ECONOMIC IMPACTS OF ELECTRIC VEHICLE INFRASTRUCTURE EXPANSION ON TEXAS METROS

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16. Abstract

The electric vehicle (EV) market in the United States is rapidly expanding, and automotive manufacturers are constantly innovating to improve vehicle range and efficiency. This switch will require additional charging infrastructure to meet demand. Although charging infrastructure is a necessary investment, cost may pose a barrier to some metro areas. Policymakers and planners need an understanding of the benefits associated with this investment, especially economic benefits, to justify the investment and potentially leverage private funds. This research focused on creating a tool to present the economic benefits associated with investing in charging infrastructure, which could be easily used and edited to user preferences. The tool provides the user with a benefit-cost ratio as well as economic output depending on the inputs selected. Three scenarios highlight the potential application of the tool as well as options for supplementing with additional data or assumptions. Results from the scenarios indicate that investments in charging infrastructure will provide economic benefits to Texas metros, but placement and operation of stations should consider equity. Overall, the economic benefit tool aids the user in communicating the benefits of investing in EV charging infrastructure; as the EV market in the United States grows, planners and policymakers will need to establish the value of providing access to this infrastructure both to public and private investors.

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Executive Summary

The electric vehicle (EV) market in the United States is rapidly expanding, and automotive manufacturers are constantly innovating to improve vehicle range and efficiency. This inevitable switch from internal combustion engine vehicles to vehicles powered by electricity will require an investment in EV infrastructure, or charging stations, by the public sector. Although charging infrastructure is a necessary investment, the potential growth in EVs and the required charging to meet demand may pose a cost barrier to some metro areas. Policymakers and planners need an understanding of the benefits associated with this investment, especially economic benefits, to justify the investment and potentially leverage private investment. This research focused on creating a tool to present the economic benefits associated with investing in charging infrastructure, which could be easily used and edited to user preferences.

In creating an economic benefit tool for EV infrastructure, the literature on the variety of benefits that EVs bring to society was reviewed. The benefits include environmental, health, economic, and potential equity improvements. After the review of the literature, the findings were used to develop assumptions for the economic model as well as identify possible data sources. The team utilized publicly available data to develop a spreadsheet tool that includes both economic impact analysis and benefit-cost analysis techniques. The use of a spreadsheet tool increases the accessibility for potential stakeholders and allows for edited inputs in terms of potential EV adoption scenarios as well as the number of charging stations or charging outlets to install. The tool provides a benefit-cost ratio as well as an economic impact in dollars for the user.

Presenting the full economic benefits of investing in charging infrastructure will require additional data and an understanding of local conditions; in order to emphasize this requirement, three scenarios were developed that analyzed a policy framework, the potential for slow adoption of EVs in a smaller metro, and equitable siting of charging stations. Austin's Community Climate Plan includes a number of policies aimed at improving environmental outcomes, which include increasing the number of EVs within the city. This scenario addresses the cost of supporting that increase with the necessary infrastructure as well as the associated benefits. A more aggressive adoption of EVs would lead to greater costs, but the city would still benefit from increased jobs and environmental benefits. The slow adoption scenario presents the possibility that the Tyler metro area seems to have a slower rate of growth in terms of EVs; the analysis highlighted the preparedness of the area in terms of fast charging as well as the benefits to increasing public charging availability at office and campus locations, such as hospitals or schools. Finally, the third scenario evaluated the impact of siting charging stations in two environmental justice neighborhoods when compared with a control neighborhood. This scenario included a consideration of the health benefits related to incentivizing EV adoption by providing adequate charging infrastructure. The three scenarios highlight the potential applications of the tool, but the results also indicate that investments in EV charging infrastructure will bring economic benefits to Texas metro areas.

This study, and the economic benefit tool developed as part of the study, aids the user in communicating the benefits of investing in EV charging infrastructure; as the EV market in the United States grows, planners and policymakers will need to establish the value of providing access to this infrastructure. The tool provides a starting point to convey the economic benefits associated with investing in EV infrastructure. Supporting these investments will lead to a more efficient and effective transportation system that enables users to easily switch to an EV without concerns over charging availability or the range of the vehicle. The scenarios presented provide options for both the use of the tool as well as the importance of considering additional factors when placing charging infrastructure, such as the neighborhood need in terms of both access and health. Equity should be considered in every transportation investment, and the equitable siting and investment in charging infrastructure requires the same consideration. Equitable distribution of the economic benefits presented by the tool must also be considered before a project is funded. Overall, the tool enables Texas metros to understand the economic benefits to their region of investing in charging infrastructure, which can be used to support projects or leverage private funding.

Acknowledgments

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Background and Introduction

Electric vehicle (EV) sales are increasing as more manufacturers release electric models with expanded range and charging infrastructure becomes more common across the United States. Although the charging network in the United States has spread in recent years, public concerns still surround vehicle range and availability of charging as well as the initial purchase price of the vehicle (*1*, *2*). Increasing the availability of public charging can enable users to switch from an internal combustion engine (ICE) to an EV as well as allow cities to meet other goals, such as environmental or air quality targets. Investing in public charging infrastructure can also provide a range of economic benefits for the region from increased employment related to the installation and manufacture of charging infrastructure to travel, safety, and environmental cost savings by reducing the distance to charging stations. Justifying investments in infrastructure requires a benefit-cost analysis and an economic impact assessment to ensure good stewardship of public funds.

The research team at the Texas A&M Transportation Institute (TTI) developed an economic benefit tool to assist local governments, policymakers, and planners in understanding the economic benefits related to investment in EV infrastructure in Texas. The tool allows the user to understand the charging needs for their metro area as well as the associated costs and benefits. The research team conducted an extensive review of the literature to understand the different economic benefits related to EV infrastructure as well as to begin the data collection process. The literature review provided a number of data sources for use in the tool as well as assumptions that generate impacts within the tool's model. The tool was then developed using standard benefit-cost analysis and economic impact assessment techniques. Finally, the research team developed three scenarios to highlight the potential of the tool for planners and policymakers across the state of Texas.

The report includes the following:

- Literature review that focuses on economic effects of EV infrastructure and discusses how social and environmental impacts relate to those economic impacts.
- Data collection and methodology focusing on the main sources of data utilized in the tool as well as an overview of the tool development.
- Scenario analysis of three different metro areas in Texas and the potential impacts from a climate policy, slow growth in EVs, and equitable deployment of charging infrastructure.

Social, Environmental, and Economic Impacts of Electric Vehicle Infrastructure

EVs are increasing in popularity, not just for consumers, but in terms of public and private fleets. President Biden's American Jobs Plan, which was recently signed into law, includes $7.5 billion for EV chargers as well as investments in clean transit (*3*). This potential investment offers an opportunity for planners and policymakers to consider their EV needs, especially in the EV infrastructure field. The EV market share is growing, but charging infrastructure is lagging behind this increase in ownership. Without access to a charger at home, the purchase of an EV can be unrealistic for certain users, which is due to concerns over range anxiety and the availability of public charging infrastructure. Enabling the switch to EVs will require a strong charging network that is publicly available and sufficient to meet future demand for this infrastructure. This literature review will discuss EV market share and ownership trends, charging infrastructure needs and costs, as well as additional benefits to the environment, health, and the economy. Perception and rates of EV ownership will determine charging infrastructure needs, and the different types of chargers have their own associated costs as well as benefits. Finally, the equity challenges related to EVs will be explored in terms of both cost of initial ownership and access to chargers.

Market Share Forecasts

The EV market share is projected to continue growing as government incentives and changes in consumer behavior shift towards clean modes of transportation. The U.S. government already has in place the Corporate Average Fuel Economy standard where ICE vehicles are required to reach an average fuel economy of 54.5 miles per gallon by 2025 (*4*). Transitioning to EVs is a possible solution for auto manufacturers to reaching this standard as EVs have become more affordable through lower ownership costs and the improvement of plug-in electric vehicles (PEVs), which includes both battery electric vehicle (BEV) and plug-in hybrid vehicle (PHEV) technology. The average price to own an EV in the United States from 2018 compared to 2019 has fallen from $64,000 to $56,000 and is likely to continue to ultimately fall to $25,000 by year 2030 (*5, 6*). Similarly, the price to produce lithium-ion batteries, which are used to power EVs, also fell 87 percent in 2019 (*7*).

Over the years, the U.S. EV market has fluctuated due to economic shifts and government intervention but is still expected to continue trending upwards. With the help of financial incentives, sales of hybrid electric vehicles (HEVs) and EVs reached a high point in 2007, with a total of 350,000 vehicles sold that year. Sales experienced another peak in 2013 with about 400,000 vehicles sold on the back of a strong economy and government policies (*8*). Looking more closely at PEV sales, Figure 1 shows that the sales trend of these vehicles has steadily increased since 2011. The United States sold approximately 320,000 PEVs in 2019, almost 200,000 more than what was sold in 2015 (*9*). PEV models have also become more diverse giving consumers a larger selection; there are currently around 220 different types of alternative fuel vehicles (AFVs) and HEVs, about 180 more than in 2000 (*10*). Projections for what the EV market share will look like in the next 10 to 30 years estimate that EV sales will reach 2 million in 2050, accounting for 20 percent of the total vehicle fleet (*11*). As for the total number of vehicles on the road, the share of gasoline vehicles is expected to shrink, making room for cleaner transportation options. Figure 2 shows that in 2030, roughly 21 percent of vehicles on the road will be BEVs, while PHEVs will make up about 5 percent (*12*).

