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EV Integration: A Global Challenge Sought To Be Addressed By Many Nations

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Abstract

While EVs have been emerging as a substitute for fossil fuels, certain limitations, such as short-range, slow speed, and apparent un-sustainability, have significantly hindered their integration into public markets. Several nations worldwide have attempted to take different measures to make the prospect of buying an EVmore plausible and efficient to address such shortcomings.

China

China is perhaps the nation with the most radical policies in successfully integratingEVvehicles into the market. The communist state established a policy back in 2012 urging all Chinese vehicle manufacturers to import/manufacture EVs for at least 12% of their entire sales. Likewise, its "十市千车"program (Ten Cities, Thousand vehicles), launched in 2009, also played a significant role in setting the foundation for China's objectives. It helped pinpointten pilot cities as the initial hotspot for EVintroductions, which subsequently launched a total of 10,000 EVs into operation within the next three years. The introduction of such pilot cities was so successful that the number of such pilot cities increased to 25 (**19**).

Public policies

What makes China so flexible in establishing these policies is its centralized leadership and prior market-planning success. The fact that government interference is virtually unlimited allows the government to directly introduce new technologies and develop and refine new business models and markets.

The centralization of significant cities, its constitution of a considerable global market share, and its aggressive investments centered toward further development characterize China's impressive EV policies & market. The 30 cities (including Beijing, Shenzhen, Shanghai, and Guangzhou) comprising the most successful EVdevelopment constitute approximately 84% of the nation's EVmarket (12). China is home to over half of the world's electric vehicles (12). In Beijing, Shanghai, and the Hubei and Guangdong provinces, the government has installed 7,400 fast-charging stations and 2.5 million charging devices in parking lots, apartment buildings, and other car-populated areas. Provincial governments have directly reduced electricity expenses by 30 percent by lowering prices. (18) Additionally, Beijing invested 50 billion dollars in the EVindustry, hoping that EVs would gain superiority over ICEVs (internal combustion-engined vehicles). Teslas account for a tenth of the cars in Shenzhen, the world's first city to establish an electric bus fleet, and the list goes on.

In 2006, the first modern passenger E.V. was developed by BYD. (Build Your Dream), which used $LiFePO_4$ (Lithium iron phosphate) batteries to integrate cathode batteries into the market correctly. The "863 Program"was also launched in 2008 for long-term development and Chinese independence of financial obligations for foreign techniques, further bolstered with the integration of 50 electric buses during the Olympics. In later years, the government took even further measures, offering subsidies for consumers and establishing strict fuel economy and emission standards.

Unintended consequences of global competition

Contrary to mainstream beliefs, however, the initial reason for the rapid expansion of the EVindustry wasn't provoked by a genuine determination to improve the climate nor the environment. Instead, getting Chinese manufacturers to be compatible in the global market was the focus of the early efforts. Companies such as NIO and Geely received substantial government subsidies, which resulted in the expedition of EVsales and productions. They took environmental-related factors as second priorities. Through such rigorous funding, China increased its product sales of EVs in China, from 250,000 units in 2015 to 410,000 units in 2016, to 660,000 units in 2017, showing an annual average growth rate of about 60% (18). The sheer numbers made the 2020 goal of five million EVvehicles seem feasible, coupled with the staggering 85% EV industry growth rate in 2018 (13). The dream value of 80 million EVvehicles by 2030 did not seem so far-fetched.

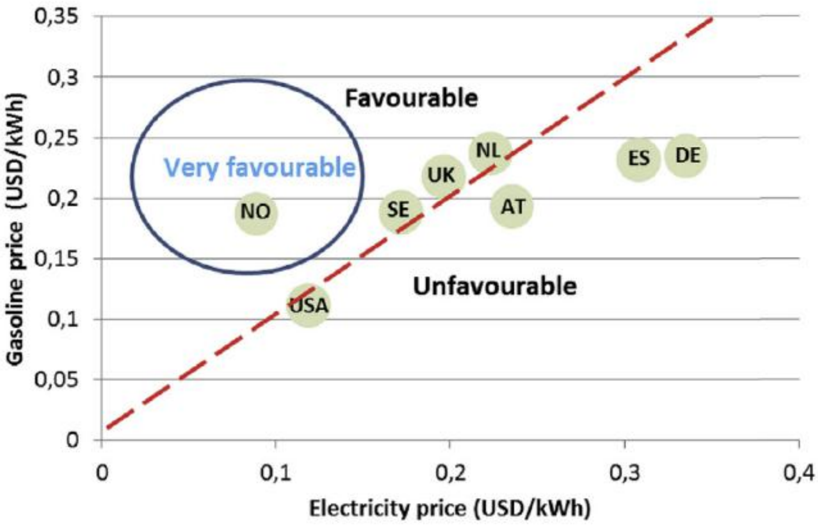
Domestic incentives and COVID-19 Impact

But things became awry last year when the breakneck expansion of the EVmarket made the government unable to deliver financial incentives for buyers. This lack of incentives resulted in a chain reaction of customers losing interest in EVs and EVcompanies having to cut back jobs due to falling revenue. NIO, China's highest-profile EVmanufacturer, proved to be one such victim. As fewer and fewer customers refrained from buying NIO products, this forced the company to cut back 2,000 jobs amidst falling revenues (3). The COVID-19 pandemic served as the KO punch, with overall automobile sales plummeting 79% in February 2020 compared to February 2019 (25). The disease led to stamping out the optimistic predictions of China integrating 5 million EVs into the market. No carmaker was unaffected by the COVID-19 pandemic; as it forced people to stay home, the need for automobiles rapidly diminished.

