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Advancing Understanding Of Opinions, Perceptions, And Knowledge In Underrepresented Communities In The El Paso Region To Promote Electric Vehicles And Electrified Infrastructure Use To Reduce Environmental Impacts

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ADVANCING UNDERSTANDING OF OPINIONS, PERCEPTIONS, AND KNOWLEDGE

IN UNDERREPRESENTED COMMUNITIES IN THE EL PASO REGION

TO PROMOTE ELECTRIC VEHICLES AND ELECTRIFIED

INFRASTRUCTURE USE TO REDUCE

ENVIRONMENTAL IMPACTS

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Dedication

To Cassius, with all my love.
And to the owner of the universe
who has profoundly loved me in your absence.

Aaron, you live in my heart.

Aria, thank you for giving me back my life.
One day, we will be together again. I promise you!

Yuyi, Julio, and Dan, amidst the insanity of life itself, we bloomed.

ADVANCING UNDERSTANDING OF OPINIONS, PERCEPTIONS, AND KNOWLEDGE IN UNDERREPRESENTED COMMUNITIES IN THE EL PASO REGION TO PROMOTE ELECTRIC VEHICLES AND ELECTRIFIED INFRASTRUCTURE USE TO REDUCE ENVIRONMENTAL IMPACTS

by

LILIANA LOZADA MEDELLIN, BS, MSCM

DISSERTATION

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

Environmental Science and Engineering

THE UNIVERSITY OF TEXAS AT EL PASO

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Lastly, Goddess of the Lab, you are a unique human species—kind, caring, generous, and a brilliant genius. Thank you for believing in me and accepting me exactly as I am. And for always being there for me, regardless of the topic, the time, or dos mas dos cuatro, lol. I am fortunate you are my friend.

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Chapter 1: Introduction

As the transportation and automotive industries continue growing, environmental and human health impacts remain a growing concern for planners, policy-makers, constructors, and the public as well *(Krause et al., 2013; Larson et al., 2014).* Although Electric Vehicles (EVs) are entering the market as a green technology solution to counteract greenhouse gas (GHG) emissions from internal combustion engine vehicles (ICEVs), there are still barriers that need to be overcome for widespread diffusion and adoption as the best solution. These include disseminating basic information about the technology for public awareness, considering equity concerns, and ensuring equitable access to infrastructure for all *(L. Lozada-Medellin, 2022).*

This work is a collaboration between the National Science Foundation's Engineering Research Center for Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE) and the US Department of Transportation's Center for Advancing Research in Transportation Emissions, Energy and Health (CARTEEH). The ASPIRE Center aims for a sustainable and fair future for transportation infrastructure systems through widespread electrification of all classes of vehicles. The center focuses on incorporating electrified roadways and wireless charging solutions for EVs to charge either in motion or parked, thus eliminating the gas-station models and offering health benefits through cleaner air and sustainable infrastructure *(ASPIRE, 2023)*. CARTEEH focuses on the impact of transportation on human health *(CARTEEH, 2024)*.

To contribute to the center's work, this study aims to advance vital knowledge regarding the environmental and social justice impacts of electrified technologies. These include EVs, EV charging stations (ChSs), and electrified roadways (ERWs). The study seeks to evaluate the environmental and social justice impacts of EV market penetration. Also, to identify and understand key barriers to EV public acceptance and adoption, concurrently fostering diversity and inclusion by accounting for historically underrepresented minorities. A primary objective of the endeavor is to understand the public concerns and significant impediments that hinder the widespread acceptance and adoption of EVs in underrepresented minority communities. This was achieved through public outreach and engagement practices designed to foster EV technology awareness and introduction as an equitable technology.

Therefore, the study evaluated the perceptions, opinions, and knowledge of EV technology in three underrepresented communities (URCs) in the Paso del Norte Region. Disparities in access to the infrastructure and perception of having ChSs and ERWs installed in their neighborhoods were also considered. For this study, underrepresented communities are defined either as having low-income ($25k-$50k annually) or as part of minority populations (African American/Black 3.6%, American Indian 0.7%, Asian 1.4%, Hispanic 82%) *(U.S. Census Bureau, 2023)*. Due to the diversity in culture and demographics, with an 82% Hispanic population, this work was conducted in El Paso, Texas, as it offers an adequate location as a testbed for the major focus of this study. As a pilot project, the study was applied only to the city of El Paso.

This work was completed in two phases. The first phase examined the participants' perceptions, knowledge, and opinions regarding EVs and having ChSs and ERWs installed in their local area. This first phase also identified the main barriers and causes limiting EV diffusion and adoption in URCs.

The second phase developed baseline metrics that focused on particulate matter (PM) and GHG from transportation sector light-duty vehicles (LDVs) at the regional and national levels. Concurrently, the study examined the potential reductions in PM and GHG emissions in the transportation sector's LDV due to reduced fuel use as the market penetration of EVs increases in URCs at the regional and national levels through 2050.

For this study, El Paso was used as a testbed to evaluate public perception and behaviors toward EVs and concurrently develop sustainability metrics (PM and GHG). The study will help inform about the social and infrastructure barriers that need to be considered to pave the way to future research directions, alternatives of infrastructure design, and testbed development. In turn, this will lead to the rollout of the widespread diffusion and adoption of EVs to include historically URCs.

Goal and Objectives

The overarching goal of this work is to evaluate how EVs in the LDV sector can help reduce the environmental impacts from the transportation sector based on URCs adoption, simultaneously accounting for social justice and equity. Specific objectives included:

1. To understand URCs' leading issues and barriers to EV diffusion and adoption. This included their perception and willingness to accept electrified transportation infrastructure installed in their neighborhoods. Additionally, fostering equity and inclusion that allows for equitable electrified infrastructure planning and deployment.
2. To determine emissions under the existing built environments in the LDV sector in URCs by developing baseline metrics for PM and GHG emissions at the regional and national level
3. To evaluate the potential decrease of emissions of PM and GHG caused by increased market penetration of EVs in the LDV sector from URCs at a regional and national level.

This study will contribute to scholars, researchers, environmental planners, and EV developers to evaluate EV environmental and social justice benefits. Due to the joint work of public perception and behavior toward EVs and the evaluation of PM and GHG emissions changes due to EV market penetration increase in the LDV sector in El Paso URCs. The outcome of this study will provide a more specific answer to the EV public perception and key barriers to widespread diffusion and adoption that can be used to prioritize future equitable locations of ChSs and ERWs. The findings of the conducted study will yield the needed tools to assess how EVs and ERWs can improve air quality, providing in turn, a better quality of life for the residents of the Paso del Norte region.

Chapter 2: Literature Review

EVs are emerging in the transportation sector as a sustainable solution to reduce fuel-use dependency and lower GHG emissions and environmental pollution. Broad research has been directed at examining consumer perception, behavior, and attitudes to determine the critical barriers to the widespread EV diffusion and adoption endeavors. Identifying the factors that influence the public perception and acceptance of EVs is a task that requires thorough evaluation. While much research has examined the attitudes and motivations of early adopters and potential users of EVs, the conceived public drawbacks and misconceptions, aspects of parallel importance, have not been regarded to the same extent. These are fundamental to creating and promoting communication that placates misinformation and negative perceptions, increasing public interest and acceptance. A high public acceptance of EVs is pivotal to determining the practicality of a successful implementation and advancing EVs as a clean and equitable alternative *(Steinhilber, Wells, & Thankappan, 2013; Yeh et al., 2008; Ziefle et al., 2014).*

EV Public Perception and Behavior

EVs continue to lead as a clean alternative to decreasing emissions produced by the transportation sector. This is in part due to the federal government's support through new strategies and policies to accelerate the transition into electric mobility; however, other state measures may appear contradictory.

The Biden administration, for instance, has passed a new emission regulation for vehicle makers that targets the manufacture of more efficient vehicles, aiming at having half of the vehicles sold by 2032 be electric *(EPA, 2022, EPA, 2023b, c).* During 2023, tax rebates and incentives to encourage the purchase of EVs have been promoted. Also, automakers developed price cuts to make vehicles more affordable for the public, and more vehicles are now eligible for federal tax credits *(Andrew Lisa, 2023)*,

On the other hand, a new bill has been implemented nationwide for registering a new EV or renewing a registration. This bill intends to offset the roadway use and maintenance taxes that EVs are indirectly exempting due to not purchasing gasoline but using the roadways. *(TxDMV, 2023).* For different states, the tax bill has been passed based on the type or size of the vehicle. In Texas, unlike other states, the tax bill was equally designated for all EVs, regardless of their size or type. This state bill might be perceived as arbitrary or contradictory to supporting the electric mobility transition from the federal government *(Jankowski, P., 2023)*.

Concurrently, a discrepancy emerges between EV developers, policymakers, and the public perception regarding the use of EVs as a solution for preserving the environment that can also meet the needs of the general public. Agreement and engagement between the government, developers, and stakeholders are needed to prioritize electric mobility's social and environmental justice impacts, incorporating better development and transition measures for an effective common benefit that also integrates the needs of the community (*Dhar, Pathak, & Shukla, 2016; Hardman et al., 2018; Jenn, Laberteaux, & Clewlow, 2018)*.

Although much research has assessed public EV perception and preferences, early adopters, owners, and potential buyers of EVs have often been the main objectives of many of these studies. Purchase cost, mile range, battery lifespan, charging infrastructure, or lack thereof, have been constant key barriers identified by most of these studies to public EV adoption (*Krause et al., 2013; Larson et al., 2014; Ouyang, Zhang, & Ou, 2018; Pevec et al., 201)9*.

As more research is conducted and new markets are explored to expand EV market penetration, historically underrepresented minorities are still excluded from evaluating public perception and attitudes. This is an important size market that remains neglected and misunderstood. Incorporating this market into research is crucial to the widespread diffusion, increasing adoption, and reinforcement of EVs as equitable and accessible technology *(Kumar, R., & Sinha, K., 2023).* Identifying the demographic diversity of potential users and understanding their needs, perceptions, preferences, and particularly their reasons is vital to accurately eliminate the set of public barriers to EV acceptance and adoption *(Hardman et al., 2018)*. Barriers come primarily from a lack of prior experience with the vehicles, from resisting a new and unfamiliar technology or that has yet to prove its benefits, thus generating misconceptions in the public *(Egbue & Long, 2012)*. Providing the public with accurate and easy-access information can potentially reduce resistance and prevent misconceptions to support EV acceptance and promote adoption in unexplored markets, such as minority populations. Clear information and community-based EV campaigns to reach underrepresented groups are vital strategies for decreasing EV adoption barriers and fostering public EV interest and adoption *(Mara Elana Burstein, 2023)*.

Equity and inclusion have increased over the last decade across the transportation field to implement more effective practices during the planning process of public infrastructure. Recent research has examined broader groups to assess public perception and integrate it into equitable transportation infrastructure designs *(Hardman et al., 2018; Mara Elana Burstein, 2023)*.

Public perception and behavior have been evaluated through surveys and focus groups to better understand the motivation behind public barriers and how to increase the acceptance and adoption of EVs and electrified infrastructure *(Krause et al., 2013; Larson et al., 2014; Ouyang et al., 2018).* Qualitative studies have also been designed to outline EV driver experience *(Egbue & Long, 2012; Noel et al., 2018; Pevec et al., 2019)*. However, the perceptions and reasoning of those not considered to be potential EV adopters, as in the case of low-income, underrepresented minorities, have been minimal. Opinion, perception, and knowledge of underrepresented minorities are critical factors that need deeper evaluation for the successful widespread diffusion and adoption of EVs as an equitable technology.

Focus Groups

More research has recently included various communities in analyzing public perception and behavior regarding the transition to electric mobility.

One study by *Silva, Carley, & Konisky (2023)* evaluated EV policymakers and manufacturers, including managers and laborers of the automobile industry, through focus group sessions, finding diverse opinions. The work showed that policymakers perceived the transition from fuel to power in the automotive factories as a positive transition to cleaner energy. Vehicle manufacturers, automotive plant managers, and community leaders also showed optimism about the benefits of transitioning to EVs. They also believe in the ability of the industry to rise at the level of the challenge, which will provide economic growth and benefit their communities by increasing decarbonization. On the other hand, the factory laborers and the local residents felt more skeptical of the so-claimed benefits of the transition. They perceived EV technology, in general, as inflated, inappropriate to supply the common public needs, and indeed a governmental charade. The workers expressed obvious issues, such as unequal access to EVs, and questioned the actual benefits and usefulness of the vehicles, including low infrastructure availability. Some of them fear their jobs and communities might be at risk as the future of the automotive industry seems uncertain with the arrival of EVs. The workers also questioned the motives behind the transition to green energy, feeling that meeting the public needs and healing the environment is not the primary focus of the EV industry and the government. The factory worker's reaction is similar and relates to what *Kester et al. (2019)* found in their focus group study of non-EV-users in five countries of the Nordic region, where the public perceptions and knowledge varied. One group (group A) in the study believed that the highlighted emissions reductions by experts were the most, if not the only, evident benefit to EVs. Participants of another group (group b) considered EVs' environmental benefits to be questionable. Group B felt unsure of the actual cleanness of the energy used by vehicle and battery makers, considering uncertain the exact amount of emission reduction through EV use and perhaps more pollution being generated by the production of EVs. The level of understanding of EVs' environmental and health impacts in another group (group C) was absent or minimal. EVs rarely crossed the minds of group C participants when selecting a transportation mode. The *Kester et al. (2019)* study also pointed out the need for additional research that includes a broader sphere of public groups regarding EV perception. This is because the barriers observed by academics and policymakers regarding EV implementation (cost and car design) differ from what the public perceives as EV challenges in their daily activities (public awareness of charging infrastructure, support policies, EV advertisement).

A similar study was performed on non-EV-users in Chile by *Guevara, Figueroa, & Munizaga (2021)*, where EV implementation is at an introductory phase. EVs are scarce and can cost three times more than ICEVs. EV subsidy is almost null. The study focused on the perceptions and attitudes of the main electricity distribution company employees. As an employee benefit, workers applied for a subsidized program to acquire an EV. The effect on preferences before and after being EV users, including that of non-users, was evaluated through focus group sessions. EV users mentioned both benefits and barriers. At first, they were concerned about driving range and limited charging networks; however, once they became EV owners, those fears were left behind, and their concern was more about the maintenance of the vehicles. They were impressed with electricity's low costs compared to fuel; however, they did not change their environmental attitudes after using EVs. Users also seemed reluctant to pay for the charging infrastructure, as they were provided with charging at home and in their workplace as part of the program. Those with no EV ownership were more concerned about the scarcity of urban charging infrastructure regarding interurban trips. They showed willingness to pay for it and showed more concern about the environment. The study identified the vehicle cost, driving range, and limited charging infrastructure as the main barriers to EV adoption in the explored Chilean market. It also noted that subsidies for purchasing EVs and home charging options increased public interest.

Another study by *Sovacool et al., 2019* examined how public EV perception and attitudes differ in the Nordic region according to gender inclination. Results in the study suggest that men, compared to women, drive more often and longer distances. Additionally, men typically own vehicles and are less likely to use public transport than women. Men were also more familiar with EVs and used them more than women. On the other hand, women showed more interest in a vehicle's safety and environmentally friendly aspects. Women were less concerned about vehicle power, acceleration, or noise, whereas men highlighted them. The study showed that, although gender seemed to have an effect on EV preferences, factors such as travel distance, travel patterns, and public transport availability were more determinants of EV ownership.