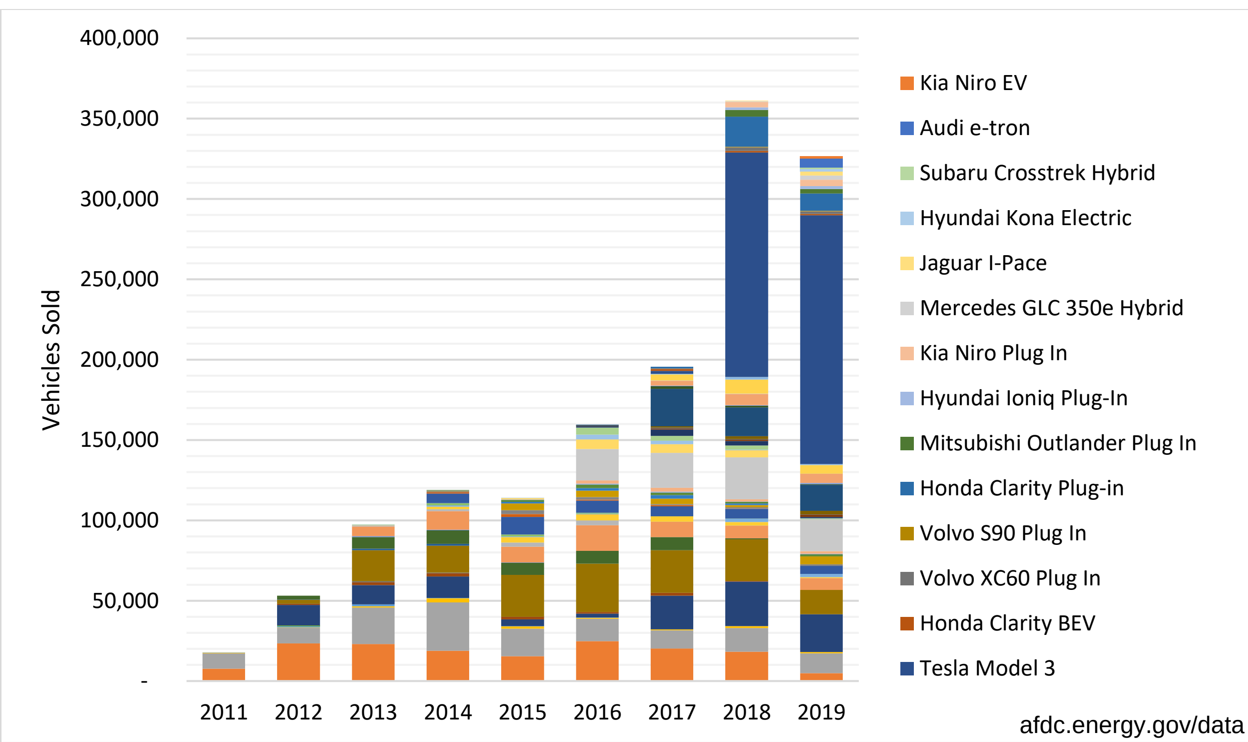

Figure 1. U.S. PEV sales by model.

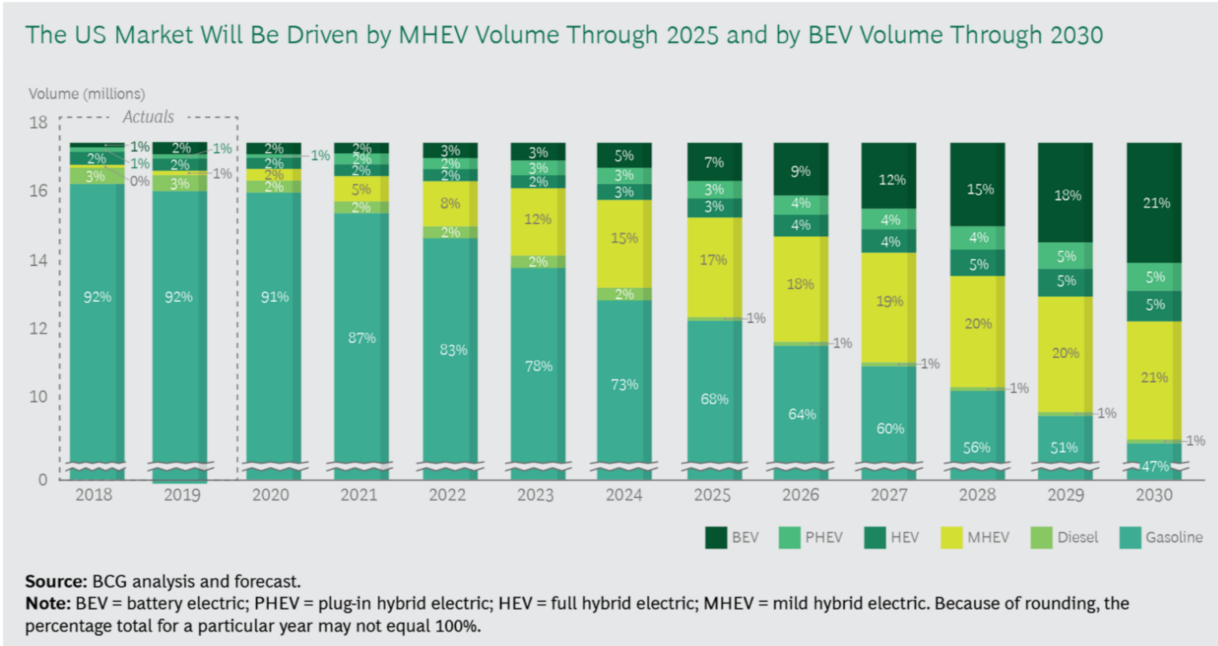

Figure 2. Share of U.S. vehicle type on the road.

Electric Vehicle Ownership Overview

Current ownership trends of EVs relate to both the perception and the availability of incentives. Due to the initial purchase cost of EVs, consumers tend to have higher incomes and own their home to provide easy charging space. Perception of EVs also plays a part in PEV ownership, largely driven by "range-anxiety," but improvements in range is helping to appease these concerns (*13*). Range anxiety is a term used to describe the insecurity drivers of PEVs, especially those who own BEVs, feel when they are using a vehicle with limited driving range in a location with scarce charging stations. Surveys conducted to measure EV opinions have found that range is a major concern for drivers, with 71.7 percent of respondents from a Union of Concerned Scientists poll stating they would be more willing to purchase a PEV if public charging were to become more widespread (*14*, *15*). A survey of Northeast U.S. consumers had similar results; the likelihood of owning an EV increased by 80 percent if charging stations become more abundant (*16*). With these concerns in mind, manufacturers are already working towards extending PEV distance capacity. Current PHEVs have an approximate driving range of 10–50 miles before switching to gasoline for an additional 300 miles (*17*). The driving range for BEVs has improved from a 100-mile capacity in 2016 to a 250- to 350-mile range at present. Although improvements to BEV range are important, increases in the availability of public charging stations are necessary to facilitate a large-scale switch to electric-powered vehicles. Those who rent instead of own homes may have limited access to charging stations at their residence, and individuals with a long commute will need easy access to chargers at their place of work.

Electric Vehicle Incentives

Given the perception and demographics of current EV owners, cost of EVs can be a barrier preventing a broader selection of consumers from purchasing these types of vehicles. Studies typically narrow EV costs into three categories: vehicle purchase, maintenance, and fuel (*18*). In 2019, the price of PEVs averaged about $55,600, roughly $19,000 higher than the average price of an ICE vehicle (*19*, *20*). To account for maintenance and fuel costs, researchers use either a range or the total miles driven to gauge lifetime costs. The consensus overall is that EVs have lower maintenance and fuel costs compared to traditional vehicles. For example, one study on EV ownership costs estimated that lifetime maintenance costs are half of those for traditional vehicles, while another concluded that lower maintenance and fuel costs outweigh the initial high costs of purchasing a PEV over time (*21*, *22*). Batteries have also undergone an improvement in technology leading to relatively more affordable prices. As technological advancement progresses and vehicle parts become easier to produce, ownership will become more affordable.

The federal government and states provide different types of incentives to promote the purchase of PEVs and overcome high EV prices, such as rebates, tax incentives, and perks. Rebate amounts vary by state, such as California and New York offering rebates of up to $2,000 or Connecticut offering up to $5,000 towards the purchase of an EV (*23*). States also offer tax incentives wherein those who have purchased an EV can apply for a credit on their tax return or can be exempted from sales taxes during the purchase of the vehicle (*24*). Additional financial benefits are given to lower income populations with the expectation that this will lower the income gap between EV owners. For example, California's Clean Vehicle Rebate Project offers low-to-moderate income households, or those below 400 percent of the federal poverty level, up to $4,500 instead of the standard $2,000 (*25*). Non-financial incentives are those that do not involve a financial component but rather offer perks like preferential parking, high-occupancy vehicle (HOV) use, and public charging to those who drive PEVs (*26*).