However, China's economy started to recover in the second quarter of 2020. While the economy experienced a steep slump of 6.8% in the first quarter, it rose by 3.2% by the end of the second quarter. This increase was faster than the predictions made by analysts in a Reuter poll (2.5%), thanks to eased lockdowns and the gradual opening of borders (14).

. China's EVindustry, in particular, seems to be capable of undergoing rapid economic recovery. As of May 2020, the sales of New Energy Vehicles (BEVs, PHEVs, Fuel Cell Electric Vehicles 수소자동차), while being 25.8% lower than May 2019, was still 19.5% higher than April 2020. Chinese EVmanufacturer NIO successfully delivered 3,436 electric cars in May, the highest number of vehicles ever sold in a year (19).
(2)

Incentives and Areas of Improvement for China



Many incentives can enable a customer to switch from ICEVs (Internal Combustion Engine Vehicles) to EVs. An obvious incentive occurs when the gasoline price far exceeds that of electricity. As shown in the graph above, the ratio of gasoline price per kilowatt-hour and electricity price per kilowatt-hour is favourable in nations like Norway, Sweden, and the United Kingdom, where oil prices are high, and electricity prices are low.

On the contrary, unfavourable conditions are prevalent in Austria, Spain, and Germany, where electricity is more expensive than gasoline. China can strive to decrease electricity costs by focusing more of its GDPon making electricity sustainable. More specifically, the nation can dedicate its efforts to changing its electricity-power distribution system from expensive energy originating from a centralized series of electric generators to much cheaper electricity generated through personal utilities, like private solar panels or windmills.

Another unutilized incentive is the environmental impact of EVvehicles. Although China comprises a large portion of the EVmarket, the nation, the UK, and the Netherlands have relatively limited ability to reduce greenhouse gas emissions. A low share of renewable energy sources affects their total electricity mix of EV. While cities like Shanghai have staggering EVfleets that could reduce air pollution, only a higher share of renewable energy sources of electricity will help achieve EVs' environmental benefits.

The United States as a Whole

General Overview

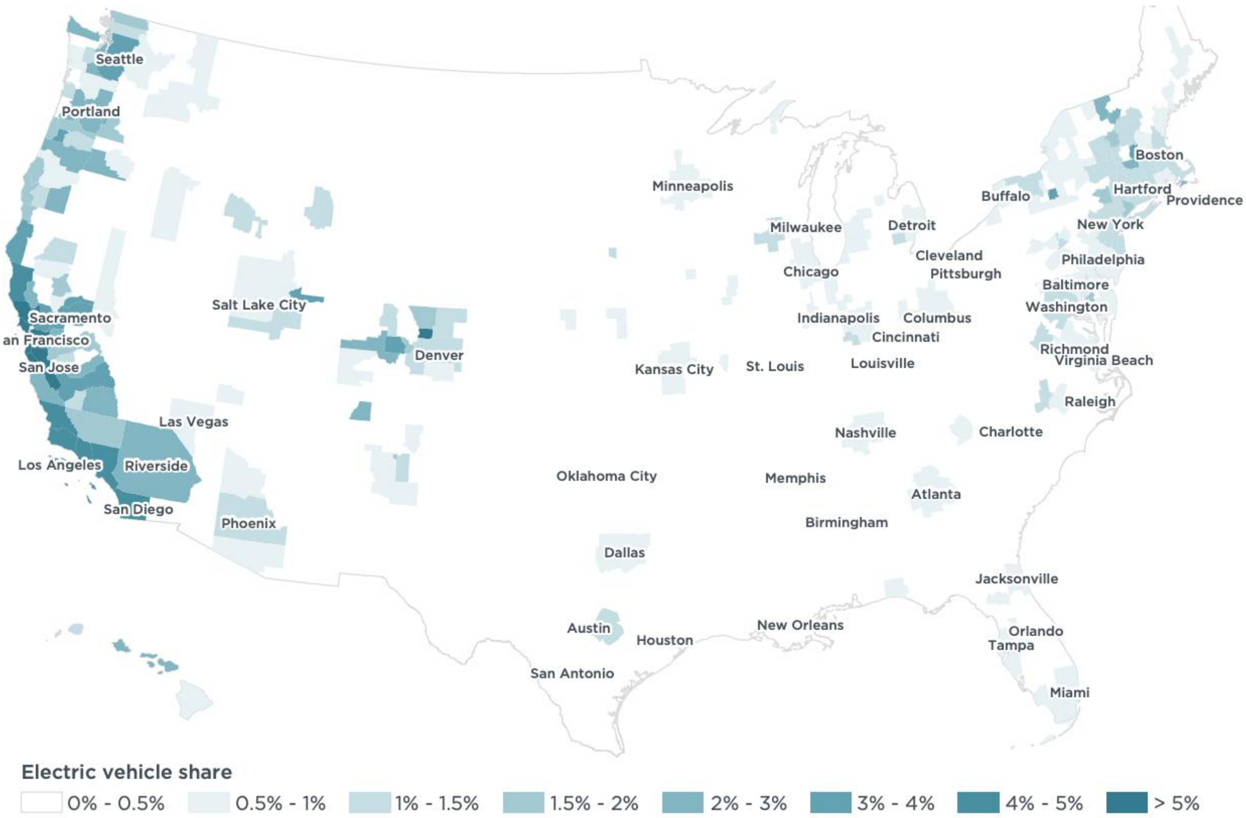


Figure ES-1. Electric vehicle share of new 2017 vehicle registrations by metropolitan area.
(New vehicle registration data from IHS Automotive)