Through focus group sessions, *Ziefle, Beul-Leusmann, Kasugai, & Schwalm (2014)* also assessed public acceptance and perception of EVs in Germany. They examined EV users' perceived benefits and drawbacks to individualize and tailor policy information. The demographic background of participants, such as age and gender, were investigated through a questionnaire using the Likert Scale (1= I do not agree at all, 4= I completely agree). The evaluations of benefits were achieved by using a pro and con argument to determine motives and barriers. Results provided a snapshot of the participants' attitudes toward technology barriers as well as the perception of environmental consciousness of women versus men. Women had a much higher consciousness regarding the environment. The study also provided an interesting perspective about the diversity of users (age and gender) having more effect on the perception of EV benefits than drawbacks. For example, with age, comfort is perceived as a more significant advantage, while younger participants showed more concern over costs. The study also found that EV "novices" may not be able to perceive the potential of EVs until they actually experience the vehicles.

Surveys

Surveys and questionnaires have also served researchers in evaluating public EV perception and attitudes to identify critical barriers towards EV diffusion and adoption. Some studies have explored EV subsidies such as government incentives, tax rebates, and EV benefit policies to evaluate the market penetration of the vehicles. *Gong, Ardeshiri, & Hossein Rashidi (2020)* evaluated EV perception in an Australian community where the current EV market penetration is low. The study surveyed non-users based on a series of EV benefits, including governmental EV purchase incentives, electricity bill discounts, and parking benefits. Their results showed that incentives increased the positive public perception of EVs regarding purchases. Power bills and parking fee reductions were also well received, as these services are costly in Australia. The study found a knowledge gap regarding the availability of current incentives for EV purchases in the general public. The study also found that most vehicle purchase decisions rely on the needs and incomes of each household and not on the improvements in EV design or promotional campaigns.

Other researchers also surveyed to assess the sustainability of subsidized adoption of EVs. According to *Zhang, Bai, & Shang (2018),* their results showed that subsidized adoption depends mainly on the benefits (economic and environmental) and the risks (charging time, short battery life, lack of charging infrastructure) that the consumer perceives, regardless of the type of incentive policies. However, the study considered that incentive policies could also impact the widespread diffusion and adoption of EVs and found a lack of knowledge and awareness regarding incentive policies among the general public.

Another survey conducted in Missouri in the United States by *Egbue & Long (2012)* evaluated attitudes towards EVs from university students, faculty, and staff. Participants were perceived as prospective owners due to their high involvement in technology development and, thus, considered candidates capable of distinguishing the main technological, financial, and environmental differences between ICEVs and EVs. The survey results showed that perception and attitude towards EVs varied according to gender, age, and education level. The results generally reflected these participants' moderate to high interest in EVs. While the cost was a highlighted concern reflected by the survey results, aspects such as battery cost and reliability, charging infrastructure, actual EV cost-effectiveness, sustainability, and environmental impacts were identified as the main barriers to EV adoption. The study found that tax credits and monetized incentives positively influence the perception of EV adoption. However, it also noted that unless measures are taken to make these resources known to the public to decrease EV technology misinformation, including current infrastructure, consumers’ confidence in EVs might not increase. *Egbue & Long (2012)* also highlighted that, regarding EV incentives, most studies have evaluated the kind and availability rather than their effectiveness. Thus, more research is necessary on how incentives are designed and applied, including whether they fulfill their initial intent and evaluate their effectiveness.

EV misconceptions have been a common aspect in uninformed groups. A work by *Sovacool et al. (2018)* assessed this aspect by applying a survey in seventeen cities in the Nordic region. According to the results, EV driving range anxiety is still one of the main misconceptions that cause hesitation in EV adoption despite the improved EV range. Driving range anxiety is well-studied but is poorly understood as a concept. *Sovacool et al. (2018)* state that to understand the public's range anxiety, it is necessary first to address the main public barriers that come from inexperience with the vehicles and a lack of basic EV information. Addressing barriers arising from misconceptions about charging infrastructure, charging timing, and affordability of EVs can allow consumers to bypass the hesitation that comes from the concern over range. Furthermore, range anxiety is a problem that has yet to occur, given that EV users do not report this as an issue with the vehicles. The authors conclude that most of these barriers should be addressed by educating the public, thus preventing reinforcing other negative misconceptions that affect public EV acceptance.

Range anxiety was also addressed by *Pevec et al. (2019)*. They conducted a survey to assess the perception of potential EV owners regarding EV range anxiety based on two aspects: the distance they consider optimal between charging stations, compared to current fuel stations availability, and the distance they are willing to drive to get to a charging station. The study aimed to raise awareness among EV developers about the need for electrified infrastructure in the transportation sector, including promoting existing infrastructure and locations to reduce EV range anxiety and promote its use among the general public.

Seventy-five percent of respondents were from Croatia, where EV market penetration is low and charging infrastructure is not quite developed. The last twenty-five percent were from different European countries, with more considerable EV market penetration. Half of the participants showed that the current distance between gas stations is acceptable for charging stations. For EVs, the larger the city, the smaller the distance respondents preferred to drive to a charging station. In the same way, the smaller the town, the more home charging stations participants preferred. The desire to charge the vehicle was shown to be dependent on participants' driving habits and technology knowledge, including the remaining charge of the vehicle.

Adoption barriers from the perspective of early EV adopters were also evaluated by *Vassileva & Campillo (2016)* in Sweden. According to the results, early adopters tended to be mainly males between 40 and 45 years of age, with households of two to four members, higher incomes, and at least a university degree. In the study, 80% of respondents answered that the main reason for using EVs was personal matters, whereas only 1% responded that they used the vehicles for work. Individuals living in apartments usually owned only one EV vehicle, while those with up to three vehicles lived in houses. Owners who were highly satisfied with the vehicles accounted for 69%, and 88% said they would only use EVs. In the *Vassileva & Campillo (2016)* study, socioeconomic aspects were shown to impact EV adoption. Regardless of minimal subsidies and benefits that included free charging and parking, according to the results, most owners decided to acquire an EV due to environmental concerns and the vehicles' cost-effectiveness. The factor that motivated 30% of participants to acquire EVs was that EVs are considered a new and exciting technology. The study did not find significant differences regarding the motives to purchase an EV between males and females, as responses were close in number from both genders.

An analytical study by *W. Li et al. (2017)* assessed the factors influencing EV adoption. Their study classified the motivational factors found as demographical (gender, age, education, income), situational (economy, environment policy, infrastructure, driving range, charging time), and psychological (experience, attitudes, social influence). The study concluded that the main motivation for EV adoption is a combination of the three categories, although some factors stood out. For example, families with more older members or having children tended to prioritize comfort. Also, the public did not know the availability of infrastructure, government policies, and subsidies available, which can contribute to the public's intention to purchase an EV. The study also found that increasing public EV experience and familiarity with the vehicles through public activities is crucial to increasing the positive perception and intent to adopt EVs. Furthermore, the lack of participation of EV manufacturers, retailers, the government, and the public is evident. EV value also differed among countries and their cultures.

A study by *P. Bhalla et al. (2017)* regarding public attitudes and motivation toward the use of EVs in India surveyed more than 233 participants between the ages of 24 and 47 in the service and business field. Survey results showed that purchase decision-making is partly influenced by psychological and situational factors specific to each customer, including their concept of EVs, environmental perception, economics, and social acceptance. The study observed that although EV technology has increased to provide longer driving distances and help reduce CO_2 emissions effectively, the struggle to advance EV market penetration is evident. A massive effort was noted to overcome the public risk of adopting new technology and create trust in EVs. These factors are partly caused by the current reliability that customers already have on

ICEVs and by the misconception of EVs (battery reliability, charging infrastructure availability, rejection of an unknown technology). The study suggested that the government and EV manufacturers need to join efforts to invest in the social acceptance of EVs. Public promotions of the EV technology's innovations, usefulness, performance, reliability, government subsidies, policies, and public benefits programs, including insurance, parking, etc., can help overcome social adoption barriers and increase EV market penetration.

The studies on public perception discussed above show that EVs' driving range, initial purchase price, battery reliability, and charging infrastructure availability remain the leading barriers to EV general adoption. These concerns can be attributed to the fact that the general public is unfamiliar mainly with EVs and, thus, reluctant to accept the technology. Furthermore, the general public's lack of information, including EV innovations and benefits, plays a more significant role in consumers' concept of EVs. And thus, it has a direct impact on the public interest in acquiring the vehicles. The literature review also describes the beneficial aspects of EV use perceived by the public. These were that EVs contribute to cleaner air and the preservation of the environment. They are cost-effective contributing to overall savings since owners do not have to purchase fuel.

EV Public Perception and Behavior Summary. The literature also showed that new researchers are expanding their studies to possible new EV markets and conducting more community-based outreach to identify the main barriers to EV adoption and propose better solutions. Nevertheless, most research centers on medium- to high-income groups, considered the best candidates for EV acquisition. Most studies overlook the underrepresented and neglect the disproportionate adoption barriers and perceptions of such groups, which can be determinant factors to a widespread and equitable diffusion of the vehicles. Accounting for such groups in research will project significant cultural and demographic contrasts, contributing to identifying EV adoption barriers and promoting social equity through more accurate solutions.

U.S. Emissions and Sources

The study evaluates GHG emissions from the LDV sector in transportation. For this purpose, two different scenarios were developed to assess possible emission changes as EV market penetration increases in URCs from regional to national levels. The following paragraphs present an overview of the national and regional U.S. GHG emissions. This data is presented from the period of 1990 to 2022. The review also considers the local initiatives that are being considered in the City of El Paso regarding clean energy production and the local promotion and support of EV use to help decrease transportation emissions and achieve better local air quality.

Emissions of Greenhouse Gases

Infrared radiation can be felt as heat and emitted by all objects in the universe. Greenhouse gases (GHG) absorb the infrared radiation kept in the atmosphere, thus causing the Earth to be warmer. Carbon dioxide (CO_2), Nitrous Oxide (N_20), Methane (CH_4), and some fluorine-containing halogenated substances such as hydrofluorocarbons (HFCs), perfluorochemicals (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) are the primary GHG produced by the human activity *(U.S. EPA, 2023)*. Since 2009, in the United States (U.S.), the Environmental Protection Agency (EPA) has made reporting data from significant GHG-emitting sources mandatory. This is the GHG Gas Reporting Program. It holds the national totals of GHG emissions and removals (the CO2 removed from the atmosphere through the absorption and storage from soils and vegetation) regarding human activity *(U.S. EPA, 2023)*.

During 1990 to 2021, the national emissions decreased by 2.3% from the 15.8% high levels registered in 2007, which were above the 1990 levels *(U.S. EPA, 2023)*. This remarkable decrease in emissions was mainly due to the COVID-19 pandemic impacts that restricted travel and some economic activities. From 2020 to 2021, as economic activity was restored after the COVID-19 global pandemic, emissions increased by 6.4% but still were 16.6% less compared to the levels registered in 2005 *(U.S. EPA, 2023)*.

EPA's National GHG Emissions and Sinks 2023 report shows that in 2021, GHG emissions totaled 6,340.2 million metric tons of Carbon Dioxide equivalent (MMT CO_2 Eq). Also, in 2021, CO_2 fossil fuel combustion emissions increased by 6.8% compared to 2020. Coal consumption CO_2 emissions, mainly from the electric sector, also heightened by 14.6%. The use of natural gas and emissions increased nationally in all economic sectors except the electric one *(U.S. EPA, 2023)*. Petroleum use emissions also increased by 8.6%, while the total CO_2 emissions from fossil fuel combustion reached 4,6391 MMT CO_2 Eq in 2021, 1.9% lower than in 1990. **Figure 1** includes the total national GHG emissions by gas type from 1990 to 2022, and **Figure 2** includes the yearly fluctuation of GHG emissions in percentage during the same period *(U.S. EPA, 2023)*.

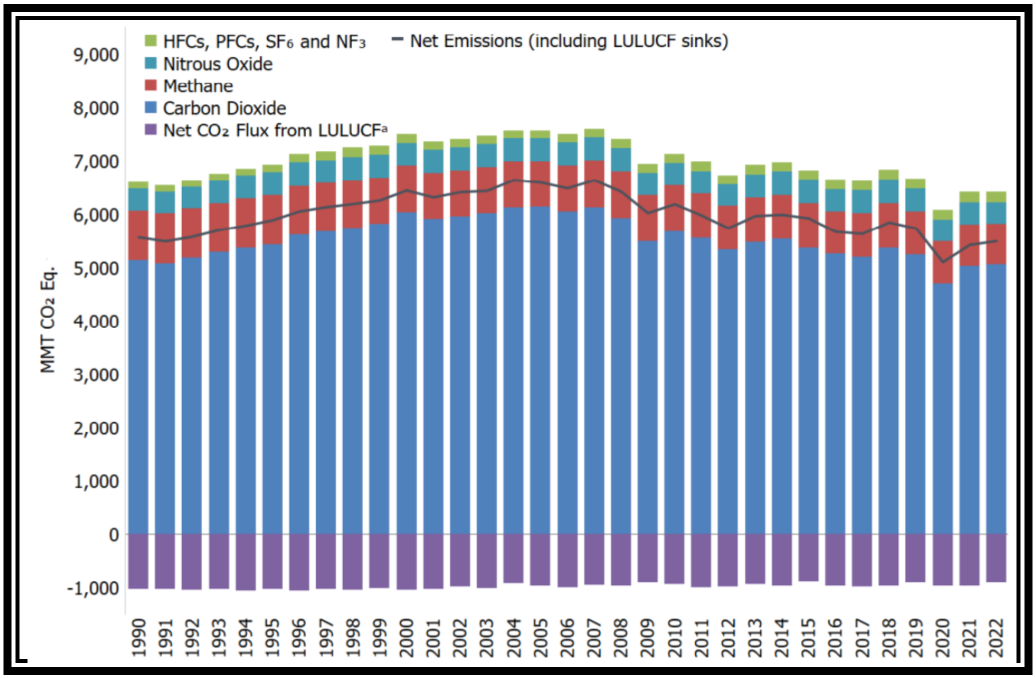

Figure 1. U.S. GHG Total Emissions by Gas Type from 1990-2020 (U.S. EPA, 2023)
LULUCF=Land use, Land use-change, and forestry. It covers GHG removals.

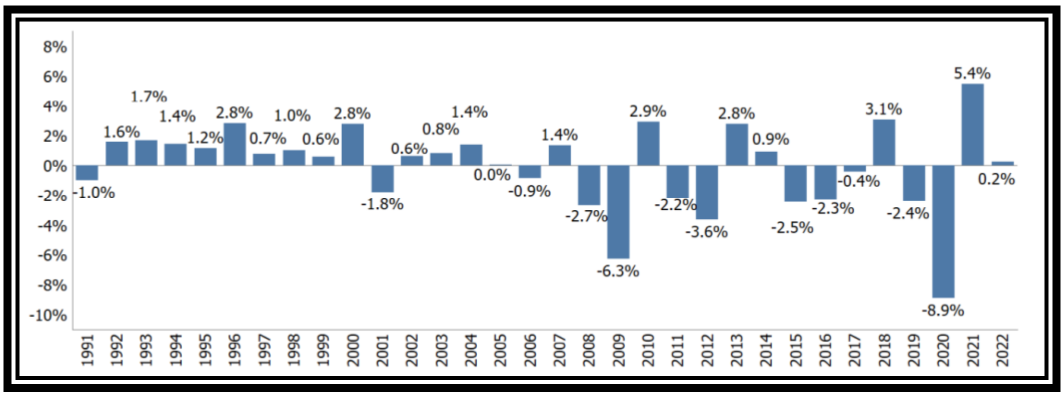

Figure 2. U.S. GHG Emissions Changes and Sinks from 1991 to 2021 (U.S. EPA, 2023)

Emissions by Sector

In the U.S., the primary sources of GHG emissions include the commercial and residential sectors, electric power, industrial, and transportation sectors, including the agriculture sector, forestry, and land use. The transportation sector's most significant GHG emission contribution was in 2021, with 28.5% of the total national GHG emissions *(U.S. EPA, 2023)*. The second contributor was the electric power sector, with 25%. Approximately 63% of all electricity is from burning fossil fuels, including oil, natural gas, and coal *(U.S. EPA, 2023)*. The industry sector was the third largest contributor to emissions in 2021, with 23.5% of the national total. CO2 emissions are generated from using fossil fuels in manufacturing processes. However, during the last ten years, the industry sector has reduced its emissions partly due to going from a manufacturing-based to a service-based economy, changes in fuels used, and improving the efficiency of energy *(U.S. EPA, 2023)*.