Although these are only a few examples of state EV incentive programs, they are widespread enough throughout the United States that researchers have studied the nature of impact incentives like these have on the EV market. Reports have acknowledged that the impacts of non-financial incentives differ across regions. Areas that experience frequent congestion are more likely to have a greater positive impact on PEV adoption, and in a similar manner, toll charges or fee waivers serve as incentives for those that frequent these roads (*26*). Among the incentives researched, public charging infrastructure availability was found to be a strong indicator of PEV adoption across the board. If drivers can be assured that charging stations will become abundant, placed at convenient locations, and have faster charging speeds, then this assurance will help promote the adoption of PEVs (*27*). As such, states and cities are working towards increasing the number of charging stations, some with the help of the private sector like in the case of the Houston, BP, and Uber partnership (*28*). The next section will discuss workplace and public PEV charging infrastructure in more detail.

Electric Vehicle Infrastructure

EV charging stations are categorized as either residential or non-residential and as Level 1, Level 2, or direct current fast charge (DCFC), each with their own respective specifications. According to the Alternative Fuels Data Center's (AFDC's) charging station locator, there are approximately 41,000 charging stations, with a total 100,000-outlet capacity, in the United States (*29*). Broken down, about 80 percent of public charging outlets are Level 2 and about 15 percent are DCFC (*30*). In the lead are states such as California, New York, Florida, and Texas with over 2,000 PEV stations; California, in particular, is home to over 12,500 PEV charging stations (*31*). Non-residential EV infrastructure is typically located in workplaces, commercial areas, and along highway corridors and is most commonly Level 2 or a DCFC. As opposed to Level 1, these types of chargers have faster charging speeds, making them the optimal choice for use in concentrated areas or places where PEVs are parked for longer periods of time, such as commercial centers, airports, and hotels. It takes Level 2 chargers about 1 hour to power a range of 10 to 20 miles. DCFC chargers, in contrast, are the fastest option capable of charging anywhere from 60 to 80 miles in 20 minutes but are also the costliest given the equipment needed to obtain higher outputs (*30*).

Infrastructure placement is vital for promoting both miles traveled by EVs and the purchase of these types of models; however, determining where to optimally place charging stations and how to accommodate the PEV market growth is a question researchers are attempting to answer. Most studies use a combination of spatial and temporal information to pinpoint charging station locations and demand. One study used a Red Line/Blue Line model to calculate the number needed for workplace and public DCFCs. Red Line is defined as only charging the PEV when benefits are gained, while Blue Line assumes that a vehicle is charging while parked, regardless of benefits (*32*). This model requires information on EV range, charger availability, location type, and charging power (Level 1 or Level 2) (*33*). A study by the U.S. Department of Energy found that around 400 DCFCs, approximately 70 miles from one another, are needed to allow long distance travel between cities (*34*). This analysis determined that 4,900 DCFC stations are required to serve cities with towns requiring around 3,200. In terms of plugs per 1,000 PEVs, 1.5 plugs are needed to meet city demand, 2.2 plugs for towns, and 3.1 for rural areas for DCFC stations. Non-residential Level 2 plugs per 1,000 PEVs were also calculated with 36 plugs needed for cities, 54 for towns, and 79 for rural areas (*34*). A case study on Massachusetts' regional PEV infrastructure used registration data by zip code to predict infrastructure needs according to county PEV density. They found that 10 to 340 Level 2 plugs are needed per 1,000 PEVs. Furthermore, to support 300,000 PEVs across the state by 2025, about 130 workplace plugs and anywhere from 17 to 149 public plugs will be needed per 1,000 PEVs (*35*).

When charging stations are scarce, several management strategies are often imposed to accommodate demand. A recent study on vehicle charging behavior interviewed 40 PEV owners and discovered that three charging management strategies, authoritative, collective, and unmanaged, are used in workplaces (*36*). An authoritative management strategy are guidelines created and overseen by the workplace itself and can include valet charging, time limits with added rates, and online reservations. A collective management strategy is one that is organized by workers, not the workplace, and relies on strong leadership for it to be an effective approach. An unmanaged approach has no set rules and PEV drivers are often found competing for a charging spot. Overall, this work recognizes that the most suitable site is one that is economically feasible, easily accessible, and with a power grid that is capable of handling higher demand (*37*, *38*).

Infrastructure costs can be significantly impacted by the type of equipment needed to obtain a certain charging speed. Although Level 1 chargers also incur costs, only Level 2 and DCFC costs are discussed as these are the types most commonly used for public stations. Cost considerations include equipment, installation, maintenance, and operation, which consist of electricity and utility needs. Equipment costs are determined by location and charging level as well as specific hardware needed (e.g., ports, mounting system, energy monitoring, and more). When added together, costs for single connector units for Level 2 range between $400 and $6,500, and $10,000 and $40,000 for DCFC (*38*). Installation costs are another component of infrastructure that are taken into account when totaling costs. Factors affecting installation costs are the location site, trenching requirements, presence of electrical wiring, workforce, whether it is networked, and others. Depending on the complexity of installation, costs per unit can average around $3,000 for Level 2 and $21,000 for DCFC (*39*). Lastly, maintenance costs are derived from periodically inspecting station parts and cables and from performing repairs. These costs can reach up to $400 per month; however, repairs can significantly increase the monthly cost if an expensive part needs to be restored (*40*).

On the electricity consumption side of PEV infrastructure is utility management and approach to mitigating excessive demand. A concern with promoting PEVs is that the power needed to charge a rising number of EVs will overload the grid and lead to higher prices. To prevent this issue from happening, and to better plan for future consumption, experts recommend charging at off-peak times or engaging in smart charging solutions. For example, utilities can implement time-of-use fees to incentivize consumers to charge at a time when electricity use is set at a lower rate. Additionally, utility companies are collaborating with station providers to better identify sites capable of accommodating a variety of chargers, as is the case with California's Pacific Gas and Electric guide and mapping tool, to not overload the grid (*41*, *42*). Utilities in New York have also developed the Joint Utilities of New York's EV Readiness Framework, which identifies ongoing or completed pilot projects like the rewarding off-peak charging, the research involving EVs' impact on the grid, and the awareness of consumers (*43*). Smart charging offers several technological approaches to efficiently and automatically manage the grid. Current solutions include vehicle-to-grid, demand response (DR), or one-way controlled charging that activate when demand begins to overwhelm the grid (*44*). A vehicle-to-grid solution enables EV batteries to return some of its stored power back to the grid, DR pauses charging when demand is high or when power supply is disrupted, while one-way controlled charging enables customized charging schedules to better meet the needs of the PEV owner and grid. Essentially, the idea is that these approaches will reduce costs and displace the amount of energy needed to power an increasing number of PEVs.

Benefits Associated with an Increased EV Market Share

In addition to lower cost of ownership and fuel cost savings, greater PEV usage helps reduce emissions, improve health, and promote the economy. In 2017, the United States emitted about 6.5 billion metric tons of greenhouse gases (GHGs), 29 percent of which were derived from the transportation sector and 28 percent from electric power (*45*). These figures are expected to decline as more PEVs penetrate the market, prompting researchers to determine the value of emissions for policymaking. One of the most common methodologies used for monetizing the costs of emissions, health, and property is the Social Cost of Carbon, developed by the U.S. government's Interagency Working Group on the Social Cost of Greenhouse Gases (*46*). Models are also available for researchers to calculate the impact of emissions by inputting data for the area of interest. This section will discuss how emissions are calculated, the impact of particulate matter (PM) on human health, and other social and economic benefits as well as how these are monetized.

The reduction of GHG emissions is a prominent benefit of EV implementation, but how this reduction is quantified can vary across studies. In the context of EVs, GHG emissions can be simplified to both how the energy used by these types of vehicles is generated and by the type of EV, but other factors can be included in the calculations such as driving conditions, charging patterns, charging infrastructure availability, and government policies (*47*). EVs do not produce any tailpipe emissions, but it is critical to note how the fuel for these vehicles is produced. If electricity generation is mostly comprised of fossil fuels, then the reduction of emissions may not be as significant as energy generated by renewable sources. Similarly, the proportion of emissions released by PHEV compared to BEVs can differ according to vehicle fuel efficiency and non-electricity miles traveled, derived from switching PHEV to gasoline mode or from choosing an ICE vehicle for longer trips instead of a BEV (*48*). These factors combined are referred to as a "well-to-wheels" approach where emissions released all the way from fuel production to tailpipes are tallied throughout the vehicle's life.