Like China, the US is also an eager nation that can rapidly integrateEVvehicles into its societies. Only trailing behind China and Europe in its EVsales, the United States is now the third-largestEVmarket globally. It has the potential to develop further, as the US has a variety of EVsales and support policies that can cater to all states. As of 2017, the West Coast had the highest proportion of newly registered PEVvehicles in the US, with San Jose leading the list at 13%. Other Californian areas like San Francisco closely followed, with an EVshare at 5-8%. The share of newly integrated PEVvehicles of the West Coast in 2017 was 1.6%, far exceeding that of the rest of the United States by 2.5 times (22). Through this data, researchers conducted a series of analyses attempting to find a connection between EVshares and the availability of more EVmodels, charging infrastructure, financial incentives, and promotion actions (e.g., advertisements). Ultimately, researchers realized that it was crucial to be aware of four things to bring forth everlasting EVdevelopment: that EVmarket growth required a collaborative effort, that expanded model availability was integral to the growth of electric vehicle usage/availability, that the importance of consumer incentives was paramount regardless of the EVcosts, and that the development of EVvehicles and its various types of charging infrastructure were concurrent. Since the second half of the previous decade, multiple cities and areas have attempted to shape their policies based on these findings.

Former US Goals regarding EVintegration (US DOE report in July 2010)

I. Establish 30 battery and component manufacturing in the US that has sufficient capacity to support 50,000 EVs a year.
II. Assist designated automakers in creatingEVmanufacturing factories nationwide.
III. Invest in Battery Technology research to push down EVcar batteries by 70% by the end of 2015.
IV. Infrastructure trial programs will add 13,000 system automobiles and 20,000 charging stations by 2013.

Portland

General Overview of Portland

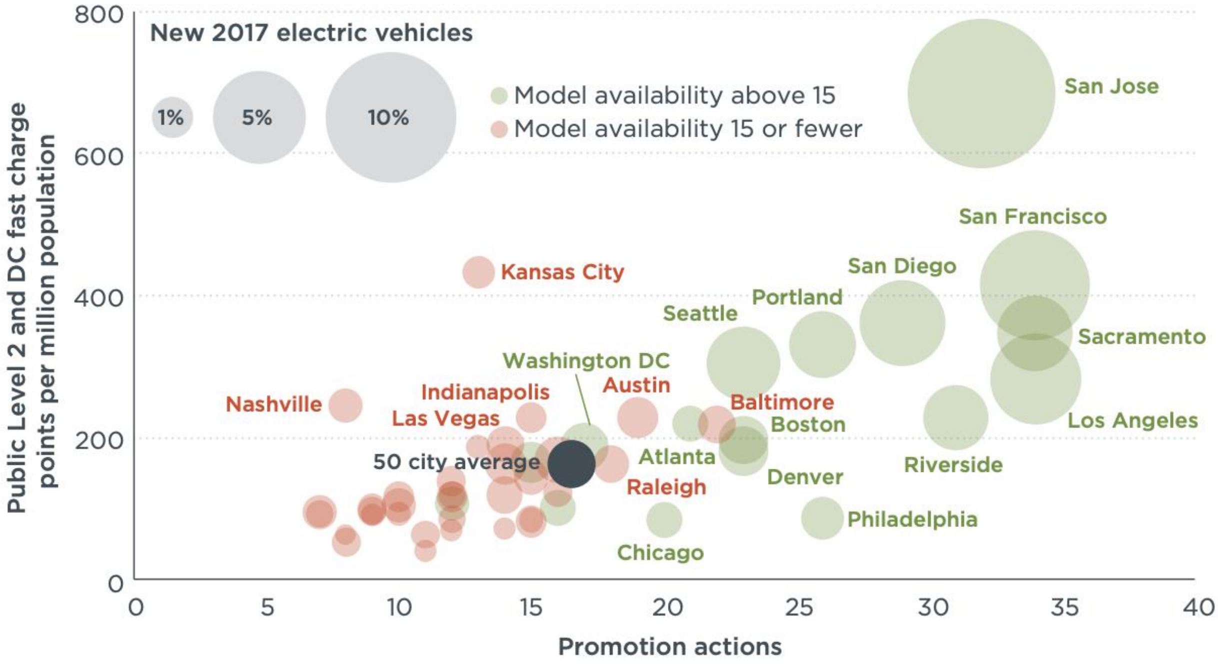


Figure 10. Public charge points, promotion actions, model availability, and electric vehicle uptake. *(New vehicle registration data from IHS Automotive; charging infrastructure data from PlugShare)*

One city that is making rigorous efforts to integrate EVpolicies is Portland. As shown in Figure 10, lower numbers of promotion actions and lower numbers of Level 2/DC chargers per unit million population usually result in fewer proportions of EVvehicles and model variants (i.e., availability). Portland stands out among the other US cities because it has the largest per capita fleet of electric vehicles. Moreover, as shown in the graph above, Portland not only has ample quantities of Level 2 and DC Fast EV Chargers but also has higher model availability (>15), lots of promotion actions, and higher vehicle uptake (as shown in the circle's size).