The agriculture sector accounted for 10% of the emissions from N_2O and CH_4 from soil use and enteric fermentation, respectively. Most of these emissions are from livestock, soils, and rice production. Operated forests and other lands act as sinks, absorbing more CO2 than they generate in general *(U.S. EPA, 2023)*. The commercial sector accounted for 6.9%, and the residential sector 5.8%. Emissions in the commercial and residential sectors are mostly from electricity consumption by lighting, air conditioning, heating units, and petroleum and natural gas used for cooking or heating *(U.S. EPA, 2023)*. Lastly, 0.4% of the total emissions were attributed to the U.S. territories contributed. CO_2 was produced and sequestered by forests, urban planting of trees, and agricultural soils, among others *(U.S. EPA, 2023)*. The total national GHG emissions per sector from 1990 to 2021 are presented in **Figure 3**. **Table 1** presents the total national emissions per sector in 2021, and **Figure 4** includes the 2021 total national GHG emissions by gas and sector *(U.S. EPA, 2023)*.

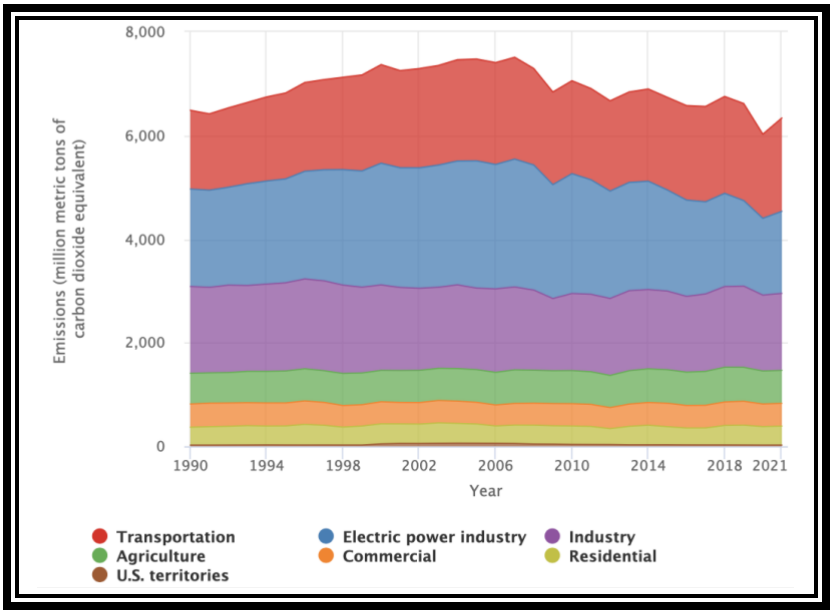

Figure 3. 1990 to 2021 Total U.S. Emissions of GHG by Economic Sector (U.S. EPA. 2020)

Table 1. 2021 GHG Emission by Sector (U.S. EPA. 2022)

Sector	MMT CO2 Eq.
Transportation	1,804.3
Electricity	1,584.1
Industry	1,487.3
Commercial	439.2
Residential	365.6
Agriculture	635.8
U.S. Territories	24.1
Total Gross Emissions (Sources)	**6,340.2**
LULUCF*	754.2
Net Emissions (Sources and Sinks)	**5,586**

*Land use, Land use change, and Forestry

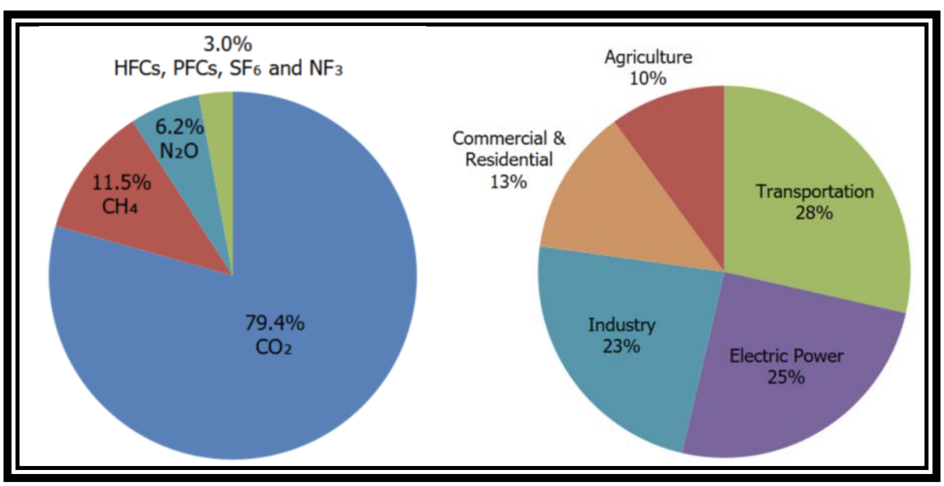

Figure 4. 2021 National GHG Emission by Gas and Sector (U.S. EPA, 2023)

Transportation Sector

The transportation sector is the most significant contributor to national GHG emissions, with CO2 being the main GHG emission in transportation. Basic sources mostly are fossil fuel burning from vehicles where almost 90 % of this fuel is petroleum-based, like gasoline and diesel *(U.S. EPA, 2023).* The transportation sector data accounts for heavy-duty vehicles (motor vehicles from 26k-33k lbs), medium-duty vehicles (motor vehicles from 10k-26k lbs), and light-duty vehicles (LDVs), which are the passenger or personal vehicles and light-duty trucks (weight less than 10k lbs) *(U.S. Department of Energy 2024)*. LDVs are the largest CO_2 emission contributor, accounting for more than half of the total emissions from transportation. In contrast, the remaining emissions come from commercial vehicles like trains, freight trucks, and aircraft. CH_4, N_2O, and HFC are also included in transportation emissions, although partially small amounts, mostly from refrigerated transports and A/C mobile units *(U.S. EPA, 2023)*.

In 2018, 28.2 % of the total GHG emissions in the U.S. came from transportation, making it the largest emission generator sector *(U.S. EPA, 2022)*. From 2019 to 2020, due to the COVID-19 pandemic, which restricted traveling, emissions decreased by 13.4% while increasing by 11.5% from 2020 to 2021. From 1990 to 2021, Vehicle Miles Traveled (VMT) by the LDVs sector increased by 45.1 % due to population and economic growth, lower fuel prices, and urban sprawl, which increased fossil combustion emissions by 17%. By 2021, VMT from LDVs recovered; however, the number remains around 4% lower than the levels of 1990 *(U.S. EPA, 2023)*.

In 2021, the most significant GHG emission contribution in the U.S. came from the transportation sector, with 28.5% of the national total gross emission *(U.S. EPA, 2023)*. These emissions consisted of CO_2, CH_4, N_2O, and HFC produced by the combustion of fossil fuel by transportation activities from pickups and minivans 37.1%, medium and heavy-duty trucks 23.1%, passenger vehicles 20.7%, aircraft 8.6%, pipelines 3.5%, ships 2.8%, and railing 1.9% *(U.S. EPA, 2023)*. Other activities included lubricant use, indirect emissions from electricity use, and refrigerated transport *(U.S. EPA, 2023)*.

The transportation sector has also used electricity for rail transport primarily. However, lately, due to an increase in the use of EVs and HEVs, the sector has grown its electricity use *(U.S. EPA, 2022)*. This form of energy has primarily been provided mainly through petroleum-based products, and more than 50% has been distributed for gasoline use by roadway vehicles. Diesel is also used for aircraft and freight activities. Most CO_2 emissions in transportation come from the combustion of fossil fuels, which from 1990 to 2021 showed a rise of 19.4% when electricity distribution was included *(U.S. EPA, 2023)*. **Figure 5** below shows the total GHG emissions from the transportation sector and its sources from 1990 to 2021 *(U.S. EPA, 2022)*. **Table 2** shows the GHG emissions in the Transportation sector from the LDVs in 2021 *(U.S. EPA, 2022)*, and **Table 3** shows the CO_2 emissions from fossil fuel combustion from the LDVs in the transportation sector from 2019 to 2021 *(U.S. EPA, 2023)*.

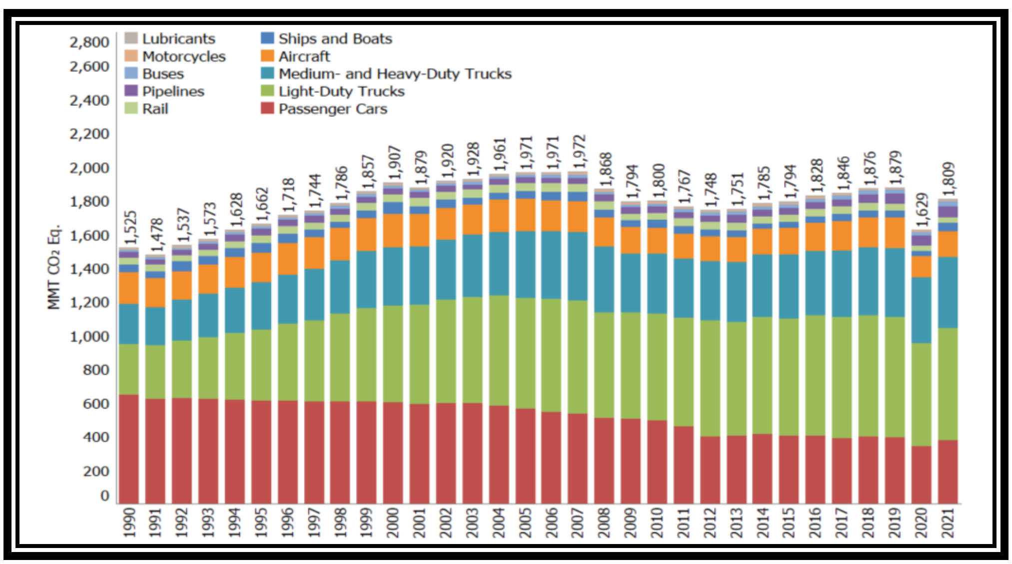

Figure 5. Transportation Sector GHG Emissions and Sources, 1990-2021 (U.S. EPA, 2023)

Table 2. National 2021 LDVs GHG Emissions (U.S. EPA, 2023)

Gas and Vehicle Type	MMT CO2 Eq.
Passenger Vehicles	Total=374.2
CO_2	365
CH_4	0.30
N_2O	1.9
Light-Duty Trucks	Total=671.8
CO_2	654
CH_4	0.5
N_2O	3

Table 3. LDVs Fossil Fuel Combustion CO_2 Emissions 2019-2021 (U.S. EPA, 2023)

Vehicle Type and Used Fuel	MMT CO2 Eq.		
	2019	2020	2021
Gasoline			
Passenger Vehicles	380	328	360
Light-Duty Trucks	658.6	565.7	619.9
Medium to Heavy-Duty Trucks	27	24.1	27.4
Motorcycles	7.4	6.6	7.4
Diesel			
Passenger Vehicles	2.7	2.5	2.7
Light-Duty Trucks	31.2	30.2	33.3
Medium to Heavy-Duty Trucks	373	353.4	380.1
Natural Gas			
Passenger Vehicles	*	*	*
Light-Duty Trucks	*	*	*
Medium to Heavy-Duty Trucks	0.1	0.1	0.1
LPG			
Passenger Vehicles	*	*	*
Light-Duty Trucks	0.1	*	0.1
Medium to Heavy-Duty Trucks	0.4	0.2	0.2
Electricity			
Passenger Vehicles	1.4	1.3	1.8
Light-Duty Trucks	0.2	0.3	0.7

*Not more than 0.05 MMT CO_2 Eq.

Electric Power Sector

The electric power sector is the second national contributor to GHG emissions mostly generated from two sources: fossil fuels consumption and unintentional emissions. The former includes the combustion of fossil fuels, the use of these fuels for non-power activities, and the combustion of waste. The latter comes from oil, natural gas, and coal production *(U.S. EPA,* *2023)*. From 1990 to 2021, most CO_2 national emissions came from energy-related activities, particularly the incineration of fossil fuels. These activities also contributed to emissions of CH_4 and N_2O *(U.S. EPA, 2023)*. In 2021, emissions from the power sector contributed 82% of the GHG national emissions. Also, in 2021, 79.3% of the electricity used in the U.S. was generated by fossil fuel combustion, petroleum, natural gas, and coal, while solar energy, wind, nuclear, biomass, and hydropower accounted for the last percentage. Fossil fuels incineration originated 92.2% of the total CO_2 emissions in the U.S. *(U.S. EPA, 2023)*.

CO_2 emissions have fluctuated over the years, but from 1990 to 2021, emissions reduced by 1.9%. Since 2005, there has been a reduction of 19.3% in CO_2 emissions from the combustion of fossil fuels, while from 2020 to 2021, emissions showed a rise of 6.8% *(U.S. EPA, 2023)*. These changes in emissions happen for different reasons, for instance, changes in technology, energy price changes, economic growth, population growth, and even a change in the temperatures through the years *(U.S. EPA, 2023)*. In the electric power sector, from 2005 to 2021 overall, the national CO_2 emissions have shown a reduction of 35.8% as a result of going from coal use to renewables and natural gas use from 2005 onwards *(U.S. EPA, 2023)*. **Figure 6** presents GHG emission sources during 1990 to 2021 in the U.S. from the electricity sector *(U.S. EPA, 2023)*.

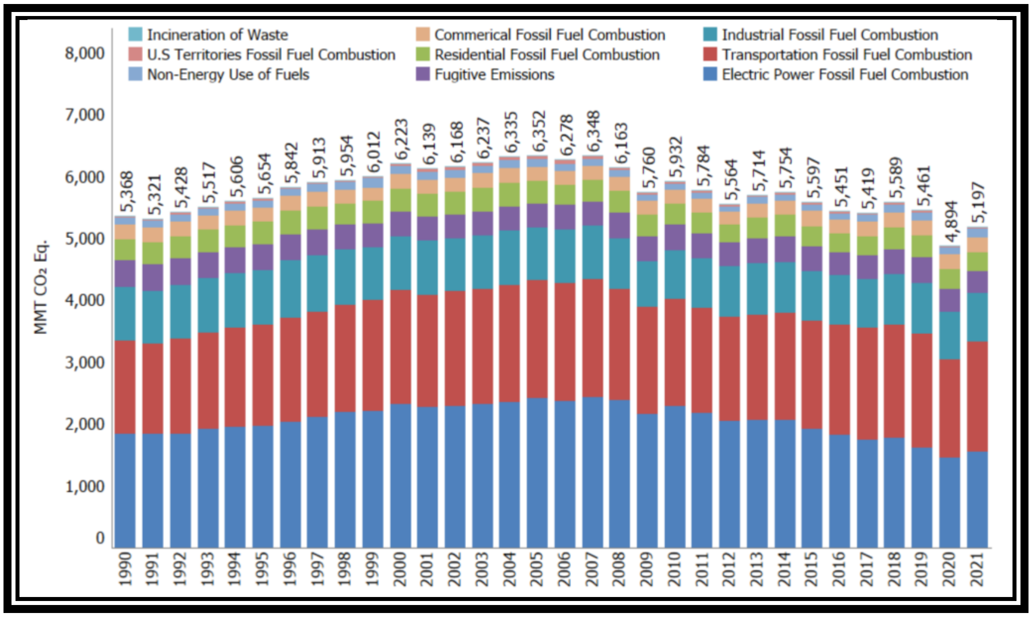

Figure 6. GHG Emission Sources 1990 to 2021 in the Electricity Sector (U.S. EPA, 2023)

According to the EPA, from 1990 to 2007, CO2 emissions from coal combustion grew and decreased from 2008 to 2021 *(U.S. EPA, 2023)*. CO2 resulting emissions due to natural gas utilization have been more constant, with a minimal rise between 1990 and 2009, and have risen at a more constant rate from 2010 to 2019 *(U.S. EPA, 2023)*. Development in drilling technology and the discovery of new gas fields boosted the change from coal to natural gas, resulting in better prices. From 2020 to 2021, coal use for electricity rose 15.4%, opposite to the tendency shown since 2008, and a decrease from 2019 to 2020 of 19.2% due to the COVID-19 pandemic *(U.S. EPA, 2023)*. **Figure 7** shows the production of energy in the U.S. by source from 1949 to 2022, **Figure 8** shows the energy consumption by source during the same period, and **Figure 9** presents the energy consumption by source as of June 2023 *(U.S. EPA, 2023)*. The main sources of GHG emissions from the electricity sector by gas type in 2021 can be seen in **Table 4** *(U.S. EIA, 2023a; U.S. EPA, 2023*).