Once the sources of emissions are identified, gasoline and electricity emissions are calculated using guidelines or models developed by national agencies, research institutions, and others. To quantify emissions from electricity generation, studies use an average emission factor (AEF) or marginal emission factor (MEF) model (*49*). An AEF takes the average emissions within an area, measured in grams per mega-watts-hour, and is then multiplied by the total energy consumption. An MEF approach is more detailed and captures the variation between regions and time of day as well as the types of fuels generating the electricity (*50*). When it comes to vehicle fuel consumption, emissions produced from gasoline are measured as grams of carbon dioxide equivalents (CO_2-e) per gallon of gasoline. For example, a study on the impact of EVs on the U.S. Mid-Atlantic and Northeast estimated the amount of CO_2 released per gallon of gasoline by using a ratio derived from the Electric Power Research Institute; this ratio incorporates tailpipe, transport, and production emissions making calculating GHG less complicated (*51*). This approach assumes that 10,800 g of CO_2-e is emitted per gallon of gasoline and will decrease to 10,477 CO_2-e per gallon by 2050 as ICE vehicles become more efficient (*51*). Emissions from PEV charging is measured as grams per kilo-watt-hour (g/kWh) from the electricity generated within a region or state and the type of fuel source. The AFDC has found that annually each PHEV releases roughly 5,500 pounds of CO_2-e while BEVs release 3,700 pounds of CO_2-e (*52*). In comparison, each gasoline vehicle emits 11,400 pounds of CO_2-e each year, roughly twice as much as a PHEV.

Health Impacts

The transportation sector not only emits GHG but is also a major contributor of harmful PM. PM are a mix of small solid and liquid particles classified by their diameter as either 10 micrometers (PM_{10}) or 2.5 micrometers ($PM_{2.5}$) and are comprised of anything from dust to harmful chemicals. PM are not the only air pollutants released from tailpipe emissions; some other examples include ozone (O_3), nitrogen oxides (NO_x), and carbon monoxide (*53*). Reports have found that air pollutants not only raise the likelihood of respiratory conditions like asthma, but can also lead to high blood pressure, dementia, and even premature death in people with an already vulnerable heart or lungs (*47*, *53*). PM exposure can also damage the environment and personal property. The integration of these fine chemicals can alter the pH balance of bodies of water, making them more acidic and less suitable for aquatic life, hurt plant life on the surface, and deteriorate buildings and important monuments (*53*). There is also a regional component to health benefits obtained from lower emissions. Although the greater use of PEVs will reduce emissions and PM, it has been noted that the greater use of PEVs will shift air pollution exposure from urban to rural areas, where energy generation facilities are located.

Lastly, from a health perspective, it is important to consider the benefits of reduced noise pollution. Vehicle noise is not only generated by the vehicle itself, but also from wind resistance and from tires making contact with the pavement. Traffic produces noise levels of 80 decibels (dBs), leaving drivers exposed to higher sound levels than recommended for long periods of time. For reference, noises higher than 65 dBs have been linked to higher blood pressure, stress levels, and heart rate (*54*). It has been found that switching to an EV can help reduce urban noise levels by at least 10 dBs (*55*). As such, this quieter alternative has the potential to improve the driving experience in urban areas and promote a healthier lifestyle.

To quantify the benefits of avoided health risks, models with varying degrees of complexity are available depending on the need, different types of data, and project scopes. A simplified approach is to find emissions produced from the total energy generated and to then associate those emissions generally to avoided health conditions. Models like the Regional Greenhouse Gas Initiative, Co-benefits Risk Assessment, and Benefits Mapping and Analysis Program (Community Edition), which are designed to measure total emissions, measure air quality, and calculate the value of health improvements, respectively, offer users the option to input their data (*56*). A more complex method takes into account the number of hospital admissions, which can be broken down further into the reason for the visit, emergency room visits, loss of workdays, chronic respiratory problems, and mortality.

Economic Effects

EV adoption also creates economic benefits like energy independence, promotion of local economy, and job creation. Roughly two thirds of the oil imported to the United States is reserved for transportation sector uses (*57*). Most expenses are incurred in securing oil through military intervention, which one study estimated to average $18 per barrel of oil or $0.95 per gallon of gasoline (*58*). This reliance on foreign energy sources makes the country vulnerable to price shocks and disruptions of supply. In contrast, most of the electricity used in the country is produced domestically making it a more secure and economically viable option. While 80 percent of funds spent on gasoline leaves the local economy, spending and savings on PEVs is returned to the local economy through the purchase of other goods (*58*). A study in Oregon determined that PEVs can increase state and local revenue from $426 to $1,503 per PEV in a span of 10 years (*59*). Another study on the benefits to utilities found that EVs can contribute about $4,100 per vehicle to the local economy (*60*). PEV adoption also promotes job creation through the manufacturing of EVs, batteries, and charging infrastructure and the higher demand in research and development fields. In 2019, there were approximately 250,000 workers employed in the United States in the EV sector (*61*). Roughly 16 percent of these workers were in the production of batteries and 76.5 percent were in the production of PEVs (*62*). This number is expected to grow, with California projecting a state workforce growth of around 394,000 by 2030 thanks to higher PEV sales (*63*).

Equity

While EVs and EV infrastructure present many benefits in terms of the environment, health, and the economy, these benefits are not always distributed fairly. Equitable EV infrastructure deployment requires investment in low-income, minority, and other previously disadvantaged communities. However, access to charging infrastructure is not the only piece that requires an equity focus. EV ownership trends show that lower income families and individuals are often priced out of an EV. The lack of access to infrastructure and affordable EVs has ripple effects in terms of additional benefits, which can cause further harm to these communities.

To understand how equity regarding EVs can be improved, it is important to identify who currently owns a PEV and what factors promote EV adoption. Studies researching PEV adoption controlled for incentives to determine if there is a relationship between customer demographics and PEVs. By strictly focusing on personal characteristics, it was found that higher income, total vehicle ownership, home ownership, preference for new technology, and environmental awareness all share a positive relationship with EV ownership (*26*, *64*). Specifically, households with an income greater than $200,000, with at least a bachelor's degree, and living in homes, not apartments, are more likely to own PEVs (*65*). Preferences surrounding BEVs and PHEVs can be broken down even further. Although both are EVs, those who prefer using carsharing services and HOV lanes are more likely to drive a BEV, while those who prefer to drive a PHEV feel less strongly about the environment (*65*). Policies such as financial incentives do help in making PEVs more affordable for low-income populations, but they need to be targeted to specifically benefit these populations. One example of this benefit are vehicle buy-back programs that allow individuals to trade-in older or less fuel-efficient vehicles and receive financial assistance for the purchase of an EV (*24*, *66*, *67*). The purchase of used PEVs can also be an option for those not wanting to buy a new EV at full price, which will become a lucrative option as more PEVs enter the market and household savings improve through these types of purchases (*68*).

Equitable deployment of EVs and EV infrastructure must be discussed as disadvantaged communities and communities of color are impacted disproportionately by pollution from vehicles. These communities will suffer greater rates of asthma, dementia, as well as increased pollution from other sources, such as industrial sites (*69*, *70*, *71*). Low-income communities often drive less, but tend to drive older, less fuel-efficient vehicles (*66*). Coupled with the high cost of BEVs and even PHEVs in some instances, neighborhoods with lower income households continue to experience the negative environmental effects of pollution without benefiting from the increase in EVs. While reducing the initial cost of EVs is part of the solution, increases in publicly available charging stations will be necessary to enable individuals and households to switch to a fully electric vehicle. A toolkit for government officials that focuses on making EVs accessible to communities of color and low-income populations emphasizes the need for access to public charging stations, along with greater EV awareness, EV affordability, and market diversification (*72*). If access to EV infrastructure in these communities remains limited, so will the related environmental, health, and even economic benefits. The jobs and increased investment from building out a charging network could cause these individuals to travel farther for work exacerbating health and environmental issues. Overall, policy and financial incentives should consider the communities that will benefit from them the most, which is often low-income and communities of color.

Approach and Methodology

The research team began by reviewing relevant literature to determine the appropriate assumptions, data sources, and calculations of the model. TTI's Transportation Revenue Estimator and Needs Determination System (TRENDS) model was leveraged for its AFV forecast as well as previous economic impact and benefit-cost models developed by the team. The first step was determining appropriate sources for both data and assumptions for the model. The research team identified previous work that could contain, or lead to, data sources related to EVs and charging infrastructure. The collected literature was then source-mined to develop a comprehensive literature as well as develop an understanding of the various organizations or tools that produce data that could help with the creation of the model. Some of the most prominent sources mentioned throughout the literature, and therefore used in this model, were obtained from TRENDS; AFDC; U.S. Department of Energy; the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) model; the Environmental Justice screening and mapping tool (EJSCREEN); the U.S. Department of Transportation (USDOT); IMPLAN; and others. Table 1 summarizes the main sources of data used to create the model.