Portland has various generic goals and motives to integrate EVs into the public, ranging from their drastic savings of CO_2 emissions to their endeavors to make vehicles accessible to people of all incomes. The Portland Climate Change action Plan, which was launched by the Portland City Government in 2017, set ambitious goals of cutting carbon emissions by 40% by 2030 and 80% by 2050, compared to 1990 levels. The Portland City Government outlined which transportation choices would be explicitly addressed in its Climate Action Plan. Walking, cycling, transit, shared automobiles, zero-emission vehicles, and other private vehicles were all favored in the method's hierarchy of preferred mobility options.(17)

Overview of Portland’s goals

Portland wants to meet the following goals by the end of 2020 to lower 1990 carbon emissions by 25%:

"In Multnomah County, replace at least 10,000 gas/diesel-powered automobiles with electric vehicles."

"Double the amount of Level 2 and DC Fast Chargers available to the public to build public exposure to electric motor supercharger network."

“Improve low-income and minority groups' access to inexpensive electric vehicle travel modes.”

“Increase the benefits of electric vehicles for low-income people and people of color in terms of air quality and cost savings.”

"Increase the percentage of electric vehicles in the city's sedan fleet from 20% to 30% by adding 60 electric vehicles." Look into the possibility of electrifying other types of vehicles in the city's fleet."

"Make electrification of shared-use vehicles, bicycles, and buses a top priority to eliminate the need for private vehicle owners."

"Inspire the powering of automated cars to increase transportation safety for non-driving individuals."

Electrifying Vehicles

Portland will increase the appeal of electric vehicles by providing charging infrastructure in regions where it now does not exist. Residents who live in places with restricted access to transit and bike paths and densely populated areas (i.e., higher proportions of multifamily housing and garage-free homes) are more likely to drive over long distances. The improvementsare stated directly in one of Portland's 2020 Electric Vehicle Strategy targets. The goal of tripling the quantity of Level 2 and DC Fast Chargers emphasizes increased EV charging infrastructure, making electric vehicles more accessible to low-income people.

Like all countries and cities dedicating themselves to integrating EVvehicles into their societies, the ultimate goal for Portland would be, of course, to have electric cars quickly and readily available for everyone regardless of their social class. Providing new charging infrastructure within various locations will act as the stepping stone to this final goal. City officials can decrease uncertainty (the worry of running out of juice on the road), give emergency recharging access, and facilitate longer journeys by providing a robust and reliable charging network at home, work, and in public locations.

After installing a reasonable number of charging infrastructure in these areas, Portland plans to electrify its city vehicles rigorously. While doing so, it can offer a crucial opportunity to reduce carbon emissions, improve air quality, and decrease long-term maintenance.There is a need to address the operating costs (i.e.,communization of electric vehicles will directly correspond to better care) and the upfront costsof this electrification (insurance fees, registration fees, roadside assistance). Moreover, the high initial prices of buying EVvehicles and the expenses required for constructing charging infrastructure are much higher than a gas-powered vehicle, as people usually charge their cars at home. (11).

Barriers to Portland’s goals

Despite Portland’s specific goals, there are still many loopholes towards Portland’s policies to encourage vehicle uptake further. For starters, while life-cycle costs (essentially the total amount of expenses that are a component of E.V.s/directly related with EVs over their entire lifetime) are generally lower than traditional gas-powered cars, the upfront prices (starting costs) can be prohibitive, costing well over $10,000. To control and regulate these upfront expenses, most consumers require financial assistance in the form of tax credits to make up the difference. Subsidization is extremely important for low-income people, who already have a difficult existence due to their small budget.

Another barrier to EVs in Portland is that people often lack knowledge about the statistical performances of their EVs. Most Portlanders are also unaware of the variety of electric vehicle models available, as well as the environmental and economic benefits and buying incentives available. A solution to this problem may be to regularly offer educationalprograms delineating the importance of the environment and the apparent sustainability of EVs compared to ICEVs (Internal Combustion Engine Vehicles). Moreover, investing in school science programs to provide schools with a budget capable of employing sophisticated science experiments that genuinely capture the scope of the environment's importance.

Los Angeles

General Overview

In addition to Portland, Los Angeles offers good conditions for EV adoption among its residents. Los Angeles features a large proportion of multifamily housing buildings and renters and new and hybrid cars, a commuter market that can accommodate multiple vehicles per household, and limited public transportation options. However, LA is working to overcome four significant roadblocks: charging infrastructure, battery price and performance, range anxiety, and the number of electric vehicles.

The LA-EV Market Survey

After surveying 2,043 people in the LA Metro Area, city officials of LAmade some significant discoveries. Based on the behaviors, attitudes, preferences, and any other variables that would influence participants'enthusiasm in entering the EVmarket, three categories of adopters were divided: Early, Mid, and Late. By categorizing survey recipients into three categories, officials realized that lowering the upfront costs (non-refundable security deposits, taxes, registration, and insurance) of EVs would allow people, especially Mid-Adopters, to adopt EVs significantly. Officials explained the anomaly by stating that respondents have a tendency to perceive huge disparities between the price of electric vehicles and the real value they provide. A competitive and simple-to-understand power tariff plan might also be used to encourage mid-adopters to buy electric vehicles. Gas prices were deemed an important issue by 70% of Mid-Adopters when purchasing EVs, compared to only 54% of Early-Adopters. In other words, lower electricity rates may have a significant impact on Mid-Adopters' decisions to purchase electric vehicles. A monthly savings of $83 when compared to fossil fuels may be enough to persuade 40% of the LA population to buy or at least consider buying an electric vehicle.(8)

Even in urban, geographically widespread cities like Los Angeles, EV battery prices are integral to adoptingEVvehicles rather than its battery performance and range. Enlarging the battery by five times only improves EVadoption rates by 5%. Why? The current batteries that electric power vehicles are costly, giving EVs a higher upfront cost than that of conventional combustion-powered cars. Enlarging the batteries would further compound this problem; the Tesla Model S, for example, has an 85-kWh battery but costs just over $80,000, whereas the Nissan Leaf has a 24-kWh battery and costs less than $29,000. Survey results from the previous paragraph also reveal that over 80% of respondents admit price to be a vital factor that influences their support of EVs,and 71% believing that their apparent expensiveness nullifies the cost of EVs.