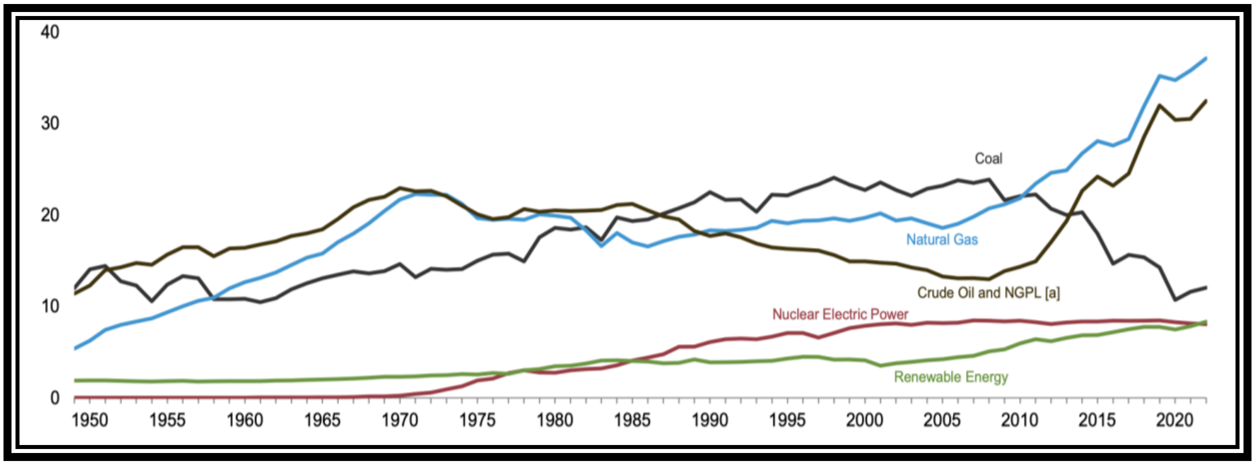

Figure 7. U.S. Energy Production in Quadrillion Btu by Source 1949 – 2022 (U.S. EIA 2023)

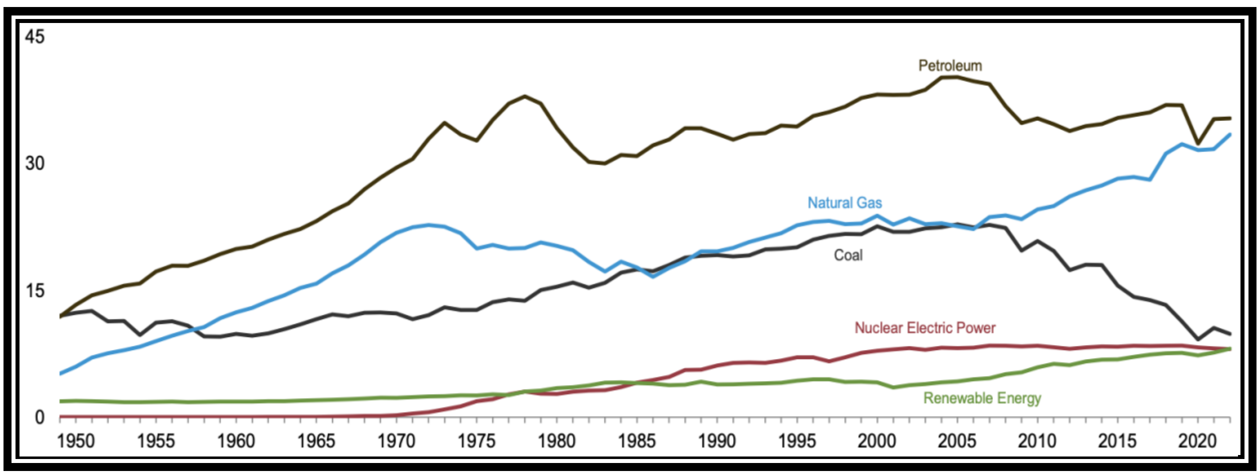

Figure 8. U.S. Energy Consumption in Quadrillion Btu by Source 1950-2022 (U.S. EIA 2023).

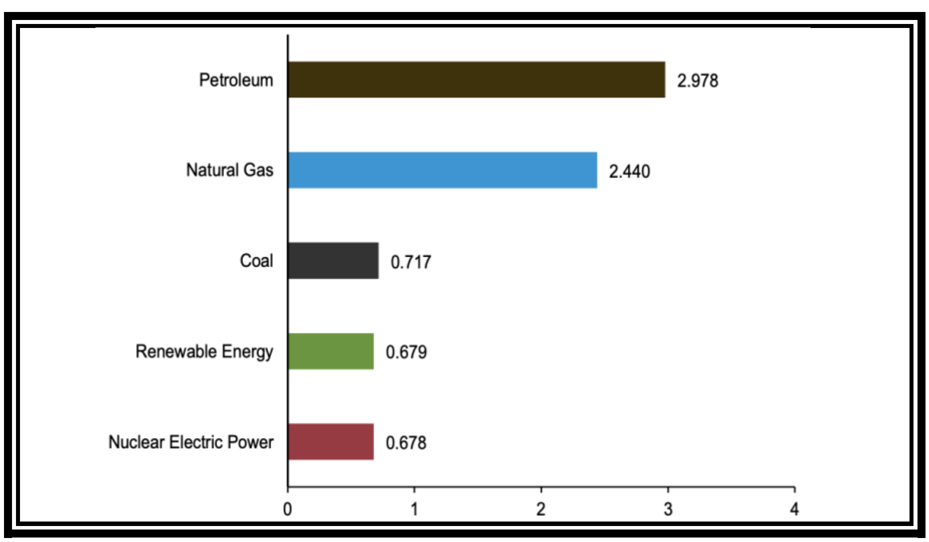

Figure 9. U.S. Energy Consumption in Quadrillion Btu by Source, June 2023 (U.S. EIA 2023).

Table 4. 2021 Main GHG Emission from Electricity Sector by Gas (U.S. EPA. 2023)

Gas	MMT CO_2 Eq
CO_2	
Fossil Fuel Combustion	4,639.1
Transportation	1,752.4
Electricity Generation	1.540.9
Industrial	775.6
Residential	313.3
Commercial	233
U.S. Territories	23.8
Non-Energy Use of Fuels	140.2
Natural Gas	36.2
Petroleum	24.7
Waste Incineration	12.5
Coal Mining	2.5
CH_4	
Natural Gas	181.4
Petroleum	50.2
Coal Mining	44.7
N_2O	
Stationary Combustion	22.1
Mobile Combustion	16.7
Waste Incineration	0.4

Emissions by State

GHG emissions vary by state. The CO_2 total emissions per state include the primary fuels used for electricity generation and direct fuel use within the sectors of transportation, all industrial, commercial, and residential *(U.S. EIA, 2019)*. Different factors affect the emissions rates, for instance, the state's physical size, climate, population size, available fuels, or the types of business. Their energy system is also important; coal may be abundant in some states while others have plenty of hydroelectric supplies. From 2005 to 2016, CO_2 emissions decreased in over thirty-six states and increased in fourteen others *(U.S. EIA, 2019)*. The largest emission increase in Texas was registered in this period, by 9% or 52 MMt. In 2013, Texas emitted more CO_2 from the burning energy process than it had before since 2004. It was also on the top of the national list of the largest carbon state producers for twenty-four straight years *(U.S. EIA, 2019, 2023)*. A general state estimate of CO_2 emissions related to energy production in 2021 is presented in **Figure 10**.

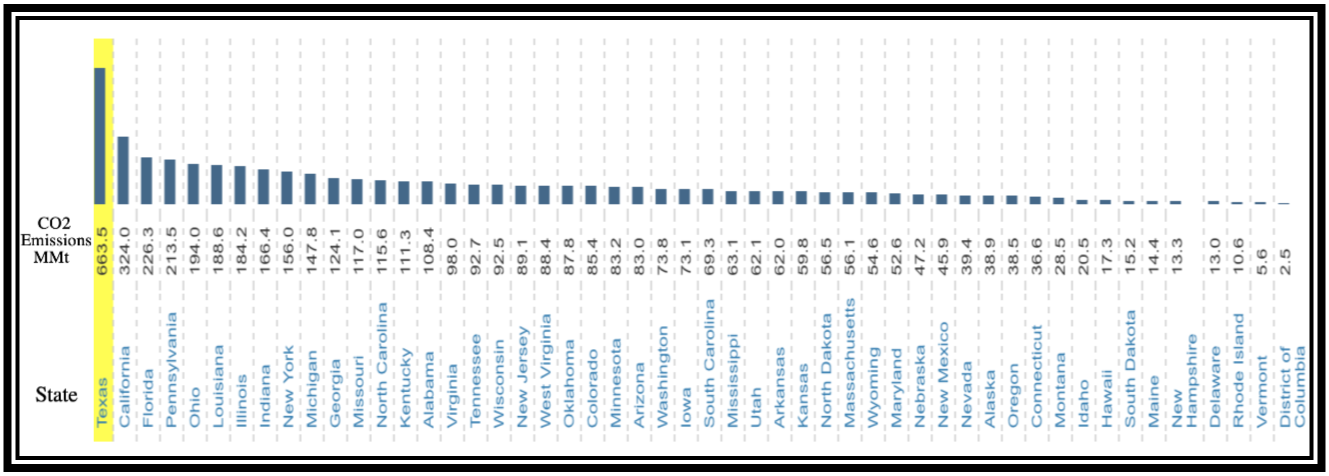

Figure 10. 2021 State CO_2 Emissions Related to Energy (U.S. EIA 2023)

Emissions and Sources in Texas

Texas leads the nation as the producer of natural gas and crude oil. In 2022, Texas produced 42% of crude oil and 27% of natural gas. Texas also has thirty-two refineries, the largest number in the nation. More than 5.9 million crude oil barrels can be produced daily, a third of the national volume *(U.S. EIA, 2023b)*. In 2022, Texas was also the country's largest electricity producer, accounting for over 12% of the total national production. All sectors in Texas also show the most energy consumption in the U.S. *(U.S. EIA, 2023b)*. This is partly due to petrochemical plants and the thirty-two refineries in the state, which are responsible for more than fifty percent of the energy consumption from the Industrial sector in Texas and 23% of the energy used in the industrial sector nationally *(U.S. EIA, 2023b)*.

The following figures provide some of Texas' energy-related information from 2021. **Figure 11** includes an estimate of the energy production, **Figure 12** estimates energy consumption by source, and **Figure 13** presents the energy consumption by end sector.

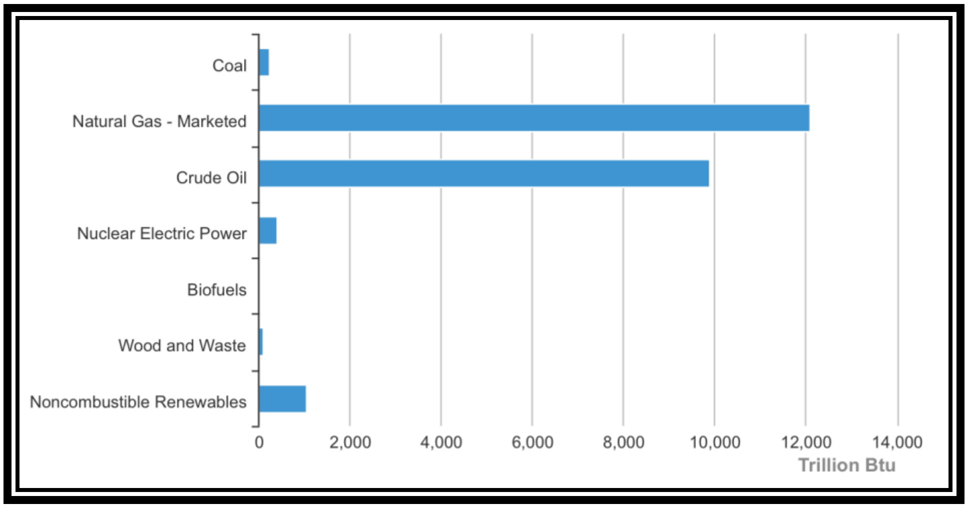

Figure 11. 2021 Estimate Energy Production in Texas (U.S. EPA 2023b).

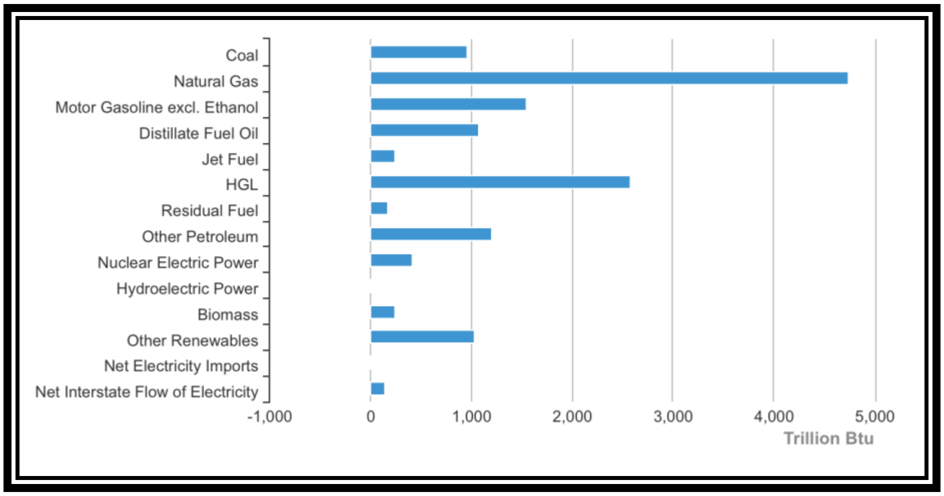

Figure 12. 2021 Estimates of Energy Consumption in Texas by Source (U.S. EPA 2023b).