Table 1. Data Sources for Model

Data	Description	Source
Vehicle Registration	PEVs registered in Texas and projections up to year 2050	TRENDS
PEV Infrastructure	Number of chargers, charger type, public or private station, and county location	AFDC
Charger Density	Number of chargers per 1,000 PEVs	U.S. Department of Energy
Infrastructure Costs	Charger level, equipment, labor, permits, and contracts	Rocky Mountain Institute
Emission Data	Miles per metric ton for VOC, NO_X, SO_2, $PM_{2.5}$, and CO_2	GREET
Emission Costs	$ per metric ton for VOC, NO_X, SO_2, $PM_{2.5}$, and CO_2	USDOT BCA/TREDIS®
Scenario	Provides charger location and environmental information for scenario	EJSCREEN
Economic Impact	EV installation economic multiplier for output, employment, and labor	IMPLAN

Data Collection Overview

Data collection occurred through set sources for economic impact and benefit-cost studies as well as from sources identified in the literature. EV registration and forecasts were obtained from the TTI TRENDS model. Information regarding the current EV infrastructure in Texas was also collected to calculate future equipment needs. Infrastructure data, obtained from AFDC, and initially broken down by each city in Texas, include the number of chargers, charger type, and whether it is a public or private station. To determine the current and future infrastructure need, the figures from the U.S. Department of Energy's 2017 report on charger density needed to meet demand were used. Costs related to charging infrastructure were also collected. These costs vary by charger type and capacity, the number of chargers per site, labor, permit requirements, and taxes and were collected from a number of studies, including a report by the Rocky Mountain Institute (*73*).

If data were not readily available, the research team entered information into available models to obtain information on other costs, emissions, and projection numbers and scenarios. The team first found the average emission rates released by passenger EVs. Emission rates, measured as miles per metric ton, for VOC, NO_X, SO_2, $PM_{2.5}$, and CO_2 were all obtained from GREET. The GREET model allows the user to select a region or state to accurately reflect the energy mix in terms of natural gas, coal, wind, and other energy sources. The research team used the energy mix for Texas to accurately reflect the environmental costs related to charging an EV within the state of Texas. Costs, measured per metric ton, were also paired to each emission rate using the averages provided in USDOT's Benefit-Cost Analysis (BCA) Guidance and Transportation Economic Development Impact System (TREDIS). Additional environmental data and potential charging station locations for scenarios were determined through EJSCREEN. TTI TRENDS provided the EV registration projection numbers for each county in Texas up to year 2050. Lastly, to conduct the economic impact analysis of installing EV infrastructure, the team used data obtained from IMPLAN for each economic region in Texas. Economic regions are determined by the Texas Comptroller (*74*).

Methodology

The model's benefit-cost analysis begins by calculating the vehicle operating cost savings totaled over a 10-year period. These savings are estimated by first determining the change in vehicle miles traveled (VMT). The baseline average travel distance to charging infrastructure assumes the average EV traveled 5,300 miles per year or

14.5 miles per day.[1] Assuming a round trip, the average driver travels 7.3 miles each way. With additional infrastructure, the model's proposed average travel distance to charging infrastructure is defaulted to 3 miles making the change in VMT 4.3 miles per week.[2] The estimated number of EVs located in the selected region is divided by the number of baseline chargers in existence for that region to determine the current number of EVs per charger. The EVs per charger are multiplied by 4.3 miles and 52 weeks to determine the annual reduction in VMT per additional charger.

The annual reduction in VMT is then multiplied by an EV operating cost per mile and an EV ownership cost per mile (*75*).

VMT Savings x (Vehicle Operating Cost per Mile + Vehicle Ownership Cost per Mile)

Next the model calculates the estimated value of time savings. The VMT calculated above is divided by an average 35 miles per hour to determine the change in vehicle hours traveled (VHT). The VHT is then multiplied by the cost per hour per occupant and then by the average passenger vehicle occupancy (*76*).

(Hourly Value of Travel Time x Passengers per Vehicle) x VHT Savings

Societal benefits include both safety and environmental benefits. Safety benefits are estimated by assuming a fatality and injury rate per VMT. The reduced VMT is used to determine the reduction in fatalities and injuries and a societal cost is applied to both.

VMT Savings x Fatalities per VMT x (Fatal Crash Cost / Fatalities per Fatal Crash)

VMT Savings x Person Injuries per VMT x (Injury Crash Cost / Injuries per Injury Crash)

Environmental benefits are calculated using emission rates reported in tons or grams per mile. The emission rate is multiplied by the emission cost for each emission type (NO_X, SO_2, $PM_{2.5}$, and CO_2) (*76*).

(Mileage-Based Emission Rate x Emission Cost) x VMT Savings

The costs include both the installation cost and the infrastructure cost. These costs are calculated based on the number and type of charger to be installed. The infrastructure cost component can use a low, average, or high cost and is determined by the user. These costs are then subtracted from the total benefits to determine the net present value and a benefit-cost ratio.

The model also estimates the economic impact. Economic output is estimated by multiplying the total infrastructure cost (including installation) by IMPLAN multipliers for the region. A multiplier is a factor that proportionally expands the effect of an economic input. The change in transportation costs resulting from the reduced travel to a charger will be used as an economic input. Production, labor, and wage multipliers will be applied to calculate the regional impact resulting from the change in transportation costs.

[1] "Adjusted for the share of out-of-home charging, the electricity consumed translates to about 5,300 electric vehicle miles traveled (eVMT) per year—roughly half as large as EV driving estimates used by regulators and also half as large as vehicle miles traveled in gasoline-powered cars." Green Car Congress. *Study finds EVs are traveling less than half the US fleet average*. February 2021.

[2] Model assumes 1 public charge per vehicle, per week (52 weeks annually).

Economic Benefit Tool Overview

The economic benefit tool for EV infrastructure provides planners and policymakers with an overview of the economic benefits associated with investing in charging stations for EVs. The tool, shown in Figure 3, provides a simple user interface to show the required infrastructure, based on forecasted EV adoption rates, and associated costs then presents their potential economic benefit. The section will present an overview of the tool emphasizing areas for user input and the underlying data and calculations behind the model.

INPUTS	
Where would you like to examine charging infrastructure needs?	
Abilene	MSA
Please choose an electric vehicle adoption scenario:	
Average Adoption	Scenario
Baseline number of chargers:	
Level 2 Public Chargers:	6
DCFC Public Chargers:	0
Proposed number of chargers:	
Level 2 Chargers Needed (2025):	14
DCFC Chargers Needed (2025):	1
Baseline average travel distance (miles) to charging infrastructure:	
7.3	Miles
Proposed average travel distance (miles) to charging infrastructure:	
3.0	Miles

Note: Default of 3 miles used.

Infrastructure Costs	
Number and type of Charger to Install:	DC Fast (150kW) (6 Chargers per Site)
Installation Cost:	$18,577
Infrastructure Cost (Low):	$493,265
Infrastructure Cost (Average):	$577,833
Infrastructure Cost (High):	$662,400
Cost to Use for Analysis:	Average

OUTPUTS	
Benefits and Costs	Value (2019$)
Vehicle Operating Cost Savings	$748,218
Value of Time Savings	$2,908,483
Safety Savings	$1,340,851
Envrionmental Benefits	$75,802
Total Benefits	$5,073,353
Installation Cost	$18,577
Infrastructure Cost	$577,833
Total Cost	$596,410
Net Present Value	$4,476,944
Benefit/ Cost Ratio	8.5

Discounted at 3%

Economic Impact	
Economic Output	$920,591
Labor Income	$774,654
Employment	684,715

Figure 3. Overview of the economic benefit tool.

Input-Output Sheet

The "Input-Output Sheet" forms the basis of the tool, which is where the user will select inputs in terms of region, charging needs, distance to charging infrastructure, and anticipated infrastructure costs. Cells highlighted in yellow offer options for user input or can be edited. The Outputs, which include the benefit-cost analysis and the economic impact analysis, are then presented based on the inputs.

Inputs

Users will first select their region from the dropdown menu. The focus of this research was metropolitan areas in Texas, so the geographic category of metropolitan statistical area (MSA) was used. If a user resides outside of a major metro area, there is a "Rest of Texas" option that provides average values for non-metro areas in the state. The tool provides two adoption scenarios: slow and average. The AFV forecasted adoption rates from TTI TRENDS model were used in the tool to present these two adoption scenarios. After an adoption scenario is chosen, the tool provides the current number of charging stations, both Level 2 and DCFC, in the MSA from AFDC. The proposed number of chargers is based on research from the U.S. Department of Energy in 2017 and will be explained further in the Model Data Section. The average distance to charging infrastructure assists with the benefit-cost calculations; the tool assumes a baseline average distance of 7.3 miles and a proposed distance of 3 miles. The user can edit these inputs if they have better data or knowledge of the typical distance to charging infrastructure for their metro area.

Infrastructure Costs

The Infrastructure Costs section allows the user to select the number and type of charger to install; the tool includes cost estimates for Level 2 and DCFC chargers as well as multiple charging station configurations based on number of chargers and kW. Installation costs do vary, so the tool provides low-, average-, and high-cost estimates. The default is average, but this can be changed using the dropdown menu.