Due to the significant increase in prices that come with the less remarkable increase in range, it is best to sacrifice coverage for lower prices (8). While there is ongoing work by IBMon a Li-500 (500 miles) 125 kWh battery that has the potential to make EVs competitive with conventional vehicles by range, such has yet to be accomplished (1). An expansion of public knowledge regarding the importance of EVs can also impel LAresidents to purchase EVvehicles; over half of the Mid-Adopters in the previous survey cited lack of knowledge as a reason why they were hesitant to adopt EVs.

The lack of importance in range compared to costs perceived among customers can also be seen in the everyday use of personal vehicles in urban areas like LA 73% of LA commutes are below 30 miles (out and back), and 76% of the average total miles driven in a day is below 50 miles. As shown in these statistics, even an EVwith a range of only 100 miles can provide LA residents with ample comfort on a regular day (8).

The LA EV Market Survey also shed light on HOV(high occupancy vehicle) lane accesses and monetary incentives like a $2000 charger installation rebate and federal and state subsidies. The survey recognized that while early and mid-adopters were easily swayed by financial incentives lowering Total Costs of Ownerships (TCOs), these incentives, like a $2000 rebate, were not enough to convince Late-Adopters in which 28% viewed them as being effective in buying EVs compared to the sample's average of 73%. The survey also acknowledged that although HOVlane access for EVs would be effective in wooing Mid and Early Adopters, free parking for EVs wouldn't be as adequate since 59% of respondents stated that they rarely used street-metered parking (8).

Enablers of Vehicle Integration in LA DOE (Design of Experiments)

Two main enablers expedite vehicle integration in LA: the future favorable government actions and the recent surge in consumer demand.

The US government has spent billions of dollars in recent years to fund high technology cars. The Obama administration, in particular, made passionate contributions to boosting the EVmarket due to its policies endorsing US independence from foreign oil, addressing climate change, and bolstering US manufacturing by introducing more EV-related jobs to the country. A 2010 US DOE report revealed that the government invested $5 billion in the electric vehicle market. The US government made significant expenditures to "install batteries, components, vehicles, and chargers that were required to put millions of electric cars on America's road."

The playful manner in which the US government has shown EVs has given private and institutional investors the confidence to make substantial investments towards the EVecosystem. Tesla raised more than $180 million in its first public offering (IPO) in 2009, and has established key stakeholders like as Daimler AG and Toyota Motor Co. CODA, an electric vehicle startup, raised $76 million in January 2011, while Fisker Automotive, which started with a small $150 investment, obtained $1 billion in January 2011.

Customer demand is another factor that can help EV adoption. The demand for BEVs and PHEVs is strong, according to early adopter data. Around 21% of city dwellers are prospective early adopters, and as a result of their needs, numerous automobile manufacturers are drastically altering their short-term production capacity predictions. Nissan said in November 2010 that it had received 27,000 global pre-orders for its all-electric Leaf, and Chevrolet announced after that it had a 50,000-name interest list for its all-electric Volt. Due to these unexpected surges in demand, Nissan will be able to produce 500,000 Leafs by September 2020 (20), while Chevrolet will raise its annual Volt production capacity from 30,000 to 45,000 automobiles. (8) Regardless of pre-launch demand for electric vehicles, there are still several outstanding problems that must be addressed to make EVs accessible to late adopters and laggards.

Barriers of EVIntegration in LA.

Despite these advantages, many barriers have to be addressed for LA to expedite its electrified process truly. Charging infrastructure, range anxiety, and EVsupply are just a few of the many examples.

Home chargers, which are put in people's houses, and public chargers, which are setting utilities accessible to the public outside of the house, are the two forms of charging infrastructure. However, all major U.S. cities, including Los Angeles, lack residential and public infrastructure to facilitate electric vehicle adoption. That mostEVowners tend to charge their EVs overnight in their homes is concerning because doing so puts tremendous strain on the availability of charging infrastructure for multifamily housing (e.g., apartments).

Multifamily housing can significantly inhibit the installation of EVinfrastructure. Residents may lack garages or parking spaces to guarantee ample quantities of charging infrastructure. Furthermore, in street parking and older buildings, charger installation is frequently difficult, if not impossible **(8).**Buyers in multifamily dwellings may need to negotiate with their landlords or surrounding estate owners to get these charging stations installed. Another factor that disrupts EVcharging infrastructure integration is payment for the electricity used (and other costs associated with the installation).

