order to help customers defer the high upfront costs. The battery can be purchased outright for $227,325 or rented for $2,555 per month.[114] The company eventually plans to further increase the proportion of local technology used in production to 70% by 2022 from less than 50% currently.[115]

Steps to reach the local content requirement could open opportunities for preferential funding from the Brazilian Development Bank (BNDES), which could provide low-interest financing or state-backed debt. Given the higher

upfront costs of electric buses compared to conventional buses, preferential financing is crucial to support bus operators and city governments to make the purchases. BYD was previously able to secure a credit line from the China Development Bank for $294 million in 2016 to finance the introduction of electric buses in Brazil.

Although the upfront costs are higher for electric buses, BYD claims that costs for operators will be much lower over the lifespan of the bus, as has been demonstrated in other markets (see Figure 10). Each unit is driven by iron phosphate and lithium batteries and costs 1 million reais (about $250,000) compared to 400,000 reais (about $100,000) for a conventional diesel-powered bus. BYD claims, perhaps optimistically, that the payback period for the higher initial cost will be 10 years, and that its proposal for transport companies will take into account the comparative operational savings along with the cost of purchasing each electric bus. The lifetime of BYD's electric buses, estimated at 20 years, guarantees the operators at least a decade of lower operating costs.[116]

Conclusions

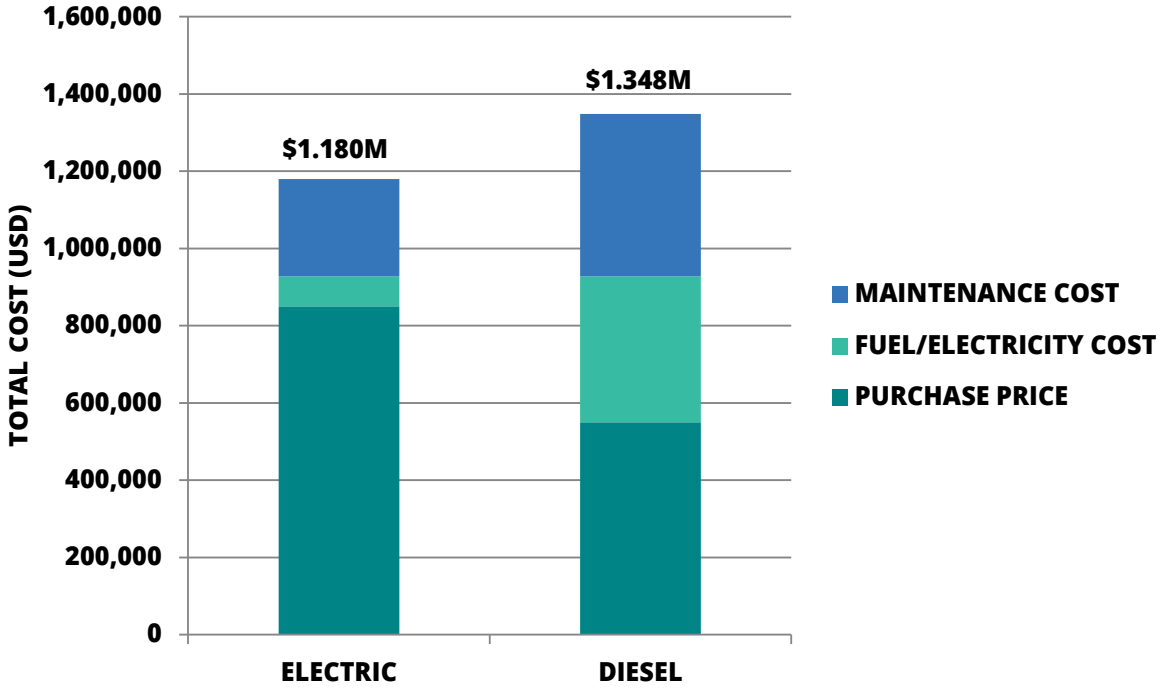
Campinas has one of the largest operating fleets of battery electric buses in Brazil and in Latin America as a whole. The decision to open the first Latin American assembly plant to produce electric buses in the city established a successful model for building electric buses locally at competitive costs.

Local government policy support will give a further push to the e-bus market in Campinas. The announcement in 2017 by Mayor Donizette that 10% of the city's 1,500 buses must be electric by 2022 gives electric bus manufacturers an advantage over their conventional bus and hybrid bus competitors. The decision to create a "white zone" exclusively for electric buses also gives bus and other infrastructure companies a strong signal about the city's policy direction.

However, the suspension of the bus tender by the State Attorney in 2018 has slowed down the delivery of a further 20 electric buses to bus operators. These delays in the tender processes represent one of the key obstacles to the timely deployment of electric buses in Campinas. Still, Campinas's target of electrifying 10% of the city's bus fleet by 2022 is an ambitious goal which could bring major benefits to the city in terms of improving air quality and lowering emissions.

FIGURE 10: LIFETIME COST OF ELECTRIC VS. DIESEL BUSES, NEW YORK CITY

Source: Judah Aber, *Electric Bus Analysis for New York City Transit.* Note: Does not include cost savings associated with health benefits.



LESSONS LEARNED AND RECOMMENDATIONS

Although Latin American EV markets are at an early stage compared to many other regions of the world, several cities have made significant advances. Our case studies showcase a diverse set of experiences from across the region and highlight a range of targets, policy tools, and regulations created to encourage the adoption of electric cars and buses. For the most part it is too soon to measure with accuracy the precise impacts of specific policies on EV uptake. However, the case studies demonstrate trends in successful policy measures and provide lessons learned from the analysis of these unique country experiences.