Outputs

Outputs are presented in terms of benefits, costs, and economic impacts, all of which are in 2019 dollars. The USDOT BCA guidance along with data from TREDIS were used to calculate the benefits. The benefits arise from reduced travel time as charging infrastructure is better dispersed throughout the metro area as well as environmental benefits relating to switching from ICEs to EVs. The infrastructure costs selected by the user form the costs, which includes both physical infrastructure and installation costs but does not consider the cost of maintenance or the potential full operating costs. Results are shown in net present value and a benefit-cost ratio.

Economic Impact

Economic Impacts were determined using IMPLAN multipliers specific to each metro area. These economic impacts relate to the installation of the charging infrastructure and the increased employment that such an investment would create for each region. The economic output includes the annual direct, indirect, and induced impacts. Output includes labor income and value added. Employment includes direct, indirect, and induced jobs supported by the investment in charging infrastructure.

Model Data

The tool spreadsheet includes a number of other tabs with the underlying data and assumptions. This section will provide a brief overview of each, but more information can be found in the Data Collection & Methodology section on the key inputs and assumptions for the tool.

The BCA tab includes the calculations for the benefit-cost analysis on an annual basis; the tool utilizes 10 years as the probable life of the charging asset. A discount rate of 3 percent is used per USDOT BCA guidance.

The Economic Impact tab includes the IMPLAN multipliers for each region in terms of output, employment, and labor for the relevant industry sector for EV infrastructure.

The Current Infrastructure tab includes information on distance between charging stations, as calculated using ArcGIS, as well as the average distances that were used as baseline inputs.

The EV sheet includes the forecasted number of EVs in each metro area for both the slow and average adoption scenarios. The forecasted AFV counts are taken from the TTI TRENDS model, which forecasts AFVs by county for revenue considerations.

The Required Infrastructure tab uses the forecasted number of EVs per metro area to determine the number of charging points or stations required to meet demand. The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy conducted a study to determine the charging needs of EVs in the future. The number of chargers required per 1,000 PEVs in a major city was used as a baseline for the calculator.

The Adoption Scenarios sheet combines data on forecasted EVs, current infrastructure, and required infrastructure to form the baseline and proposed scenarios in the Input-Output sheet.

Finally, the Default Values sheet contains the calculations and assumptions for the benefit-cost analysis. These default values are from USDOT's guidance of benefit-cost analysis for 2021.

Scenario Analysis

The Economic Benefit Calculator for Electric Vehicle Infrastructure was tested and applied using three different scenarios for different Texas metro areas in the state. The research team selected the metro areas of Austin for Scenario 1, Tyler for Scenario 2, and Houston for Scenario 3. These scenarios take into account additional factors that are not included within the tool, such as broader social, environmental, and health impacts. The first scenario models the economic impact of Austin's Community Climate Plan (CCP). Austin's CCP identifies more than 130 actions to achieve the Austin City Council's goal of reaching net-zero community-wide GHG emissions by 2050 (*77*). The plan includes three different EV adoption forecasts, which are compared to updated estimates of EV adoption. Meeting climate goals will require investment in reducing transportation emissions, but economic benefits do arise from this increased investment. The first scenario highlights these benefits. The second scenario analyzes the difference between slow and moderate adoption forecasts for the smaller urban area of Tyler. Smaller urban areas may experience different trends in EV adoption and therefore require less infrastructure initially. This scenario addresses the difference between slow and moderate adoption trends and how that may impact planning processes and economic benefits in the short term. Finally, the third scenario focuses on an equitable deployment of EV infrastructure. The scenario chose three different locations in the Houston metro area to show the impact to underserved communities, such as low-income and minority populations. Low-income and majority-minority communities often suffer the worst air quality within urban settings and therefore suffer greater health consequences from that exposure. Investment in these communities can provide additional benefits alongside those presented in the calculator. The third scenario addresses these impacts to highlight the importance of effective siting for any charging infrastructure investments.

Austin Community Climate Plan—Policy Scenario

This scenario determines the potential infrastructure needs under the CCP and presents both the cost of installing the additional charging stations as well as the economic benefits. Austin's CCP provides a number of strategies to meet their climate goals beyond just transportation; these strategies relate to utilizing renewable energy sources and reducing waste both through the city procurement process and by promoting recycling and diversion of materials to another use by residents and businesses. In terms of transportation, EVs are one of many strategies that also promote alternative modes, such as walking and biking as well as transportation demand management to reduce congestion through increased use of transit. In terms of EVs specifically, the CCP includes three different forecasts that represent low-, mid-, and high-end adoption rates of EVs. These forecasts model the required renewable energy to ensure the full environmental benefits of EVs. The scenario in this report will use the current energy mix of Texas rather than modeling a switch to full renewable energy. The calculator is focused on the year 2025, so it may not be possible for Austin to scale renewable energy production in that timeframe. Table 2 shows the number of EVs in each forecast, and these EVs are modeled through the calculator to provide an overview of economic benefits for Austin's CCP.

Table 2. Austin Community Climate Plan EV Forecasts

Forecast	Number of Battery Electric Vehicles
Low Adoption	300,000
Mid Adoption	600,000
High Adoption	1,200,000

Small Urban Area—Slow Adoption Scenario

Not all Texas metros will adopt EVs at the same rate, and the incentives will initially be higher to make the switch from an ICE vehicle to an EV in larger urban areas. The second scenario models this slower adoption rate for Tyler, Texas, as the city may see slower growth in terms of EV purchase and usage. The Tyler metro area had a population of 235,806 in 2020 (*78*). The healthcare sector is the largest employer in the region (*79*). A comparison between the moderate/average and slow adoption scenario describes the different infrastructure needs and the most cost-effective method for meeting those needs. In addition, the potential for investment in infrastructure by key industries in the Tyler region will be discussed to address the impact of commuting and commuter charging needs. This scenario highlights the two different scenarios provided by the tool for regions that may experience a slower adoption rate in the next few years. This scenario also assesses the financial needs to meet the lower end adoption expectations and prepare smaller metro areas in Texas for the financial cost as well as the economic benefits associated with such an investment.

Health & Emissions in Houston—Equity Scenario

The third scenario focuses on the equitable deployment of charging infrastructure across the metro area. The research team selected three different neighborhoods or communities for investment and assessed the difference in impact when considering equity. In contrast to the previous two examples, this scenario uses additional environmental and health data to model the increased benefit of deploying additional charging infrastructure in disadvantaged and often underserved neighborhoods. Although demand may initially be lower in these communities, the benefits are expected to be greater when considering current air quality, environmental issues, and historic practices that have emphasized inequities. The different site locations focus on underserved groups in transportation with a comparison site representing a suburban neighborhood in the Houston metro area. Data from EJSCREEN were used in selecting the neighborhoods as well as for calculating the difference in environmental and health effects (*80*). The assumptions and methodology for determining the health benefits in dollars were determined through a review of the literature.

The following neighborhoods were chosen for this analysis: the Third Ward, North Shore, and a neighborhood in Friendswood. The City of Houston has a median income of $52,338 (2019) with 20.1 percent of the population living below the poverty line (*81*). More than 24 percent of the population identifies as white alone with 45 percent identifying as Hispanic or Latino. Nearly 22.6 percent of the population identifies as Black or African American, 6.8 percent as Asian, and 2.2 percent as two or more races. Table 3 presents the demographics for the three sites focusing on poverty level and percent of the population that identifies as people of color (POC) as well as Environmental Justice (EJ) indices relating to transportation. The EJ indices calculated by the U.S. Environmental Protection Agency (EPA), and provided through EJSCREEN, combine the environmental data with the low-income and minority populations to highlight the disparities in majority low-income or minority block groups compared to average values for that environmental factor (*82*).

Table 3. Demographic and Emission Overview for Houston Neighborhoods

	Third Ward	North Shore	Friendswood
Percent POC	90	85	27
Percent Low-Income	48	55	4
EJ Index for Traffic Proximity & Volume (%ile in State)	90	91	23
EJ Index for Particulate Matter ($PM_{2.5}$) (%ile in State)	65	69	9
EJ Index for Ozone (%ile in State)	61	64	12

In calculating the health impacts (in dollars), data were collected on emissions for each neighborhood using EJSCREEN and reduction in emissions from EVs versus gasoline vehicles from the GREET model (*83*). The GREET model estimates consider the energy mix of Texas when calculating reductions in emissions. The analysis used a 7 percent switch from ICEs to EVs for the year 2025 based on the underlying forecasts in the tool. Then the health impacts were determined through the literature on the mortality effects of exposure to emissions, specifically $PM_{2.5}$ and O_3, and were converted into dollars using the value of statistical life from EPA (*84*, *85*, *86*). $PM_{2.5}$ levels for the three neighborhoods were used in determining the number of premature deaths due to exposure (*80*). All three neighborhoods met the low concentration cutoff for O_3 based on the literature; therefore, the reduction in premature deaths was considered the same for this analysis. The O_3 premature deaths only cover attributable respiratory deaths (*86*). Premature death estimates were adjusted based on the population covered by this analysis and to only cover the emissions that can be attributed to the transportation sector from each source (*87*, *88*). Transportation sector responsibility for emissions includes commercial as well as passenger transportation.