Installed EVcharging stations have to be paid among all EVowners based on their usage of their charging stations. The equipment installed and the regular maintenance checks on the charging stations must also be evenly distributed among the residents. We can easily sidestep this problem by installing more public charging facilities. Although 75% to 90% of charging occurs at home, the awareness that there are charging stations available beyond one's garage or parking lot significantly eases range anxiety **(8)**. Increasing the number of public charging infrastructure, however, poses three questions:

1. Who will foot the bill for the infrastructure upgrade?
2. What locations should public infrastructure be built?

3. What equipment should be put in place?

As for the first question, the private sector (EVcharging companies like ChargePoint) should be responsible for infrastructure investment rather than the public. The private industry would pay for and install the infrastructure, while the public sector (i.e., the government) would foster EV/EV charging infrastructure integration through various legislation, tax exemptions, and defined standards.

The best places to install public EVcharging infrastructure are independent retailers (Whole Foods and Best Buy) and gas stations (Chevron, Shell). In other words, places that either has high vehicle densities or are related to automobiles, like gas stations, can maximize the usage of public infrastructure if implemented there. In fact, Whole Foods and Best Buy are already installing charging stations to attract customers into their stores directly.

As for the final question, there are currently three charging infrastructure levels available. The lowest, Level I, is just 120 volts, plugging a car into a regular power outlet. At this rate, an empty Nissan Leaf can be fully charged in about 22 hours. However, a nearday's worth of charging causes excellent inconvenience for EVusers. This usually impels users to purchase the more common 240 volt Level II charger, which can recharge a Nissan Leaf's battery in 8 hours. Finally, the 480 volt Level III (or DC Fast) charger has the ability to charge a Nissan Leaf in just 25 minutes. However, Level II chargers, although an upgrade from Level I, are considered too slow to keep up with LA's consumer demand, and Level III chargers are too expensive due to their considerable infrastructure upgrade. Moreover, the fast rate of DCchargers'electricity input in EVs can overwhelm the battery, compromising its life span and performance. The only focus on speed for DC chargers also means that Level III charging does not meet the Society for Automotive Engineers' criteria (SAE).

A critical issue that must be addressed is the lack of electric vehicle supply. According to recent DOE estimates, the number of electric vehicles is predicted to grow at a CAGR of 69 percent over the next five years (e.g., 45,000 units to 370,000 units). In 2011, BEVs accounted for 64% of EV production, with the Nissan Leaf accounting for 56% of EV supply between 2011 and 2015. While supply figures indicate that demand will be met, the issue emerges in the supply and demand of different electric vehicles. In 2015, Pike Research predicted that 60,000 BEVs were needed, compared to 200,000 PHEVs. On the other hand, the US DOE forecasted a supply of 237,000 BEVs and 131,000 PHEVS in 2015. While the supply of BEVs outpaced the demand for BEVs, the collection of PHEVs (plug-in hybrid electric vehicles) fell around 70,000 automobiles short of the order.

Amsterdam

Along with China and the United States, Europe is another region that makes rigorous efforts to mitigate climate change by saving as much energy as possible. Since cities like Amsterdam comprise the bulk of energy consumption, they offer the most significant opportunities for energy saving. Two of the most prominent technologies that can enable European cities to gain momentum towards achieving climate change mitigation are EVs and renewable energies (5). While European cities are developing at an astronomical rate on these aforementioned aspects, such development comes with some limitations. It is crucial for these limitations to be promptly solved in order to preserve the urban ecosystem. In order to do so, Amsterdam fabricated innovative policies that significantly reduce greenhouse gases and increases energy efficiency, intending to achieve its goal of banning all gasoline and diesel vehicles from the city by 2030.

Amsterdam policies

Amsterdam offers generous subsidies when it comes to EVvehicles. For quite a while, the Dutch government gave all of the Netherlands federal subsidies ranging between €2000 and €4000 for private EV owners. From June 4th, 2020 onwards, the Dutch government even allowed subsidies of €4000 for customers when leasing or purchasing new EVs and €2000 for customers who were purchasing/leasing second-hand EVs (9). The only requirement that individual EVpurchasers needed to satisfy for earning this subsidy was completing an application form submittable from July 1st and a purchase/lease agreement for the EVwithin the application form that would be less than 60 days old at the time of submission. The Amsterdam City Government took a step further, providing EVaccess not only to individual users but also to corporate transportation.

The City Government would pay €5,000 for an EV business car, €5,000 for an EV delivery car/taxi van, €3,000 for a regular EV taxi, and 20% of the purchase cost for an EV truck and bus for a maximum of 5 cars per corporate EV purchaser. In addition to the original payment of €5,000, the Amsterdam City Government has speculated on an extra subsidy plan paying €5,500 to entrepreneurs who drive at least three times a week within the city. Entrepreneur drivers can get up to €10,500 in incentives for a maximum of two electric vans under this arrangement. (15).

Positives of Amsterdam

Amsterdam has optimal environments to integrate EVs compared to other cities. The city already has around 3,000 charging stations in public parking spaces and has plans to install a thousand more. Amsterdam also has five low-emission zones where vehicles that cause the most pollution are banned; actions are being taken to expand these zones and intensify regulations. The Dutch capital is also one of the few, or perhaps the only city, backed by private corporations to achieve its goal of zero emissions by 2030. Vattenfall, a European energy company that provides energy via wind and solar farms, has already constructed charging stations near the homes, businesses, and public places of Amsterdam.

A tendency of Amsterdam to be rather left-wing and with this favoring sustainable energy and a green environment is also an advantage that Amsterdam has over other nations; there is the “political will”to succeed in Amsterdam (4**).** Amsterdam's political and social motivation can act as one of the catalysts for the number of EVs to quadruple from the current 17,000 to 68,000 by the end of 2022.