The case studies consistently demonstrate that city-wide and national efforts to improve air quality and tackle climate change are the primary driving forces behind the growing interest in electric mobility. To a lesser extent, efforts to strengthen energy security by reducing fossil fuel imports, enhance the competitiveness of vehicle fleets, and improve public transport are also playing a role.

Various factors appear to have enabled the growth of electric car markets in the three cities studied. In Bogotá, financial incentives and a growing number of available EV models are spurring EV sales. In Santiago, strong climate change and electric mobility goals are providing long-term direction for markets, while a green vehicle tax is helping to level the playing field for EVs. In Mexico City, a wide range of models and extensive charging infrastructure are available to consumers, though sales of EVs are being overshadowed by those of conventional hybrids, which receive similar fiscal incentives. In all three cities, programs introducing electric taxi, corporate and government fleets have increased the number of EVs on the road, though progress is simultaneously being undermined by the slow modernization of the vehicle fleet.

In our case studies on electric buses, Santiago, São Paulo, and Campinas are advancing impressively to introduce this new technology to city bus fleets. BYD is a leading protagonist in all three cities as it seeks to replicate its astonishing advances in China. City authorities in Brazil and Chile have been aggressively pushing electric mobility as part of new tenders to modernize and improve their fleets. Local governments and bus operators have been impressed with pilot programs testing electric buses in their regular bus operations. Private sector actors, such as Enel Distribution in Chile, have played a key role in supporting the financing of the pilot programs and purchase of new electric bus fleets.

Below we outline four recommendations for Latin American countries to promote electric cars and buses.

STRENGTHEN FINANCIAL INCENTIVES AND STANDARDS FAVORING CLEAN TECHNOLOGIES

Partial incentives are necessary to encourage EV adoption by reducing costs for consumers. While the price of EVs is becoming more competitive with that of conventional vehicles, many consumers are deterred by the high upfront costs, and in most Latin American countries EVs remain more expensive even when considering the total cost of ownership over the life of the vehicle. Financial incentives might include tax reductions for EV purchase and the installation of home charging systems or a tax on higher emissions vehicles. Efforts to improve incentive regimes can also encourage car manufacturers to bring a broader range of EV models to the market. Nonfinancial benefits, such as access to preferential parking and driving lanes and discounts on toll roads, also create incentives to purchase EVs, although it's unclear that road access incentives have influenced the purchase of EVs in Latin American cities, where many drivers simply have a second car to avoid road restrictions.

Various policies that penalize high emissions vehicles, considering their health and environmental costs, can also level the playing field for EVs. Latin American governments should phase out fossil fuel subsidies that favor conventional vehicles and introduce stronger emissions and fuel economy standards to give car manufacturers incentives to invest in EV technology.

EXPAND PROGRAMS FOR ELECTRIFYING HIGH-USE VEHICLES AND FLEETS

Latin American city authorities and EV manufacturers should expand programs that promote electrification of high-use vehicles, especially buses, taxis, and garbage trucks, as well as corporate and government fleets. The electrification of high-use vehicles maximizes the environmental and public health benefits, demonstrates the effectiveness of EV technology to the wider public, and is likely to be the most cost-effective option. Electrifying corporate and government fleets also exposes the technology to the public, creates incentives to accelerate the roll out of charging infrastructure, and can scale up the arrival of more EV models, which can in turn bring down costs.

Starting with pilot programs has proved a successful way to build trust in the technology among city authorities, vehicle operators, and the public before expanding fleets. Comprehensive deals that include maintenance and training by the manufacturers could help operators of buses, taxis, or other vehicles to overcome the risk perceived in adopting new technologies. For urban electric bus programs, given that a major barrier is the upfront cost, the leasing of electric buses, batteries, and electricity and charging infrastructure as part of the pilot program has been shown to encourage participation.

DEVELOP NATIONAL AND MUNICIPAL ELECTRIC MOBILITY STRATEGIES AND LONG-TERM GOALS

Both local and national governments should put policies in place today to promote electric mobility as part of long-term planning to develop renewable energy and sustainable transport systems. Policies to boost electric mobility should be aligned with the Paris Agreement's goal to achieve net zero emissions in the second half of this century. Electric mobility strategies that take into account input from a range of actors, including businesses and consumers, can provide clarity to markets and direction to guide government policy. These strategies should include long-term electric mobility goals with clear mid-term steps. Policymakers should also adopt goals and policies to improve competitiveness among local businesses for EV-related goods and services.

Aligning national climate change and electric mobility goals with concession contracts to acquire new vehicles, such as bus and government fleets, is also vital to ensure that these processes are complementary. New concession contracts should evaluate a broader set of factors beyond the least-cost options, such as the health and environmental impacts of competing technologies. The incorporation of these elements would markedly improve the ability of electric vehicles to compete with incumbent technologies.

CREATE PUBLIC-PRIVATE ALLIANCES

Partnerships between city governments and private utilities, automakers, bus companies, and other private sector actors have accelerated the uptake of electric vehicles in several Latin American cities. For example, public-private partnerships to install charging stations in gasoline stations, parking lots, offices, and shopping centers encourage EV sales.

For cities looking to electrify their bus fleets, bringing together public and private financiers is also vital. Multilateral development banks and public financial institutions can play a transformative role by providing concessional debt, credit guarantees, and seed capital for investment funds aiming to leverage private capital for developing electric bus projects. Connecting public authorities, bus operators, technology providers, and financiers is required early on in the investment process to ensure that the interests of stakeholders are considered.

Civil society and consumers should also be included in partnerships. The creation of alliances of electric mobility champions, including EV owners, advocacy groups, national and local leaders, and car manufacturers, is critical to make the case for incentivizing electric mobility and showcasing the value and potential impact of these technologies.

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