This calculator and analysis focuses on passenger transportation, so an adjustment was made to only include emissions attributable to on-road, non-diesel vehicles as a proxy for passenger vehicles (*89*).

Results

The results from each scenario are presented in this section in terms of both benefit-cost and economic impacts; these results are reported as a benefit-cost ratio and total economic output. The third scenario that focuses on equity also includes health benefits that relate to a reduction in premature deaths from switching to electric-powered as opposed to ICE vehicles.

Austin Community Climate Plan—Policy Scenario Results

The Austin CCP scenario results are presented in Table 4 for a 10-year period beginning in 2025 and ending in 2034. The low adoption analysis assumes a 25 percent average annual growth rate while the mid and high adoption analyses assume a 34 percent average annual growth rate. The growth rate refers to the forecasted growth in EVs derived from the TTI TRENDS model. For infrastructure costs, the analyses assume an average cost and include Level 2 and DCFC chargers (150kW).

Table 4. Austin Community Climate Policy Scenario Analysis

	Low Adoption	Mid Adoption	High Adoption
Number of Level 2 Chargers Required	10,800	21,600	43,200
Additional Level 2 Chargers Needed	9,728	20,528	42,128
Number of DCFCs Required	450	900	1,800
Additional DCFC Chargers Needed	345	795	1,695
Total Benefits (millions)	$16,700	$19,900	$26,200
Total Installation Cost (millions)	$30	$64	$131
Total Infrastructure Cost (millions)	$940	$1,980	$4,070
Benefit-Cost Ratio	17.3	9.7	6.3
Total Economic Impact (millions)	$1,750	$3,700	$7,590

The results indicate that, to meet climate goals, Austin needs to invest in public charging options across the city and promote expansion around the metro area. The Austin CCP is aiming for these adoption rates by 2050, while our tool is showing the investment over a 10-year period starting in 2025. Infrastructure costs may decrease over time as economies of scale and technology reduces costs at different stages of the process. However, even with the higher costs shown in the scenario, the economic benefits still outweigh the initial investment. The City of Austin and the surrounding metro area needs to increase the availability of public charging in key areas today to enable the eventual transition to EVs for the majority of their residents. This investment will ultimately support the local economy regardless of whether the low or high adoption rate is achieved and supported through charging infrastructure.

Small Urban Area—Slow Adoption Scenario Results

The Small Urban Slow Adoption scenario results are presented in Table 5 for a 10-year period from 2025 to 2034. Similar to the Austin CCP scenario, a 25 percent average annual growth rate was assumed for the slow adoption analysis, and a 34 percent average annual growth rate was utilized for the average adoption analysis. For infrastructure costs, the analyses assume an average cost and includes only Level 2 chargers. The Tyler metro area already has eight DCFC chargers available for the public to use. Since this provision meets the needs in 2025, no additional investment in DCFC would be required under either scenario. The presence of additional fast chargers provides good options for those traveling through Tyler that need a faster charge option; these DCFCs also show a preparedness for the forecasted increase in EVs.

Table 5. Small Urban Area Slow Adoption Scenario Analysis

	Slow Adoption	Average Adoption
Number of Level 2 Chargers Required	14	35
Additional Level 2 Chargers Needed	2	23
Number of DCFCs Required	1	1
Additional DCFC Chargers Needed	N/A	N/A
Total Benefits	$1,698,000	$19,523,000
Total Installation Cost	$3,000	$8,800
Total Infrastructure Cost	$9,700	$112,100
Benefit-Cost Ratio	23.3	14.0
Total Economic Impact	$20,600	$195,900

The results from the second scenario present the potential for slower adoption rates in smaller urban areas in Texas. The majority of growth in EVs is expected to stay within denser urban environments with more short trips that reduce the potential for range anxiety. Tyler is a smaller metro area that is well prepared, based on the results of our analysis, for a greater switch to EVs. Targeted investments in the next few years would position the region well to meet charging demands in the future. The current availability of fast charging provides a great option for both residents and those traveling through the metro area, but a greater number of Level 2 options could support businesses, shopping centers, and multi-family dwelling neighborhoods. This investment would also support the local economy, shown through the economic impact results, by providing additional jobs and wages related to installations. The new charging facilities would also bring travel, environmental, and safety savings, as shown in the benefit-cost ratio, by reducing the distance to charge a vehicle.

Health & Emissions in Houston—Equity Scenario Results

The Equity Scenario modeled the impact of siting a Level 2 charging station, with two charging points, and a DCFC charging station (150kW) with one charging point in three different neighborhoods within the Houston metro area. The benefit-cost ratio and economic impacts reflect the impact to the metro area as employment cannot be guaranteed to be derived from these neighborhoods. The health benefits reflect the reduced mortality risk associated with improved environmental conditions; current environmental data on each neighborhood were used for the health analysis.

Table 6 provides an overview of the economic benefits relating to installing one Level 2 charging station, with two charging points, and one DCFC charging station with one charging point. The calculator uses the Houston metro area as a geographic unit of analysis so the benefits would be similar for each neighborhood. The overview presents the total economic benefits for one year to the Houston metro area as a whole.

Table 6. Health & Emissions Scenario—Economic Benefit Overview

	Average Adoption—Houston Metro Area
Additional Level 2 Chargers	2
Additional DCFC Chargers	1
Total Benefits	$4,340,000
Total Installation Cost	$48,500
Total Infrastructure Cost	$93,400
Benefit-Cost Ratio	30.6
Total Economic Impact	$265,600

The third scenario focuses on the potential equity impacts to health in terms of charging station location. Three neighborhoods were chosen to highlight the impact to EJ neighborhoods of investment. Table 7 shows the annual benefits relating to the reduced exposure to pollutants, specifically $PM_{2.5}$ and O_3, from transportation.

Table 7. Health Benefits to Houston Neighborhoods

Neighborhood	Health Benefits ($)
Third Ward	$8,005,000,000
North Shore	$8,004,700,000
Friendswood	$7,999,700,000

The health benefits relate to reducing the number of premature deaths due to transportation emissions; the dollar amount shows the value of reduced mortality risk. In reality, the health benefits from reducing emissions would be higher as cost savings could be realized due to lower respiratory illnesses and incidences of cancer due to these exposures. Lower income and majority-minority populations tend to be at higher risk due to both socio-economic determinants of health and increased exposure (*90*, *91*). In addition, exposure to high traffic levels in urban areas can be especially harmful to heath (*92*). The two neighborhoods chosen for analysis have high exposure to traffic based on data from EJSCREEN as opposed to the comparison neighborhood of Friendswood. These two neighborhoods also have higher levels of $PM_{2.5}$ and O_3 than the comparison neighborhood. True health impacts would need to take into account other risk factors, the actual levels of O_3 in these neighborhoods, and potential savings from improved health outcomes overall rather than just reduced premature deaths.

Discussion

The three scenarios show the potential varying infrastructure needs across metro areas in Texas; however, the results all show that the benefits of installing charging stations outweigh the cost. Increasing infrastructure needs will lead to jobs in both installation and manufacturing of parts; Texas is poised to meet these demands through its well-established, and still growing, tech industry, as well as the manufacturing capabilities in the Dallas–Fort Worth area. The first scenario highlights the impact of rapid EV market share growth in a city that is known for focusing on the environment and climate-friendly policies. Regardless of the adoption rate, the City of Austin will need to install additional charging infrastructure to meet demand. The Tyler metro area scenario results show that they have enough fast chargers to meet their needs but should consider investing in more Level 2 charging stations to fill in the gaps and provide an alternative if the fast charger is in use. Finally, the equity scenario results highlight the differing environmental conditions across a metro area and how reducing transportation emissions can be a part of an equitable climate solution. This scenario also shows the importance of charger siting decisions when considering an equitable deployment of EV infrastructure. This section of the report will discuss the implications of the results from each of the three scenarios.

The Cost of Climate Goals in Austin

In 2025, the number of EVs within the Austin metro area is forecasted to be approximately 87,000 under the average adoption scenario in the tool. In 2034, the number of EVs increases to approximately 1.2 million. The Austin CCP estimates the number of EVs within the area reaching between 300,000 and 1.2 million by 2050 to meet climate goals. The scenario analysis attempts to estimate the costs and benefits of meeting the goals but does not consider potential savings from economies of scale or technological advancements that may reduce the costs of charging infrastructure. EV forecasts indicate that Austin may reach 1.2 million EVs years before 2050, and therefore needs to plan accordingly to meet infrastructure needs. While the benefit-cost ratio is reduced as more EVs are incorporated from the low, medium, and then high scenarios in the climate plan, each adoption scenario would present a benefit to the Austin metro area. The City of Austin could use these results to leverage partnerships to install charging stations or justify their own investments.

As Austin scales their EV infrastructure, the focus should be on effective locations for these chargers that provide the most benefit to both the city and its residents. Single-family homes can often support a home charging system or vehicles can often be plugged into a traditional socket to charge. However, multi-family dwellings such as apartment complexes and townhomes often cannot accommodate charging at home due to lack of infrastructure or space to access outlets. Public chargers in residential neighborhoods should be focused on those without options at home. Other charging station locations could include areas of high employment or leisure destinations where people will spend more time and can charge their vehicle for a few hours rather than needing a rapid charger. The rapid chargers work best for those passing through town or heading further outside of Austin requiring more range.