Negatives of Amsterdam

With the pros, however, comes the downsides. The biggest problem is that while taxi and chauffeur services can quickly go electric, private car owners may be unable to make the switch due to financial reasons. The upfront costs for EVs are high; EVs, especially those in the premium tier, tend to use more expensive and advanced lightweight materials that cost a lot to replace in case of an accident. While EVs may hold the upper hand in TCOs over that of ICEVs (in Korea, an average EVcan travel the same distance on just ₩12,000 of electricity as an average ICEV would on ₩23,000 of gasoline) (21), people usually disregard the lifetime costs and focus on the short term upfront costs. Moreover, Vattenfall’s large-scale construction of charging points within Amsterdam leaves the possibility of the entire charging system breaking down in case of overuse completely unaddressed.

While Vattenfall’s head of e-mobility Pieter van Ommeren suggests that maintaining an inverse relationship between the demand of electricity in a particular area and the charging rate of that area can be a possible solution, this action will only serve to exacerbate the critical disadvantage that EVs have over ICEVs: it takes much, much longer to fully charge a vehicle than to refuel one. Finally, Amsterdam has to deal with the challenge of building 20,000 charging points in five years in order to have any hope of achieving its goal of fully electrifying its vehicles by 2030 (4).

Generating Clean Electricity and Maximizing Charging

However, the current way in which EVelectricity is generated is entirely unsustainable. As mentioned in the China section, the current generation mix of electricity consists mainly of fossil fuels and only a fraction of renewable energies. Another disadvantage of EVs is that due to the limited number of charging stations, EVs may be inconvenient as lots of time may be sacrificed for recharging since a full charge typically takes 30-60 minutes even by DCfast charging, a stark contrast to the 3-5 minutes that it takes for refueling an empty ICEV fuel tank (7).

More copper will be needed to address the unsustainable generation mix of electricity. Also, more copper will be required to back the copper-powered solar photovoltaic necessary panels to harness energy for operating these vehiclesto accelerate the emergence of independent energy vehicles (EIVs). Moreover, while EVs themselves have zero fuel emissions and have low carbon levels compared to ICEVs, EVs can reach their full potential only by altering their electricity generation mix to zero-emission. The increase of copper can enable this alteration to happen, as copper's conductivity allows the material to generate power from all renewable energy sources like wind energy, solar energy, geothermal energy, and hydroelectric energy.

For EVs to be highly energy-efficient, the proportions of the current electricity generation mix have to be altered to have 4-12 times more copper than fossil fuel-based electricity generation. More specifically, Level 1 EVchargers require at least 1.5 lbs of copper each. In contrast,DCfast chargers may need almost 12 times as much as its counterpart to provide zero-emission electricity to EVs. The good news is that BEVs already use considerably more copper than ICEVs; an internal combustion engine uses an average of 23 kg of copper, whereas a BEV uses an average of 83 kg of copper (23).

Copper is just one of the many metals that will be needed to guarantee a low-carbon future. A 2017 World Bank Report, "The Growing Role of Minerals and Metals for a Low Carbon Future,"stated that demand for metals might increase by ten times in the next 30 years due to a variety of environment-related factors, including the shift to EVs. For copper precisely, researchers have speculated a 50% increase in demand within just the next 20 years. It is imperative to guarantee that the needs for these metals be met to create a low-carbon future. Inevitably, this will mean more mining, so it is vital that copper and other metals are produced sustainably. To this end, the International Copper Association established the Copper Mark in order to assess the copper mines and refiners'performances based on responsible production criteria to ensure that investors and copper customers would know a lot about the sustainability of their purchase materials.

It is best for EVcharger startups to identify the regions most densely populated with EV vehicles to solve or mitigate the problem of time and comfort, and then find the balance between electricity tariffs and the installation costs needed to put the charger in place. The installation costs will include factors such as electricity fees, land rents, constructing bathrooms, and charges for a variety of other basic convenience utilities/practical considerations needed to ensure the wellbeing of EVdrivers during their time at the charging station (24).

In the case of installing charging stations in public utilities like malls and supermarkets where many long-distance commutes are directed, it is best to install Level 2 Charging or DCfast-charging stations in order to ensure that these commuters have ample fuel to return home. By doing so, EVusers can overcome the disadvantage of their vehicles'shorter ranges and long recharging times by utilizing the broader availability of charging stations to gain the distinctive advantage of leaving their cars unsupervised while recharging, something that cannot be imagined when refueling ICEVs.

For the faster integration of EVs, maximizing charging will be required upon the EVusers'side to correct the public's overestimation of charging stations' limited range & unsustainable charging speeds. The reality is that as long as an EVuser drives 80 miles or less a day, which is what most people do, even Level 1 "trickle charging"is entirely sustainable (24). For example, a Nissan Leaf has a range of 84 miles for its 2014 and 2015 models (24). Let's say that you used all of your Leaf's field in your commute to/from work, which is 42 miles (a very long commute, as the average commute distance to work is 19.7 miles), and say that the commute takes two hours out and back (24).

That will leave your car parked for 22 hours a day, which is more than enough time for even your 12 amp 120V Level 1 charger (which gives your Leaf an added range of 4 miles per hour) to fully charge your Leaf battery as it leaves an hour of leeway. While additional charges have to be installed to guarantee that the car will be recharged for its unused 22 hours, hundreds of chargers can be installed using the regular electrical supply for a commercial building. This can be justified mathematically.