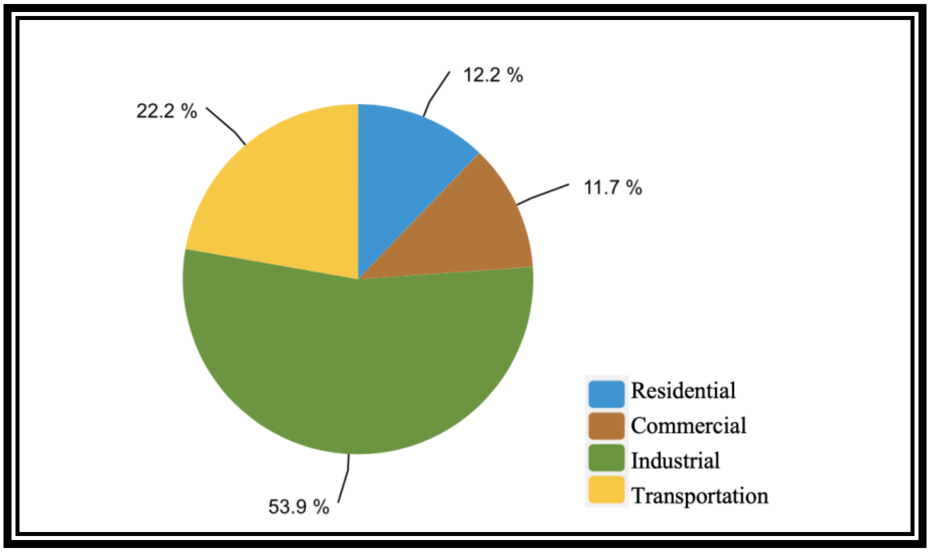

Figure 13. 2021 End-Use Sector Energy Consumption in Texas (U.S. EPA 2023b)

Emissions and Sources in El Paso

Air quality. The Texas Commission of Environmental Quality (TCEQ) examines air quality in El Paso by collecting data through and maintaining the state air monitoring network. TCEQ also models air quality predictions to estimate possible effects of chemical reactions, emissions reduction, climate changes, or population and/or economic growth (*TCEQ, 2024)*. All electric and chemical plants, refineries, and industrial sites must submit an annual air emission to the TCEQ. To improve air quality, the State Implementation Plan (SIP) requires industries and agencies to submit compliance reports to meet all state regulations (*TCEQ, 2024)*. These SIPs are established to comply with all the National Ambient Air Quality Standards (NAAQS) and the requirements of the Federal Clean Air Act (FCAA) *(TCEQ, 2024; U.S. EPA, 2023b)*.

After being designated as Particulate Matter 10 (PM10) non-attainment in 1990 by the NAAQS, the city of El Paso presented a PM10 SIP that included control measures and an emissions inventory. The SIP also included the oxygenated fuels program, Carbon Monoxide (CO) emission source review, and vehicle inspection updates *(City Of El Paso, 2022; TCEQ, 2016)*. EPA approved this revision which indicated that the area would, in time, attain the standard for PM10, except for those emissions coming from Mexico *(City Of El Paso, 2022; TCEQ, 2016)*. Also in 1990, a study was conducted for the cities of El Paso, U.S./Juarez, Mexico for PM10, showing that the concentrations were higher in Juarez city (adjacent to EP) than when El Paso was showing high PM10 concentrations; thus, most of the air particles were from areas in and around Juarez city *(City Of El Paso, 2022; TCEQ, 2016)*. Texas modeled PM10 concentrations (1990 and 1994) through the El Paso emission inventory, showing that if the city of El Paso had not received emissions originating within the Juarez area, El Paso would attain the NAAQS MP10 in both years *(City Of El Paso, 2022; TCEQ, 2016)*.

In 2016, the TCEQ implemented a limited maintenance SIP revision to incorporate the El CO plan (presented by TCEQ in 2006 and rejected by EPA in 2007 but reviewed and accepted in 2008) *(City Of El Paso, 2022; TCEQ, 2016)*. The revision was adopted by the TCEQ as it satisfied the FCAA. The FCAA requires an additional SIP state revision eight years after any area has been redesigned to attainment. This revision shows El Paso keeping CO NAAQS from 2018-2028 *(City Of El Paso, 2022; TCEQ, 2016; TCEQ, 2024)*.

Air Quality Monitoring. The city of El Paso controls and monitors the daily air quality through the city's Air Quality Program (AQP), established in the 1960s by the TCEQ and the City of El Paso. The AQP also adheres to the SIP of Texas and the FCAA with respect to monitoring ground-level Ozone, PM, SO_2, and CO *(TCEQ, 2022a; TCEQ, 2022b)*. Furthermore, the AQP is in charge of keeping the Bio Watch monitoring network program, established by the Department of Homeland Security (DHS) and directed by the TCEQ, as a prime public warning and protection system from potential biological attacks after the terrorist attacks on September 11, 2001 *(TCEQ, 2022a; TCEQ, 2022b)*. The AQP develops the program's daily activities in the city and Ft. Bliss through four local stations and four other stations from the TCEQ to monitor the air quality in El Paso *(TCEQ, 2022a; TCEQ, 2022b)*. The following are some of the frequent investigations covered by the AQP:

1. Dust Control in construction sites, complaints from outdoor burning,
2. Parking lots, car body shops, odor nuisances.
3. Gas stations for seasoning fuel blending (Volatile Organic Compounds (VOC) and CO), compliance with the underground storage tank, and stage I vapor control.
4. Facilities like asphalt mix plants, concrete batch plants, and surface coating.

Regular air quality ambient monitoring combines:

1. Management of the eight air monitoring stations from El Paso and TCEQ
2. Filter collection for analysis
3. Ensuring that the air monitoring meets all FCAA on sulfur dioxide, carbon monoxide, ground-level ozone, particulate matter,
4. Gas pollutants and reporting data
5. Quality assurance
6. Calibration and audit of the monitors
7. Repair and maintenance of equipment.

The monitored data from these stations in El Paso is sent to TCEQ for examination and validation before being sent to the EPA *(City Of El Paso, 2022; TCEQ, 2022a*). **Figure 14** presents the location of some of the TCEQ monitoring stations in the El Paso Area. **Figure 15** includes an example of the basic site image and information that can be found on the TCEQ official site for the UTEP station *(City Of El Paso, 2022; TCEQ, 2022a*).

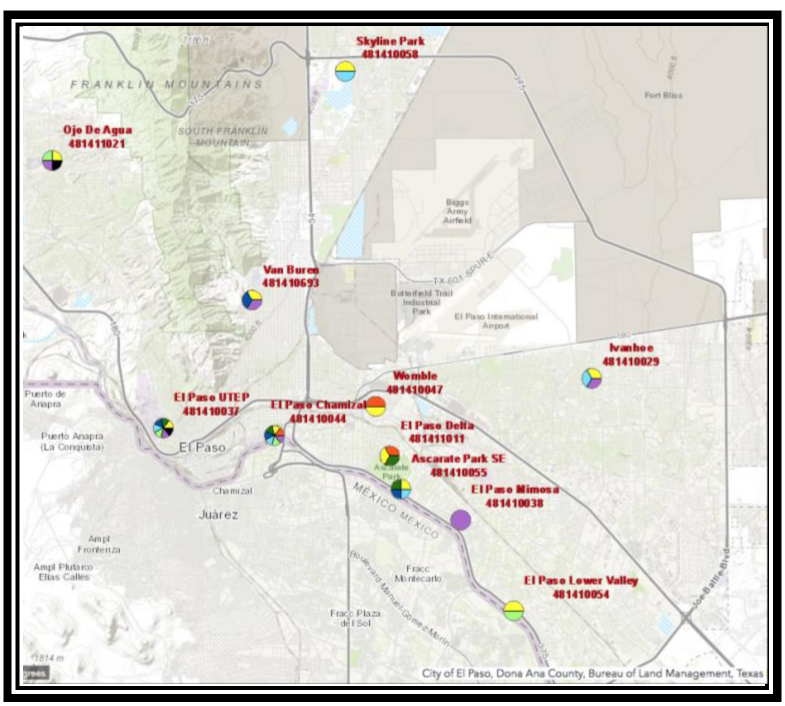

Figure 14. TCEQ Monitoring Stations Locations in EP (TCEQ, 2022c)

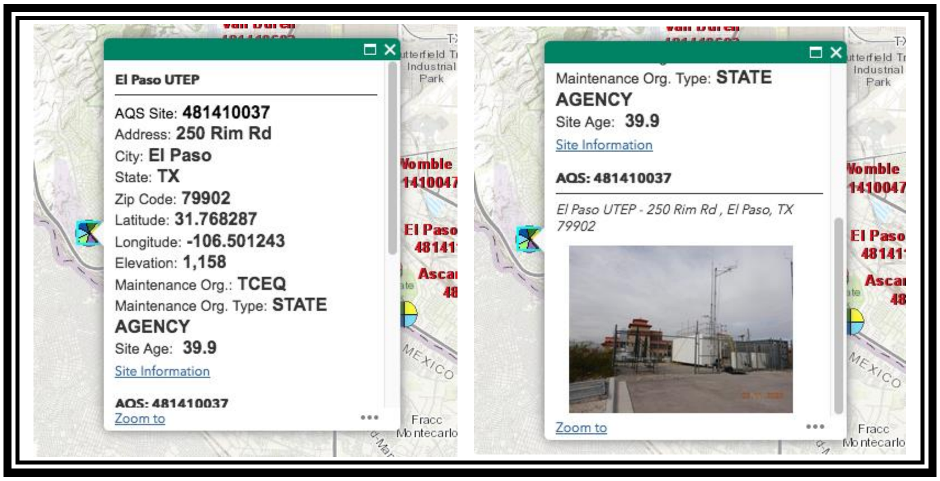

Figure 15. UTEP Monitoring Site Information (TCEQ, 2022c)

El Paso Electric (EPE). EPE has served the city of El Paso by providing safe and sustainable energy for over 120 years. For more than ten years, EPE has also been classified among the top two state electric utilities regarding system reliability rates for the system average interruption frequency index and duration of interruption index *(EPE. 2023)*. EPE is also among the top 20% of the national electricity generators that emit the lowest CO_2 emissions. EPE is under the rules and regulations of the Public Commission of Texas and the New Mexico Public Regulatory Commission *(EPE. 2023)*. In 2016, EPE became a 100% coal-free utility powered by carbon-free natural gas and nuclear *(EPE, 2023)*. **Figure 16** shows EPE's current resources and their 2023 renewable projection, while EPE energy production from 2020 to 2022 is shown in **Table 5** *(EPE. 2023)*.

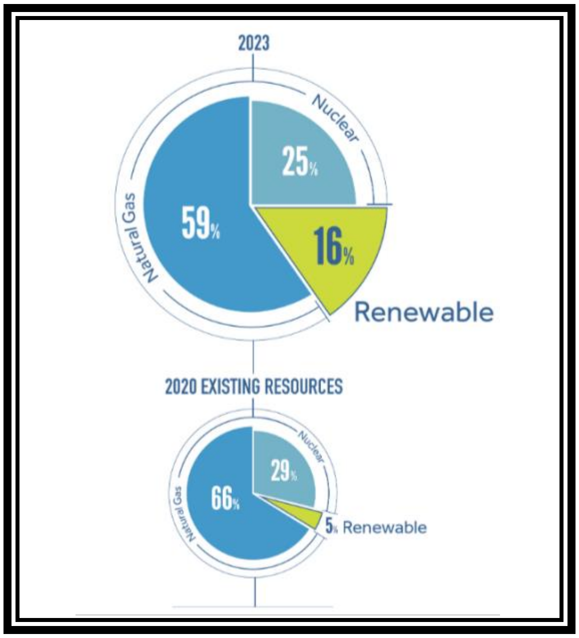

Figure 16. EPE Generation Projections for 2023 (EPE. 2023)

Table 5. EPE Net Generation from 2020-2022 (EPE. 2022)

Type of Fuel	**Net Generation (MWh)**		
	2020	2021	2022
Coal	N/A	N/A	N/A
Natural Gas	4,800,344	4,523.151	4,485,493
Nuclear	4,976,312	4,997,511	5,045,366
Renewable (solar)	17,459	17,408	20,017
Photovoltaic Purchased Power	289,705	278,989	272,594
Other Purchased Power	1,292,104	1,104,222	1,503,523
Carbon-free Generation	46.4%	48.5%	47.1%
Natural Gas and Purchase power	53.6%	51.5%	52.9%

The city of El Paso plans to reduce its carbon footprint on a megawatt/hour (MWh) rate of load served by 2025 to 25% less than the 2015 levels and to 40% less than the 2015 levels in 2035. This is by means of the Newman Unit 6 (228MW state-of-the-art natural gas electric generation unit) planned for 2023 in the Northeast of El Paso *(EPE, 2023; EPE, 2024a)*. The unit replaced the Newman Units 1 and 2 and Rio Grande Unit 7. Newman Unit 6 will save 600 million gallons of water annually. Additionally, the unit will produce three times the renewable energy in the coming three years, with the extra 200 MW large-scale solar energy plus 50 MW battery storage *(EPE, 2023; EPE, 2024a)*. EPE aims to be 80% carbon-free energy by 2035 and

100% decarbonization of its production portfolio by 2045. As of 2023, EPE's own resources include 71% natural gas, 25% nuclear, and 4% solar. By 2025, EPE aims at 59% natural gas, 25% nuclear, and 16% renewable *(EPE, 2024a; EPE, 2024b)*.

Although EPE remains within the best rates of CO_2 emissions from the different electric generating production units, during 2019, the numbers in carbon emissions increased due to its continuing load growth, while emissions of criteria pollutants stayed almost leveled *(EPE, 2019)*. EPE carbon emissions remain among the average rate of the national power generators, placing EPE as the third lowest for CO_2 emission rate and total CO_2 emissions from generation sources. EPE CO_2 emissions from 2018 to 2022 are presented in **Table 6**. **Table 7** presents the EPE scorecard for air quality during the same period. *(U.S. EIA, 2019)*.

Table 6. EPE 2018 -2022 Emission of CO2e[1] in Metric Tons (EPE. 2019, EPE 2022)

Source	2018	2019	2020	2021	2022
Stationary Combustion Units Emissions	2,730,085	2,791,568	2,610,637	2,548,448	2,485,124
Mobile Combustion Emissions	4,577	4,435	4,464	4,268	4,406
Electric T&D Emissions	1,996	32,013	31,128	43,846	46,692
Natural Gas Fugitives Emissions	2,766	2,766	2,766	2,766	2,767
Energy Procurement Indirect Emissions	2,760,590	20,711	26,393	19,650	24,619
Total CO_{2e} Emissions	2,760,590	2,851,493	2,657,386	2,618,978	2,563,609

1 CO_{2e} is comprised of carbon dioxide (CO_2), methane (CH4), nitrous oxide (N_2O), and sulfur hexafluoride (SF_6)

Table 7. 2018-2022 EPE Air Quality Scorecard (short tons*)**, (EPE. 2019, EPE 2022)

Parameters	2018	2019	2020	2021	2022
Nitrogen Oxides (NO_x)	2,893	2,780	2,304	2,513	2,374
Carbon Monoxide (CO)	585	608	364	871	604
Particulate Matter (PM)	234	232	217	148	201

*A mass measurement unit = 2,000 pounds-mass (907.1847 kg)
** Criteria pollutant totals are for local generation only (natural gas

EPE Carbon Footprint. As a free coal-fired generation facility, EPE's main emissions come from fixed-site natural gas incineration. EPE's total carbon emissions are included in **Table 8,** showing all carbon sources in 2019 and comparing them to 2022 *(EPE. 2019, EPE 2022)*. The numbers from 2015 serve as a baseline to measure progress. The carbon footprint includes CO2, CH4, and N2O emissions from fuel combustion at the power plants, fluorinated gases (SF6) from transmission and distribution equipment, and CO2 emissions from the vehicle fleet *(EPE. 2019, EPE 2022).*

Table 8. Carbon Footprint Trend (Short Tons of CO2e/MWh) (EPE. 2019, EPE 2022)

2015 Baseline Rate	**0.282**	**Change from 2015**
Rate in 2019	0.271	< 4%
Rate in 2022	0.249	<11%

Another way that EPE is making efforts to reduce emissions is through the gradual electrification of the company vehicles *(EPE. 2019, EPE 2022)*. In this way, fuel use is reduced, while vehicle performance is improved, including lowering maintenance costs. EPE also aims at providing charging stations through its facilities and incentivizing employees to acquire EVs and HEVs *(EPE. 2019, EPE 2022)*. During 2019, the use of HEVs and Plug-In Hybrid Electric Vehicles (PHEVs) in EPE showed an approximate decrease in fuel use of 1,260 gallons of gasoline and 472 gallons of diesel. This represents a reduction of emissions of nearly 24 tons of CO2. In 2022, four electric power take-off (ePTO) bucket trucks were added to make 10 of these vehicles *(EPE. 2019, EPE 2022)*. **Table 9** compares EPE's electric and hybrid vehicles in 2019 and 2022.