Preparing a Small Metro for EV Expansion

Cities of all sizes will need to prepare and consider a transportation system that is more electric than our current system. However, the adoption rate of smaller metros may be slower, which allows them more time to prepare and carefully choose locations for charging infrastructure that allows for optimal public charging as well as supports a transition for fleet and commercial vehicles in the area. Tyler is a smaller metro area in the state of Texas whose primary employers are hospitals and school systems (*93*); these campus environments provide perfect locations to test and eventually fully install EV charging infrastructure. High employment centers, especially hospitals where the opportunities for remote work are reduced, also offer the possibility of public-private partnerships that can help reduce the cost of installing, operating, and maintaining the infrastructure. The Tyler metro area may also consider public charging for residential areas where the rates of home ownership are low, or the majority of the house is multi-family. Investing in EV charging infrastructure in these areas can work to incentivize individuals to switch to an EV as concerns over charging capabilities at home or range anxiety may be reduced. Leveraging private funding for employment center charging could help the city and region leverage publicly available funding to support residential charging as well. Overall, the Tyler metro area is well positioned for an increase in EVs, and a modest investment in the next few years could both incentivize and enable a greater transition to electric transportation.

The Importance of Equity for EV Infrastructure

The switch to EVs from ICEs has benefits for the user in terms of reduced cost over the life of the vehicle, both in terms of fuel and maintenance, but also improves environmental conditions by reducing emissions from transportation (*94*, *95*, *96*). These benefits would likely accrue within wealthier neighborhoods due to the high initial purchase price of an EV as well as the limited used market. As governments consider investment priorities and potential for charging infrastructure, equitable distribution of benefits and burdens must be kept in mind. Providing charging stations in EJ neighborhoods is one piece of incentivizing the switch to EVs and providing a fair portion of the benefits to these communities. This fairness is especially important when the current environmental conditions of these neighborhoods are considered as they often suffer from negative health impacts due to increased traffic levels and therefore increased emissions. The equity scenario attempted to address these considerations by calculating the potential benefits and costs of selecting EJ neighborhoods for charging infrastructure investment. The results shown in this scenario offer a limited slice of the potential benefits; greater health and quality of life benefits could be realized, which were not covered in this analysis.

The results highlight both the economic benefits to the entire region as well as the health benefits associated with reducing premature deaths; the two EJ neighborhoods would see greater benefits due to their current pollutant levels. However, to truly realize these benefits, investments in charging infrastructure alone is not enough. Cities and regions must incentivize the switch to EVs for lower-income families and individuals by providing affordable options, such as used EVs or programs that reduce the cost of a new vehicle. In addition, switching fleet and transit vehicles to fully electric will have an impact on these neighborhoods due to the volume of traffic they experience on a daily basis. Overall, greater benefits can be realized than shown in this analysis through a multi-pronged approach that allows for a range of transportation options, including a switch to fully electric vehicles.

Each scenario highlights the benefits that arise from increased charging infrastructure in Texas metro areas. The Austin and Houston scenarios highlight the needs of larger urban areas when considering climate goals and equity. The Tyler metro area offered an example of slower growth in EVs for smaller or mid-sized urban areas, which highlights that charging infrastructure can be scaled in smaller metro areas without a large upfront investment, as well as emphasizes how prepared smaller metros could be in slower growth scenarios. Although there are key differences in charging infrastructure between urban, small urban, and rural communities, each metro area needs to carefully consider charger locations for ease of access and equity, the potential impacts to the electric grid of an influx on charging infrastructure in the area, as well as other policies to incentivize the switch to EVs if the metro area is hoping to improve environmental conditions or meet climate goals.

Conclusions and Recommendations

The introduction and expansion of EVs and therefore EV infrastructure, such as charging stations, will have a number of impacts on cities and regions from improved environmental outcomes to subsequent health impacts. However, another key impact to consider is the economic value of investing in EV infrastructure. The economic benefit tool is designed to assist policymakers and planners with justifying the economic case for public investment in EV chargers. The tool presents the economic benefits relating to reducing travel to charging stations, in terms of time, safety, and the environment, as well as the employment and wage impacts relating to installation and maintenance. Understanding the economic impacts and benefits of charging infrastructure is an additional piece that can provide an incentive to invest. The scenarios highlight that smaller metro areas can even benefit from low levels of investment that boost their capabilities in terms of meeting charging demand. While larger metros may need a greater investment to meet their needs, this investment will ultimately provide environmental, safety, and economic benefits to their region. Key decisions will need to be made on the location of charging stations, the potential impacts to the power grid, and revenue models to cover operational and maintenance costs. Location decisions must consider demand, current infrastructure placement, as well as equity. The equity scenario highlights the potential for greater benefits from siting chargers in neighborhoods that suffer from worse environmental outcomes currently. Investing in these neighborhoods can help to incentivize purchases of EVs by reducing anxiety over charging availability or range, but planners and policymakers should also consider options to reduce the high initial purchase price of an EV. The larger investment costs of the climate policy scenario indicate a need to consider potential revenue models or public-private partnerships to reduce the burden on local governments. Overall, the economic benefits of installing EV infrastructure are clear, but there can still be a high upfront cost for larger metros that must be taken into consideration.

The tool and subsequent scenario analysis have highlighted some key considerations for investing in EV infrastructure as well as areas that require further research. The following recommendations present best practices for utilizing the tool as well as additional considerations that are needed when investing in charging infrastructure:

- The economic benefit tool should be used to justify investments in charging stations and related infrastructure. The tool shows the potential costs as well as the impacts related to employment and wages from those costs.
- In addition to utilizing the tool, the research team recommends that equity as well as demand be considered for charging station sites.
- EV sales forecasts indicate an increased need for charging stations over the next few years. Cities and regions should be preparing today by considering charging needs, potential costs, as well as benefits.

In addition, further research is needed in terms of both charger siting and additional environmental and health impacts. Planners and policymakers will need further assistance with siting charging infrastructure based on a number of factors, including access; demand; availability of other infrastructure; as well as equity, environmental, and health factors. In making those decisions, better data on the time to charge, electricity needs, and true range of each vehicle will be required. The public nature of these charging facilities will also necessitate a consideration of the different privately owned charging options within their region. Public facilities should be compatible with the majority of EVs and sited in areas with low charging availability, which should consider manufacturer-provided chargers that are not compatible with other EVs on the road. In addition, to understand the true economic impacts relating to increasing access to charging stations and incentivizing EV ownership, more data on the environmental and health aspects of installing chargers, as well as reducing ICEs on the road, are required. The scenario analysis presented in this report only considered the impact related to premature deaths, but the increased environmental and health cost savings will arise from improved respiratory health and reduced cancer risk as well.

Outputs, Outcomes, and Impacts

The research conducted for this study produced a basic economic impact tool that can be easily utilized by key stakeholders. A spreadsheet model reduces the need for additional software while providing flexibility for the user to alter or edit inputs to their situation.

In terms of outcomes, the research highlights the benefits, beyond enabling users to charge their EVs, of investing in EV infrastructure. The tool can be used to support the expenditure of public funds to provide charging infrastructure in metro areas across the state of Texas.

Successful implementation of the tool should lead to economic benefits in Texas metros by providing employment opportunities in terms of charging infrastructure installation and manufacturing. In addition, a reduction in economic and health costs related to a greater number of EVs has significant benefits to urban environments.

Research Outputs, Outcomes, and Impacts

From the research conducted, the team is developing a paper that showcases the economic impact tool and the subsequent scenarios. The paper will be submitted to a relevant peer-reviewed journal for consideration in the first quarter of 2022. The research team is also preparing to present the findings at the next Center for Advancing Research in Transportation Emissions, Energy, and Health symposium. In addition to academic distribution, the team is exploring ways to engage policymakers and planners to make the tool available for their use.

Technology Transfer Outputs, Outcomes, and Impacts

The economic benefit tool is a key technology transfer from this project. The tool and this report details the data compiled to create the tool, which allows for the user to update or edit inputs if better data are available in the future. The tool was designed to be easy to use and implement by policymakers and planners that may not have access to complex software.

Education and Workforce Development Outputs, Outcomes, and Impacts

The study supported the employment of two students throughout its duration. A graduate student at the Ph.D. level who completed her dissertation and degree during the study period, Nishita Sinha received her doctorate in agricultural economics and is now a full-time researcher at TTI. Brittan Rhome is in the final year of his economics undergraduate degree. Both students were invaluable members of the team and have been able to utilize the knowledge gained through their respective degree programs within this study.

The research and results of this study will also inform educational materials for a new master's course offering by both TTI and Texas A&M University's Department of Multidisciplinary Engineering. The tool highlights a new section on concepts in transportation economics, including the ripple effects of investments on the regional economy as well as cost-benefit analysis.

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