Imagining that a commercial building as having 100 hotel rooms, it would be safe, or even an underestimation, to assume that the only electricity circuit available in each hotel room is a standard 20 amp 240-volt circuit (which is equivalent to two 20 amp 120-volt circuits, or two 20 amp Level 1 charger for each room) powering the room's heater (24). So with the wiring for each hotel room, a 100 hotel-room building would have the wiring to support 200 EVs. While this optimal case would mean that if one dedicates all the electricity to operate the heaters to Level 1 EVcharging, this shows that far more EVs than expected can be accommodated by the regular electricity supply in a commercial building (which, in this hypothetical case, solely accounts for the heaters'circuits).

Consider this for those who still think that the "trickle charging" of Level 1 is greatly unsustainable. A 20 amp circuit like that of a hotel room heater can potentially add 5.5 miles of range per hour if converted into a Level 1 EVcharger, meaning that with 22 hours of charging, the car could add 121 miles of range, a value that very few drivers in the United States exceed per day (**24**). And even if some unexpected circumstances exceed this value on a particular day, the deficit can be made up over time. So what is the bottom line? As long as EVusers have a sufficient number of Level 1 "trickle charging"stations, they can drive their vehicles without range anxiety in their regular commutes. And buildings already have abundant wiring to support many EVvehicles.

The only problem is that these wires aren't connected to the parking lot or the parking garage, which is cheap to communicate as a Level 1 charger only costs about $400. This is a minuscule increase from the original cost of a space in a new parking garage, which averages around $21,500 (**10**). Level 2 chargers may be needed for long commuters, and Level 3 chargers may be required for places that are frequently visited over long-distance road trips like gas stations. But in short distance commutes, these faster chargers are almost always superfluous.

Analysis of Policy and Technology

China, the United States (LA and Portland), and Amsterdam have all taken similar yet different measures in order to integrate EVs into their societies. China implemented strong, totalitarian policies such as the "十市千车 (shifuQian che)"program and started the introduction of EVs not out of environmental improvement, but out of the desire to make Chinese automobile manufacturers compatible in the global market.

The United States has also used government interference, making passionate contributions to boosting the EVmarket in order to address range anxiety and increase model availability to cater for both short commute urbanist and longer-commute suburban or even people in the rural area. Finally, Amsterdam has gotten a distinct head start in striving to create a zero-emission nation by 2030, installing 3,000 chargers with plans to install 1,000 more, and furthermore being backed by private energy companies like Vattenfall for its integration plans. Who is doing the best job? First of all, Amsterdam is far too ambitious on its zero-emission goal by 2030.

While Amsterdam already has 3,000 chargers, they need over 20,000 more chargers by 2025 in order to have any hope of fully integrating EVs into their society. Whether they will also be able to accommodate for the staggering quantities of electricity (the rate) also remains in question, and the slower charging rates that may emerge as a possible solution also have their shortcomings. For the US, the nation needs to address its arsenal of multifamily housing residents and mixed races; more competition will emerge in these densely populated areas where EVdrivers would want access to the same nearby charging stations. Moreover, the US has to implement more public charging infrastructure in order to rid prospective buyers'misconceptions of unsustainable charging, has to delegate the private sector to infrastructure investment rather than the public to refrain from dampening city governments'efforts to invest in sustainable technology, and also has to provide wider availability of EVmodels due to the variety of locations Americans tend to live in.

Although China needs to create favorable gasoline-electricity prices and modify their electricity generation mix to come from sustainable resources like copper, China has the largest EVmarket in the world, comprising over half (51%, which is 1.1 million units of EVs) of the yearly global EVsales and being three times the size of the European and the US market. Their strong policies and their versatile nature in establishing procedures due to their single-party nature will expedite their rate of growth compared to other countries that either have far too ambitious goals or have too many needs to accommodate.

Future Implications

For China, future implications seem pretty optimistic. The nation has managed to pull off a record monthly sales of EVs and other energy-saving vehicles in September 2020 and recently opened the Beijing International Auto Show in late September to formulate products and technical programs on an international scale (**16**). The Chinese auto industry prosperity index (ACI)'s 39 point increase from 15 to 54 also foreshadows significant EVdevelopment for the nation (**16**). China's lower material costs than the overseas market may also work as an advantage that the Chinese may use to intensify their monopoly on the EV market further. Government interference is a continuing trend that enlightens future prospects for China, with subsidies of more than 30 billion Yuan enabling Nio to enter the New York market in 2018, with the automobile company expanding by more than 340% ever since (6).

The US, on the contrary, is somewhat lagging. China's significant progress in introducing EVs compared to the US can be clearly seen in each respective nation's share of lithium-ion megafactories; 107 out of 142 lithium-ion battery megafactories are set for China compared to just 9 in the US (6). It is also predicted that $300 billion will be invested in EVdevelopment and production by automobile manufacturers over the next decade, with almost half of that being delegated to the Chinese market. In contrast, the US's dependence on oil is currently higher than it has been even compared to its peak of reliance on OPEC, in which the nation claimed 40% of the entire organization's oil supply (6).

Similar to the U.S, Amsterdam's future prospects are also bleak like the US as the city is unable to find a viable way to address their significant lack of chargers required to achieve its 2030 zero carbon-emission goal. The political motivation inherent in Amsterdam can only have a considerable impact if Amsterdam accelerates its rate of infrastructure installation and finds a way to comfortably deliver enormous amounts of electricity at a rate convenient enough for the EVusers without having the charging systems shut down due to overvoltage.

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