Table 9. EVs and HEVs in EPE (EPE 2019, EPE2022)

Vehicle Make and Model	Power Source	Quantity 2019	Quantity 2022
Ford Fusion Hybrid	Flex E85	1	1
Toyota RAV4 Hybrid	Unleaded	3	3
Ford Fusion Energy Plug-Ins	Electricity and Flex E85	3	3
Ford F-550 ePTO bucket trucks	Diesel and Electricity	10	23
Chevy Bolt	Electricity	4	12
Lifts, Forklifts, Off-Road Vehicles	Electricity		10
Total	4 % of total fleet	21	52

EPE Water Use. EPE utilizes nearly 2 billion gallons of water annually and looks forward to having approved an improved measure of its water use efficiency by divesting the coal assets (*EPE 2019; EPE, 2022)*. Water use rates depend on the technology that is used for power generation. Cooling purposes and a controlling pollution process to lower Nitrogen Dioxide (NOx) emissions are the two primary water consumption sources in EPE (*EPE 2019; EPE, 2022)*. The most efficient technology for water cooling is found at the "Montana" Power Station. At the Newman" and "Rio Grande" Power Stations, the newer gas turbines and the older water-intensive boiler units are found. The "Copper" station utilizes water to control pollution as it lacks a cooling water tower (*EPE 2022)*. **Table 10** shows EPE's water consumption rate per year, and **Table 11** shows rates per power station in 2022.

Table 10. EPE Water Consumption Rate1 (EPE. 2022)

Year	2020	2021	2022
Rate (Liters/Net MWh)	2,426	2,474	2,349

Table 11. EPE- Water Rates for 2019: Owned Generation (EPE. 2022)

Power Station	Water Use[1] (gal/kWh)
Montana	0.18
Rio Grande	0.64
Newman	0.55
Cooper	0.10
Palo Verde[2]	0.71

1: Water consumption data calculated based on gross generation

2: Palo Verde rate calculated as 15.8 percent (EPE's ownership) of water consumed by Units 1, 2, and 3

EPE Goals for Climate and Energy. As of March 2020, El Paso had no official renewable energy municipal goal *(ACEE, 2020)*. Regarding energy reduction, the city participates in the "Better Buildings Challenge," aiming for a 20% reduction below the 2009 levels by 2020 *(ACEE, 2020)*. El Paso does not have a goal for reducing greenhouse emissions or climate mitigation, nor has it adopted a sustainability or a municipal climate action plan. As for fleet policies, a purchasing policy for alternate-fuel or hybrid vehicles was implemented by the General Services Department (GSD) once those vehicle options became available *(ACEE, 2020)*. The goal was to reduce the number of road vehicles in 2015 by 20%. A policy has also been adopted through employee training on anti-idling, carpooling, and efficient driving *(ACEE, 2020)*.

The city of El Paso has teamed up with the U.S. Department of Energy's (DOE) "High-Performance Outdoor Lighting Accelerator," whose goal is to accelerate high-efficiency outdoor lighting adoption and system-wide substitution in the municipality *(ACEE, 2020)*. An efficient outdoor lighting policy has not been implemented, as in the ordinance of the International Dark-Sky Association's Model Lighting ordinance; however, the city has switched to using LED for 60 % of the streetlighting and scheduled it to be on only when needed. Multiple renewable energy systems have been installed in the city, totaling 200kW installed capacity *(ACEE, 2020)*. Since July 2020, El Paso has been working on but has yet to implement benchmarking of buildings in the municipality in EPA's ENERGY STAR portfolio manager. This online tool measures and tracks water and energy consumption *(ACEE, 2020)*. El Paso, however, offers incentives for projects that use renewable energy and energy efficiency. Extra above-code energy-saving action is not required for building owners. El Paso has also implemented the

Sustainable Development Design Standards for all municipal buildings that are over 5,000 sqft to reach at least a LEED Silver Certification *(ACEE, 2020)*.

Transitioning to Electric Mobility

The Federal Government is seeking to diminish emissions from the transportation sector by promoting a shift to electric mobility. This shift aims at providing all communities with better mobility modes and improved technology at a lower cost while needing minimal maintenance *(U.S. Department of Transportation, 2023)*. The use of EVs is projected to meet the community's transportation needs and minimize emission environmental impacts. The Biden administration has taken steps for this shift regarding EV charging infrastructure, technology development, and funding for electric mobility supporting initiatives *(U.S. Department of Transportation, 2023)*.

The Biden Administration Pollution Standards

As the EV industry continues to gain ground as a cleaner option to decrease air pollution produced by the transportation sector, it develops more efficient vehicles and batteries. The EPA has also increased its efforts to ensure future cleaner vehicles and transform the whole automobile industry *(EPA, 2023b)*. Through the proposal of new and constricted federal vehicle emission regulations, the Biden administration attempts to accelerate car makers' transition to electric vehicles *(EPA, 2023b)*.

The EPA aims to decrease 7.3 billion tons of CO2 through 2055 by having cleaner vehicles in the market. Thus, contributing to cleaner air and offering a better quality of life for the community by decreasing respiratory and cardiovascular illness and premature deaths *(EPA 2023b, EPA 2023 c)*. The strict emission standards estimate that by 2032, new light-duty vehicles (LDVs), on average, should target 67% zero-emissions or 82 gr/mi, according to the automobile type and size, for vehicles model year 2027 onwards. It also proposes standards for medium-duty and heavy-duty trucks, aiming for half of the buses and a quarter of haul trailers to be electric by 2032*)*. The standard for the model year 2032 vehicles projects a decrease in GHG by 56% of the original rates from the existing standards *(EPA 2023b, EPA 2023 c)*.

Different automakers in the United States are already switching to EVs with outstanding achievements. For instance, Ford and General Motors sold over 60,000 and 30,000 vehicles in 2022 and are projected to increase their sales by the end of 2023 *(EPA, 2023b; EPA, 2023c)*. Some companies have felt thwarted, considering that the period the rule offers is too soon. Other manufacturers have not stated a plan to achieve the expected target of two-thirds of all vehicles fleeing to be electric by 2032. However, the regulation includes different emission control technology options, which allows automakers to find the best solution to comply with the new rule *(EPA 2023b, EPA 2023 c)*.

This rule is the most ambitious initiative to reduce air pollution from the transportation industry. It is promoted as inclusive by working closely with the automotive industry, labor groups, advocates, and community leaders. This proposal will be accessible for public review in the Federal Register. During its development, EPA ensures the continuation of open communication with the general public and all the parties involved in this regulation *(EPA, 2023b; EPA, 2023c)*.

The transition to electric mobility is evident, and vital steps are considered to support this transition. For instance, the Biden administration is foreseeing resources to ease the transition for the automotive industry, develop new EV infrastructure, and generate cleaner energy and clean hydrogen to remove carbon from the transportation sector. Incentives and tax rebates are also available for the purchase of EVs *(EPA, 2023b; EPA, 2023c)*.

Similarly, efforts should be increased to account for underrepresented and minoritized populations, making the transition equitable. It is important to note that underrepresented groups tend to have the oldest and least efficient vehicle, and immediately acquiring a new vehicle would be a struggle *(Mara Elana Burstein, 2023)*. Thus, assisting low-to-medium-income households' access to EVs is as important as supporting the automotive industry and infrastructure developers transitioning to electric mobility.

Governor Greg Abbot's New Texas EV Tax Bill

With the seemingly inevitable growth of electric mobility, new efforts and initiatives are implemented to promote and increase EV use amongst the public. While some measures appear proper, others seem to be contradictory or punitive *(Jankowski, 2023)*. Without a previous public announcement, Texas Governor Greg Abbot signed the new tax bill 145-0 into law for the Texas state EV owners on July 29th, 2023, to take effect on September 1, 2023. Under this law, EVs must pay a $200 annual registration fee, independent of the vehicle size and type, plus the standard annual registration fees *(Jankowski, 2023)*. However, new EV owners must pay the registration fee of two years up-front, which makes it $400. HEVs, PEVs, and ICEVs are excluded as these vehicles pay a state tax of 20 cents per gallon of fuel, either gasoline or diesel, while 18.4 cents for gas and 24.4 cents for diesel is the federal tax. Autocycles, mopeds, and motorcycles are also exempt from this law *(U.S. EIA, 2024)*.

Currently, 32 states have already enacted registration fees for EVs. Nineteen of those states also included PHEVs in their fees, ranging from $50 to $200 from the traditional vehicle registration fee *(Igleheart, 2023; Jankowski, 2023)*. However, some states have assessed the fees according to the EV type or weight of the vehicle. The revenue from the registration fee is intended either for the state or federal transportation fund, while some states have destined part of the revenue for the development of EV infrastructure *(Igleheart, 2023; Jankowski, 2023)*.

Texas House Representative stated that this law ensures that all users pay their fair share for highway use and future maintenance because EVs have been excluded from this tax by not purchasing fuel *Jankowski, 2023)*. Although this fee might seem exaggerated to the public, in previous bill sessions, the Senate Transportation Committee chairman and bill creator had pressed for higher EV registration fees *(Jankowski, 2023).*

According to the Federal Highway Administration and the EPA, ICEVs pay close to $130 dollars in annual state fuel taxes *(U.S.DoT, 2022)*. Although a $100 fee was proposed for lighter-weight vehicles during the bill debate on April 2023, the bill was passed with many supporters. Fuel and EV taxes are intended for the state's highway fund, while part also goes to public schools. According to the Controller's office, the new tax will generate nearly $38 million for the state's highway fund, while $3.8 billion from diesel and gasoline are expected for 2024 *(Jankowski, 2023)*.

According to the executive director of the Environment Texas non-profit advocacy group, a driver of a small, light, and efficient EV could be paying the same tax as a Hummer driver, which is fuel-powered and much heavier on the roadway *(Jankowski, 2023)*. EV users would be contributing more to the Texas environment with cleaner air and generating less impact over the roadways than a Hummer; however, both users would pay the same amount of taxes. On the other hand, law supporter Terri Hall, founder and director of Texans Uniting for Freedom and Reform, considered that due to the increase in EV use, EV road usage needs to be compensated *(Jankowski, 2023)*. In his opinion, most EVs are not light and small, but of the Tesla style and size, and if users can afford a Tesla, they surely can afford the new tax as well. Although the new tax is a fair measure for all vehicle owners to pay for their use and maintenance of the highways, for many, these fees seemed exaggerated and close to retaliation for those who opt into electric mobility, which questions the efforts of the Biden administration to support the transition *(Jankowski, 2023)*. This new law may not jeopardize the EV market but might weaken the transition into electric mobility *(Jankowski, 2023)*. EVs are touted as cost-effective due to the savings from not using fuel. However, the new law could draw EVs from their main public benefit and seem punitive since users could pay more taxes than fuel-powered vehicle owners *(Jankowski, 2023)*. According to Dallas-Fort Worth Clean Cities data, more than 250,000 electric vehicles currently circulate in Texas, while more than 30,000 new EVs were added to the Texan roadways only in 2023 *(Dallas Forth-Worth Clean Cities, 2024)*.

EPE EV Initiatives

2024-2026 Transportation Electrification Plan (TEP)

EPE has striven to facilitate the transition to electric mobility for its customers in El Paso and New Mexico. Based on customer surveys, stakeholders' assessment, current public charging infrastructure, current and projected local EV adoption rates, state and federal plans, and subsidies, the company has proposed a transportation electrification plan (TEP) for the years 2024 to 2026 *(EPE, 2023)*. The plan considers light, medium, and heavy-duty vehicles, including electric bicycles. This proposal includes residential and commercial programs, partnerships, research and innovations (PRI), construction, public outreach, different EV classes, and rate options to apply EVs practically to daily life *(EPE, 2023)*. Through the TEP, EPE aims to advance transportation electrification in its serviced area to increase the local EV market penetration and overcome public EV misinformation with a special focus on low-income and underrepresented communities *(EPE, 2023)*.

TEP proposes four residential programs, "EV smart rewards," "smart charging," "home wiring," and "electric bicycle rebate" *(EPE, 2023)*. The programs aim to provide public incentives to acquire and install residential charging equipment, purchase electric bicycles that introduce the public to new sustainable and affordable transport methods, and promote off-peak charging *(EPE, 2023)*. Additionally, the programs will serve to explore the public acceptance of a charging program to guarantee that transportation electrification does not affect the electric grid. Through these proposals, EV adoption is expected to increase and contribute to a cleaner local environment *(EPE, 2023)*.

For the commercial programs, the TEP also includes four proposals *(EPE, 2023)*. Power Connect: which provides incentives for charging equipment. EV charging equipment rebates: to cover 70% of the equipment cost if located in underserved communities and 50% in other communities. EV charging installation rebates: to cover 70% of the installation cost if located in underserved communities and 50% in other communities. And take charge: which eliminates the cost of infrastructure for both the meter and the customer side, prioritizing those located in underserved communities, multi-unit dwellings, and EV fleets *(EPE, 2023)*.

The TEP also considers a rebate program for the construction of new EV-ready homes and EV-ready multi-units located within EPE's service area *(EPE, 2023)*. For new homes, the program subsides the installation cost of outlets 240V NEMA 14-30 or NEMA 14-50. For multi units, the program subsides the cost of up to 70% of the wiring, which can be combined with the rebate program that covers the cost of EV charging equipment *(EPE, 2023)*.

Regarding customer outreach programs, the TEP includes customer instruction, customer outreach, and marketing *(EPE, 2023)*. These initiatives aim to educate the public about the benefits of EVs, the available EVs, the availability of incentives, and the different rate options while dissipating EV misconceptions and fostering advocacy for EVs *(EPE, 2023)*. Marketing will promote the different programs through social media, search engine marketing, television, radio, and community activities *(EPE, 2023)*. A collaboration with stakeholders, including public organizations, universities, vehicle dealerships, etc., is considered to conduct customer outreach to advance the TEP through various events tailored either for underserved communities or commercial clients *(EPE, 2023)*.

Finally, the PRI program is centered on new solutions and emerging technologies to enhance public access to EV infrastructure. With projects such as energy storage to optimize fleet charging and bike sharing, the initiative has a particular focus on low-income and underserved communities *(EPE, 2023)*.

EV Charging Station Pilot Program

EPE is also contributing to decreasing GHG emissions and providing a greener future for the city of El Paso. For instance, EPE is investing in public EV charging infrastructure to provide the public with more charging options. Also, in December 2022, the city of El Paso approved the EPE EV Charging station pilot program to support the installation of twenty new EV charging stations *(EPE, 2023)*. Through the program, EPE covers the costs of purchase, installation, and maintenance of a charging station for property owners interested in providing this service as an amenity for their clients or promoting their business at no cost to them. This October, the latest level 2 station that allows tow vehicles was installed in the Ascarate golf course. This is expected to increase El Paso EV ownership. The city of El Paso currently has more than 100 public stations within the EPE service area. They offer level 1, level 2, and 3 (DC Fast charging). The public stations that have been installed in El Paso through the pilot program are located in El Paso County Coliseum, Vista Urban Market, Denny's Restaurant in Montana Ave., Coronado

Country Club, Arcadia at Montecillo, The Canyons at Cimmaron, and The Substation *(EPE, 2024b)*.

Public EV Education and Outreach

Another way that EPE is contributing to advancing El Paso's EV mobility is through several online services that allow the public to be informed. The EPE website offers the public the opportunity to learn about what an EV is and its benefits, the different types of charging (Level 1, Level 2, home, multi-unit, public, workplace, and flee charging), and also compare the rates of EV charging vs fuel fueling *(EPE 2024a).*

In 2020, EPE launched the EV community website registration page. The website allows the public to learn about EVs, charging options, incentives, rates, and transportation electrification *(EPE 2024a)*. The site also provides a newsletter and different events, allowing the community to interact with current EV owners who can share their experiences with EVs, charging infrastructure, incentives, maintenance, etc. Additionally, the site collects EV owners' feedback regarding infrastructure locations and charging time to evaluate service capacity and prevent possible failures in a timely manner *(EPE 2024a)*. EPE also engaged with local parking lots and home-apartment constructors about the EV-ready homes initiative and reached local vehicle makers and dealerships regarding staff EV knowledge and vehicle inventory to consider collaborations *(EPE 2024a)*.

In May 2022, the EPE developed an online service tool for customers to explore available EVs, EV and charger incentives, tax credits, and charge discount rates *(EPE 2024a)*. This service lets Customers learn about savings when buying or leasing an EV. Vehicle price, type, fuel type, miles per charge, battery size, electric range, time to charge, CO2 emission reduction, and gasoline savings are also provided. EVs and ICEVs purchase costs, maintenance, insurance, fuel vs electricity, and the purchase method can be compared to determine the most beneficial. Clients can also personalize an incentive by means of different options that include their location, the vehicle they plan to purchase, household size, and household income, among others. This service also offers discount rates for eligible customers who want to charge their vehicles during off-peak hours, from 6:00 to 12:00 pm *(EPE 2024a)*.

Transitioning to Electric Mobility Summary. It is important to assess whether the new law favors or slows the transition to EVs in the automobile industry and with the public interest, particularly with new markets being explored for EV penetration. The new law might appear discouraging, particularly to new potential users, such as minorities and underrepresented groups, since a distinction between small and large EVs has not been made. Thus, the benefits offered by the different EV types might seem equally null in terms of cost. New measures should be taken into consideration strategically to compensate for the newly imposed fees and thus increase the positive public perception and promote the use of EVs.

Modeling

EVs enter the market as a reliable solution to meet the growing demand for cleaner LDVs and reduce the impacts of GHG emissions on the transportation sector. One of the key benefits of EVs is the reduced consumption of petroleum-based fuels, from which the growing interest in alternative fuels derives *(Egbue & Long, 2012; Krause et al., 2013).* Yet the actual benefits regarding the decrease of GHG emissions remain a topic for research.

Research has examined a myriad of aspects regarding EV technology, including cost and performance, market penetration rate, environmental effects, and policy implementation *(Larson et al., 2014; Zhang et al., 2018; Gong et al., 2020;)*. Modeling studies have used scenario-based approaches to investigate trends in GHG emissions under various assumptions. For example, assessing the production and use of energy for EVs to identify possible future decreases in emission *(Mcleod et al., 2014; U.S. EIA, 2023)*. Other research has assessed future challenges to plan accordingly by examining decision-making using scenario projection *(Brown et al., 2018)*.

The MARKAL energy system optimization modeling software and the U.S. EPA nine-region database have served different researchers to model case scenarios for EV technology evaluation *(Yeh et al., 2008; Mcleod et al., 2014; Keshavarzmohammadian et al., 2017).* Some studies have evaluated implementing new technology, fuel alternatives, pollutant emissions, and transition policies to surpass market barriers and considerably reduce GHG emissions *(Larson et al., 2014; Meier et al., 2015; Wattana & Wattana, 2022)*. Research has also assessed EV market penetration to assess vehicle travel demand and fuel alternatives for GHG emission decreases.

A study by *Mcleod, Brinkman, & Milford (2014)* used the Markal model to assess GHG, volatile organic compounds (VOCs), and Nitrogen oxides (NOx) emission effects of the production and use of natural gas to replace the use of fossil fuels in the U.S. and the Rocky Mountain Region and promote renewables. Their scenarios compared natural gas supply and demand, constraining electricity production and adding emission fees. Results showed that GHG emissions had a minimal change due to compensations through the different economic sectors. *Brinkman, & Milford (2014)* also found that NOx emissions decreased, and VOC emissions escalated, offsetting some of the forecasted decreases within the transportation sector.

Another work by *Brown, Henze, & Milford (2014)* integrated the life cycle of pollutant emissions and their harmful effects with energy cost to evaluate changes in emissions in the U.S. economic sectors through 2055. They modeled emissions damage fee case scenarios and compared them to those without fees. Their results showed that CO2 emissions tended to decrease, and revenue rose when fees were applied. *Brown, Henze, & Milford (2014)* concluded that the development of newer technology, including efficiency improvements, and the amount and type of fuel used, according to each energy use sector, can produce a notable decrease in pollutant emissions.

A study conducted by *Keshavarzmohammadian, Henze, & Milford (2017)* analyzed the emissions impact of EV market penetration through scenario projections of performance and cost of the vehicles through 2050. Their results showed that although EV adoption would increase by 2030 and 2050, ICEVs remain the preferred vehicles in the market. GHG emissions showed 5% and 9% reductions through all economic sectors by 2030 and 2050. Emission fee application also showed minimum emissions decrease while a more effective result in the electric sector. Another study that used the MARKAL model to assess future energy use and demand aimed at acquiring better air quality (*Brown et al., 2018)*. These scenarios combined policy implementation with the interaction of stakeholders regarding technology development and societal changes in attitudes toward the environment to model future emissions. *Brown et al., (2018)* found that even with no policy modification, a social change in attitudes toward the environment alongside technological innovation can positively decrease emissions. However, their study also proposes implementing discount rates on specific technology development.

U.S. EPA nine-region database has also been used with the MARKAL-TIMES, the newer version of the MARKAL, a bottom-up energy system model, to examine EV technology and HGH emission reduction *(ETSAP, 2023)*. *Babaee, Nagpure, & Decarolis (2014)* assessed the increase of EV market penetration in the U.S. through 2050 to quantify emissions change by developing 108 scenarios. Their assumptions included EV battery cost, oil and gas prices, policy changes, and federal renewable standards. The results of the study showed that the cost of EV batteries and oil were the greatest determinants to impact EV market penetration, while no clear tendency regarding lowering emissions was found.

The research that *MARKA-Yeh et al. (2008)* conducted analyzed the decreases of GHG emissions in the transportation sector's LDVs in the U.S. through mitigation policies. They suggested that these should be designed in accordance with the actual transition stage of technology adoption, assumptions to long-term targets, and social concerns. To assess emission reduction, *MARKA-Yeh et al., (2008)* developed different scenarios. These considered increasing the transportation technologies efficiency and other fuels use (ethanol or electricity). The promotion of alternative transportation modes, such as public mass transit supported through policy implementation, was also considered. The study results determined that the most influential factors in policy implementation were technology cost, for example, infrastructure for alternative fuels. Also, social factors to promote and achieve technology adoption.

Regarding biofuel use, a study by *Meier et al., (2015)* examined the U.S. environmental impacts of EVs in the LDVs sector based on two studies previously performed by the Electric Power Research Institute and Natural Resources Defense Council. *Meier et al., (2015)* reorganized the vehicle portfolio to assess EV market penetration, vehicle travel demand, and the decarbonization of electricity. They found a decrease in GHG emissions from LDVs in the transportation sector through projections of a decreased 50% of petroleum use and providing 40% of the travel demands through electrified vehicles. However, as they targeted a larger reduction of GHG emissions by increasing market penetration of electrified vehicles, projections did not show the expected target. Emissions seemed to relate to electricity use and not only to the use of fuels. *Meier et al., (2015)* concluded that to achieve a significant emission decrease, besides increasing the number of EVs, low-carbon fuels should also be implemented to supply a moderate travel demand.

Life cycle of ICEVs and EVs in the LDV sector was analyzed in a study by *Elgowainy et al., (2016).* The vehicles power sources (petroleum, gas, ethanol, hydrogen, and electricity) were also considered to understand each vehicle type emissions and find the best pathway to technology implementation. *Elgowainy et al., (2016)* found that the vehicle technology is commercially ready; nevertheless, the development of new ones, especially for EVs, still represents an implementation challenge. Regarding alternative fuels, they found different challenges. For example, for renewables and biomass, the regulations process seemed unclear, the implementation would be costly, and the geographic restrictions could complicate its development. Regarding hydrogen, they found a current lack of pipeline network which complicate its distribution.

Markal-TIMES was also used by *Wattana & Wattana, (2022)* to evaluate EV market penetration and advancement policy using a low-emission analysis model that examines scenarios from 202 through 2037. The study recognized that EV advancement equally represents possibilities and obstacles. Through their analysis, *Wattana & Wattana, (2022)* discovered that as EV market penetration increases, CO2, NOx, and PM2.5 were reduced. However, increased electricity use was required, which could imply possible grid impacts and security concerns. *Wattana & Wattana, (2022)* concluded that long-term planning was required to mitigate such challenges. This included electricity generation considering its capacity, the addition of charging infrastructure, usage fees development, and policy implementation across all the economic sectors.

Modeling literature review summary. Research widely uses scenario analysis to explore a combination of perceptions and assumptions to assess different conditions that serve to project and assess future outcomes *(Babaee, Nagpure, & Decarolis, 2014)*. Many studies have focused on the interaction of EVs with the rest of the energy system in terms of GHG emissions; few have evaluated PM emissions *Wattana & Wattana, (2022)*. Previous research on public perception of EV use and consumer behavior has identified key adoption barriers for first adopters or potential users in higher-income markets. To expand this research, this work considers historical URCs. The study identified the main adoption barriers in this unexplored market by evaluating their perception, knowledge, and opinions of EV technology. The study also integrated the analysis of possible GHG and PM emissions reduction due to an increased EV market penetration in the URCs.

Chapter 3: Methodology and Application

This work evaluated the environmental and social justice impacts of EV market penetration in URCs. The study identified key barriers to EV public perception and consumer behavior specific to this market. For this purpose, the study included a social science component comprised of focus group sessions and the application of a survey instrument in URCs. Concurrently, GHG emissions were evaluated using two scenario projections to estimate any emission changes after increasing EV market penetration. The first scenario assessed LDV sector GHG emissions under the current infrastructure and vehicle market. The second scenario assessed a projected increase in EV market penetration due to an adoption rate increase in URCs. The results of the two scenarios were then compared to determine the possible GHG emission impact if EV adoption increases among URCs.

Social Science Component

As EV technology evolves, adoption rates continue to increase. Policymakers and vehicle manufacturers also accelerate the transition into electric mobility, aiming for a future with cleaner vehicles and better air quality *(EPA, 2023)*. Similarly, research increases the evaluated potential of EVs regarding environmental benefits, public perception, and attitude while exploring new markets. Nevertheless, this endeavor toward strengthening the transition to electric mobility has been disproportionately inequitable. Most studies have focused on early EV adopters, potential users, and high-income markets. Low-income households and underrepresented communities have been left unnoticed. These markets are the most impacted by transportation costs and emissions health effects due to their likelihood of residing near areas with elevated traffic *(Hardman et al., 2021)*. This study assessed URCs in the Paso del Norte area to understand their perceptions, knowledge, and opinions regarding EV technology. This was to identify key barriers to public perception and behavior and help promote and diffuse the technology and promote it as equitable.

Selection of the Communities

The Environmental Protection Agency (EPA) environmental justice screening and mapping tool (EJScreen) *(EPA, 2022)* and the Texas Commission on Environmental Quality Monitoring Stations *(TCEQ, 2020c)* were used to evaluate local areas potentially exposed to elevated levels of GHG and PM2.5 pollutants and then select the communities. To account for social justice and equity, majority-minority populations and low-income demographics were considered.

Focus Groups

The research consisted of three focus group sessions, including a questionnaire and a protocol with Institutional Review Board (IRB) approval. Key participants included current residents of each community, who were considered the best candidates to convey their experience and perspectives according to their residency in the neighborhoods. Participation was open to any resident of these areas being at least 18 years of age. The sections and topics of the questionnaire are presented in **Table 12**.

Table 12. Focus Groups Topics by Section

Section	Description
Section I:	Knowledge and Perception of local AQ and EVs as environmental benefit
Section II:	Knowledge and perception of EVs
Section III:	Knowledge and perception of EVs Purchase and Incentives
Section IV:	Knowledge and perception of EVs ChSs and ERWs

The collected data was analyzed using qualitative and quantitative research methods using the Minitab and MAXQDA data analysis software *(MAXQDA, 2023; Minitab, 2024)*. The vehicles included in the study were battery electric vehicles (BEVs), hybrid electric vehicles

(HEVs), plug-in hybrid electric vehicles (PHEVs), and internal combustion engine vehicles (ICEVs), presented in **Table 13**.

Table 13. Vehicles Considered in this Study (Egbue & Long, 2012; Guevara et al., 2021; Kester et al., 2019)

Vehicle	Description
Battery electric vehicles (BEVs)	Fully powered by plug-in rechargeable electric batteries
Hybrid electric vehicles (HEVs)	Powered by both a gasoline/diesel engine and an electric motor simultaneously (fuel engine recharges the battery that powers the electric motor)
Plug-in hybrid electric vehicles (PHEVs)	Powered by a gasoline/diesel and electric motors, where the electric motor is powered by a plug-in rechargeable electric battery and the gasoline engine is used as a backup
Internal combustion engine vehicles (ICEVs)	Conventional gasoline and diesel engine vehicles

Surveys

The study examined non-EV users in URCs in the Paso del Norte region to evaluate their perceptions, opinions, and knowledge about EVs and EVs-ChSs and their perceptions about having them installed in their neighborhoods. Contrasting previous research on EV public perception and attitude that has identified key adoption barriers from EV early adopters, owners, and potential users, this study identified the main EV diffusion and adoption barriers from URCs. The study targeted members of these communities who were at least eighteen years of age and non-EV owners. The goal was to understand their knowledge, perception, and opinion of EV technology and charging infrastructure to help determine key factors that can strengthen EV diffusion and adoption in unexplored minority groups. The research was developed in three stages:

1. *Development of a survey questionnaire and protocol*: A combined in-person and online survey was designed and distributed in the Paso del Norte region to collect data from a sample population of five URCs, including the Institutional Review Board (IRB) for Human Subjects Research Performance formal approval to

comply with the University of Texas system policy, the federal guidelines, and local covid-19 restrictions applied at the moment.

2. *Connecting with the Communities:* El Paso's Department of Community and Human Development provided contact information to facilitate communication and access to the communities.

3. *Analysis of the results:* Mixed methods were used to analyze the collected data results, using the Minitab and MAXQDA analysis software *(MAXQDA, 2023; Minitab, 2024).* to identify the differences in opinion and perception among the study participants, he chi-square test of independence was employed. This hypothesis test evaluates the likelihood of two categorical or nominal variables being statistically associated by measuring the differences between the expected and observed values (set of groups and a response). Chi-square in a row (i) and column (j) value table is:

$$\text{Qp} = \sum_{i=1}^{s} \sum_{i=1}^{r} \frac{(0_{ij} - E_{ij})^2}{E_{ij}} \quad \text{and} \quad E_{ij} = \frac{O_i \, O_{ij}}{O}$$

Qp means the chi-square statistic with asymptomatic normal distribution, meaning that as the sample size "n" grows, estimators and tests are assessed under n = ∞. "E" means the expected value of the frequencies in the columns (j) and rows (i), and "O" means the total values in the margins.

The test rejects the null hypothesis or first idea that the variables are not related. A 5% significance level was used to determine that both variables are not independent or that there is a significant association level. A p-value < 0.05 shows a significant relationship between the two variables *(JMP Statistical Discovery, 2024)*. The test shows whether the two variables are associated; however, it does not state that one is a consequence of the other.

Due to the global COVID-19 pandemic restrictions, the study was attempted to start online. However, the results were not acceptable. Once the city lifted some restrictions, the study resumed in person. Participation was fully voluntary, and responses were strictly confidential. Key participants included current residents of the selected communities, who were considered the best candidates to convey their experience and perspectives for their time of residency in the neighborhoods, and who were at least 18 years old. The questionnaire topics by section are presented in **Table 14,** and the vehicles evaluated in the survey are described in **Table 13.**

Table 14. Survey Topics by Section

Survey Section	Section Topic
Section I:	Demographics; five questions
Section II:	Perception of Environment; two questions
Section III:	Driving and Transportation Habits; four questions
Section IV:	Knowledge of the technology; six questions
Section V:	Vehicle Ownership; three questions
Section VI:	Charging Stations; three questions

Modeling

GHG emissions impacts from the transportation LDV sector were evaluated in this study at regional and national levels. Scenario planning was used to evaluate current and future GHG emissions. Two scenarios were modeled to represent the ICEV and BEV technology advances, projecting their emission accordingly. A base case scenario (BCS) was implemented based on the current infrastructure to estimate an emission baseline. To estimate possible GHG emission changes, a second future scenario (FS) was developed with an increased EV market penetration as a result of increased EV use from URCs based on the results of the survey applied in the social component. Both scenarios were contrasted to examine emission changes of the EV technology's increased penetration from 2025 until 2050. Cost estimates and specific policies were not considered in this study. Rather, the objective was focused on reducing GHG emissions due to the increased use of EVs in historically minoritized populations, decreasing fuel dependency while meeting vmt demand.

Markal-Times

The MARKAL-Times energy system optimization model was used to project two different scenario projections. The Integrated MARKAL-EFOM System (TIMES) model generator was developed by the Energy Technology Systems Analysis Programme (ETSAP). Its methodology for energy scenarios evaluates environmental and energy analysis. Markal is a linear programming-based mathematical model. It calculates energy changes through the entire energy system, from primary resources to energy systems, to supply energy demand related to technology use and fuel at the lowest cost. Markal explores energy futures by contrasting different scenarios, allowing the user to define constraints of energies, demand, supply, technology efficiency, and emission limits. The models can be generated at a regional and national level. It provides a wide technology basis to estimate energy use through five-year periods of time from 2005 to 2055. This work considered a time frame from 2025 to 2050. The model includes a reference case per region where the user provides the end-use energy demands such as vehicle miles traveled, the base year for all sectors, existing stock estimates of the energy-related equipment, available and upcoming technology, and current and future supply sources of primary energy. With these inputs, the model attempts to supply the energy services with the least global cost or minimum surplus loss, deciding simultaneously on equipment operation, equipment investment, energy trade, and supply of primary energy *(ETSAP, 2023)*.

The TIMES model portrays emissions and materials related to the energy system adapted to evaluate fuels and technologies policies in all sectors. The model covers all the steps from the primary resources to their transformation process, transportation, distribution, and energy conversion to supply energy demand. Material prices and quantities are balanced, meaning that resources will not exceed the portion used; suppliers will produce the exact quantity demanded by the consumer *(ETSAP)*. The basis of the TIMES model is the engineering relationships between the energy supply side (primary resources and production) and the energy demand side (supply). The TIMES model considers processes and commodities. The processes are the physical devices that transform the primary resources into other materials, such as oil extraction, transformation, plants that produce electricity, processing, refineries, and end-use devices, like vehicles or heating systems. The commodities are materials, such as fuels, emissions, energy carriers, energy services, and cash flows. Commodities are generated by one process and consumed by another process.

EPA US9R Database

The EPA Nine Region (EPA9R) database shown in **Figure 17** was used as an input for the MARKAL-Times model. The study used the West South-Central data or Region Seven (R7) for the regional analysis and the 9 regions (9R) data for the national analysis. The model incorporates data from 2005 to 2055 in time periods of five years for the projections. However, the results of this study are considered only from 2025 to 2050 so as not to showcase outdated data in the projections. The data includes current and new technology while connecting energy carriers to conversion to the end-use sectors such as refineries, electricity, residential, commercial, industrial, and transportation. The transportation data for the LDV sector database was used to project the scenarios in this work. It includes energy service demands for the LDVs, which is 38% of the total energy utilized. The LDVs account for 55% of the total demand in the transportation sector. This demand is the fuel used by the vehicles. It is represented in vehicle miles traveled (vmt) and based on the Annual Energy Outlook 2022 projections for the nine regions. The total demand is considered in billion vehicle miles traveled (bn-vmt), increasing from 397.15 bvmt in 2025 to 533.25 bvmt in 2050 in R7 and from 3,057.221 bvmt in 2025 to 3,564.16 bvmt in 2050 nationally (R1 to 9R) as shown in **Table 15**. The fleet is composed of conventional vehicles, which are gasoline (GSL) and diesel (DSL), and alternative-fuel vehicles, which are ethanol-gasoline (E85), Compressed Natural Gas (CNG), Liquified Petroleum Gas (LPG), EVs with 100-, 200-, and 300-miles rage, and HEVs (hybrid diesel or hybrid gasoline) with 10 and 40-mile range, Fuel cell (Methanol and Hydrogen). This corresponds to 95% of the total national demand. In the projections of the BCS and the FS, the demand was adapted to reach 100% of the fleet to meet demand. The size vehicle classes include mini compacts available only in gasoline and BEVs, compact, full-size minivans, and pickups available in all fuels, and small SUVs and large SUVs available in all fuels except CNG and LPG. After 2030, the older and more pollutant vehicles will retire from the market, which generates a decrease tendency in emissions over time in the projections *(EPA, 2013)*.

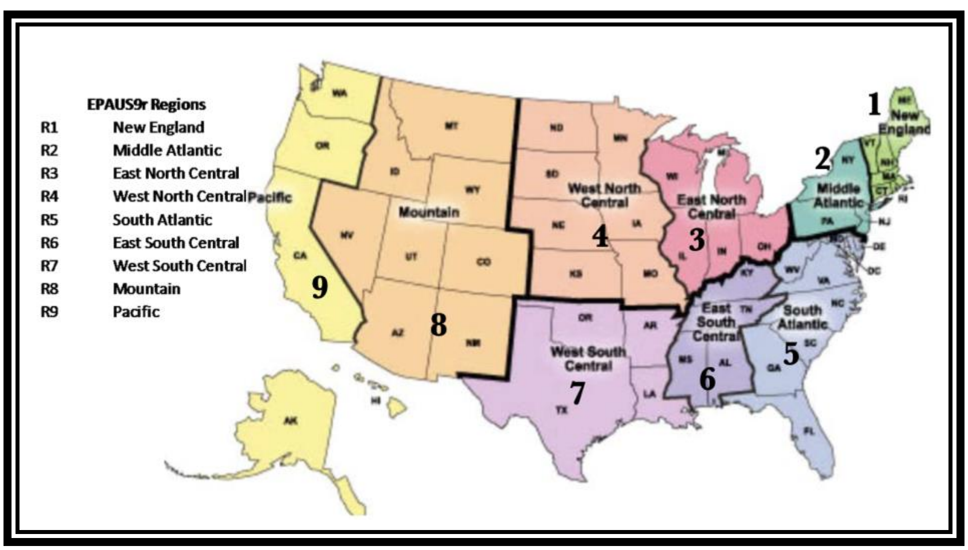

Figure 17. EPA U.S.A. 9 Regions *(EPA, 2013)*

Table 15. Demand in vmt Projection by Region

Region	2020	2025	2030	2035	2040	2045	2050	2055
R!	135.54	136.58	138.44	139.21	139.35	139.68	140.86	140.05
R2	378.98	378.71	380.85	380.44	378.82	377.83	379.19	375.23
R3	414.69	416.56	421.52	423.70	424.41	425.89	428.47	425.03
R4	197.99	201.66	206.61	210.46	213.89	217.88	222.65	224.34
R5	588.51	614.99	646.58	675.33	703.38	734.67	768.85	793.37
R6	169.72	172.79	176.98	180.09	182.79	186.07	190.59	192.49
R7	376.94	397.15	420.46	441.96	463.17	486.57	512.98	533.25
R8	225.18	239.22	255.56	271.28	287.16	304.79	325.12	341.95
R9	482.16	499.56	519.88	537.24	553.73	573.06	595.45	610.07
Total	2969.71	3057.22	3166.88	3259.71	3346.7	3446.44	3564.16	3635.78

For conventional vehicles, the Corporate Average Fuel Economy (CAFE) fuel efficiency standards are also included to set the fuel and vehicle class shares limit. This is not applicable to vehicles running on alternative or cleaner fuels. Through CAFE standards, the model:

- Regulates vehicle fuel efficiency to minimize oil dependency and lower the environmental impacts in the LDV sector
- It requires an average target that increases each time period according to the vehicle dimension and category. The standards are expressed in gallons per mile (gal/mi).
- Considers the standards until 2035. From 2010 to 2035, the vehicle classes are being adjusted or constrained to meet the demand for more efficient and smaller vehicles. **Figure 18** includes the vehicle class distribution in the model from 2010 to 2035 and is assumed to remain constant after 2035. As no additional EVs and alternative fuel vehicles are introduced in the model, emission projects tend to decrease as the older and less efficient technologies exit the market.

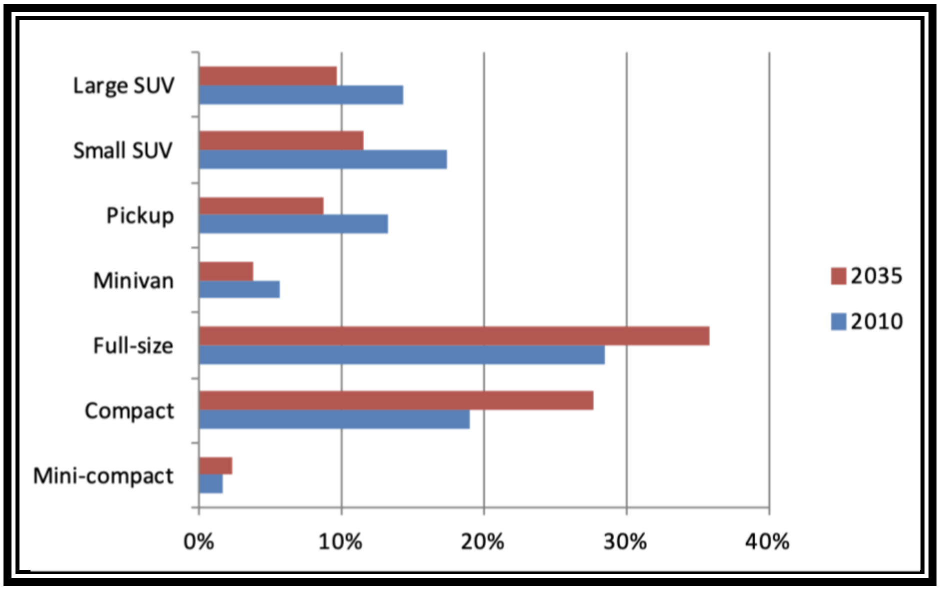

Figure 18. Vehicle class distribution from 2010 to 2035 (EPA, 2013).

It also includes GHG and criteria air pollutant emissions from the production, transformation, and utilization of energy that comply with the Federal Clean Air Act (FCAA) criteria. Emissions are considered per unit of each technology activity and constrained by a total emissions yearly cap. The emissions estimates focused on GHG (CO2, CH4, N2C), particulate matter 2.5 (PM2.5), and particulate matter 10 (PM10) at regional and national levels, and are expressed in grams per mile, being equivalent to kTonnes/billion-vmt (EPA, 2013).

Base Case Scenario

Before the future scenario (FS) was developed, a first base case scenario (BCS) was defined without modifying the database. It was consistent with the bound standards, such as minimum renewable energy from renewable sources or CAFE standards and their corresponding GHG emissions established in the model. No policy constraints were applied to the model, such as maximum GHG emissions or renewable energy minimum share, so the model could develop a new energy system with the least cost and different selections of fuel and technology. Vehicle constraints entered the model in 2010. From there to 2035, vehicle classes are adjusting to meet the demand with more efficient and smaller vehicles and remain this way from 2035 to 2050.

In the BCS, energy use decreased by 2% in each time period due to CAFE efficiency standards until 2035. The market penetration in the BCS projection consisted of 88% ICEVs (gasoline and diesel), EVs (BEVs and HEVs) 4%, and 8% alternative-fuel vehicles (Ethanol, CNG, LPG) in 2025, with the full fleet corresponding to 100% to meet the total national vmt demand with power from the local grid. The projection by 2050 consisted of ICEVs decreasing to 79%, EVs increasing to 17%, and alternative fuels decreasing 4%, corresponding to 100% of the national fleet. The demand projection increased or reduced gradually in each five-year period, as shown in . Energy demands for the time frame were computed by selecting the demand elasticities according to drivers per region defined in the model. Demands were only modified when running the model for the FS.

Table 16. BCS Demand by Fuel Type in Bn-vmt and Percentage (ETSAP, 2023)

Fuel to meet Demand	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	Demand vmt					
Gasoline	2,672.22	2,733.25	2,748.67	2,754.18	2,750.47	2,811.86
Gasoline/Electric	100.62	151.93	221.2	272.15	331.72	338.01
Diesel	13.96	14.72	15.44	16.31	17.24	18.11
Electric	37.48	73.79	113.55	156.96	202.84	251.54
Ethanol	232.23	192.89	160.51	146.7	143.76	143.97
CNG	0.13	0.12	0.12	0.13	0.13	0.14
LPG	0.59	0.17	0.22	0.26	0.29	0.53
Total	3,057.23	3,166.87	3,259.71	3,346.69	3,446.45	3,564.16
Fuel to meet Demand	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	Demand %					
Gasoline	88	86	84	82	80	79
Gasoline/Electric	3	5	7	8	10	10
Diesel	0.46	0.46	0.47	0.49	0.50	0.51
Electric	1	2	3	5	6	7
Ethanol	8	6	5	4	4	4
CNG	0.004	0.004	0.004	0.004	0.004	0.004
LPG	0.019	0.005	0.007	0.008	0.008	0.015
Total	100	100	100	100	100	100

After defining the scenario, the model selected the energy system that would meet the demand across the time horizon with the least cost. It decides on equipment investments and operation, energy supply, and trade by period and region, considering future occurrences. The model establishes commodity production and consumption (like fuels, materials, and energy services), including their costs. Once the model matched demand and supply, it was considered balanced, optimizing demand and supply.

It is important to note that the outcomes may not comply with the national energy forecasts that simulate future demand and supply because TIMES optimizes the system by bringing the solution with the least possible cost. This means that although a certain solution may suit the projected outcome, the model would modify it to achieve it at the least cost. The model's outcome meets end-use demand with the least cost and complies with the defined constraints. The TIMES model assesses the feasibility and its cost outputting energy flows, GHG emissions, technology capacities, cost of commodity energy, and marginal reduction cost *(ETSAP)*. The outcome depicted the optimal mixture of fuels and technologies per period, along with emissions estimates to meet the energy demand.

Future Scenario

In this scenario, vehicle market penetration was modified to assess a possible decrease in GHG emissions as a consequence of this change. EV use was increased while ICEV use was reduced throughout the entire time frame of the scenario. The percentage increase in EV market penetration was based on the results of the survey applied to URCs in the social component of this work. Starting in 2025, alternative fuel vehicles were modified to start at a higher percentage of market penetration, differently from the BCS.

According to the survey results, 65% of participants were interested in EV acquisition. This percentage of users, or drivers, was extrapolated to a regional and national level using data from the U.S. Senses Bureau Hispanic population and the EIA 2022 to adapt it into demand units to run the FS. Demand units are expressed in vmt (1 driver = 13,000 vmt) see **Table 34** in

Appendix C. The corresponding number of vmt was used as input to increase the EV market penetration in the FS to supply a higher level of demand as compared to the BCS. The market penetration in the FS consisted of an initial 73% of ICEVs (gasoline and diesel), 15% of EVs (BEVs and HEVs), and 12% of alternative fuel vehicles (Ethanol, CNG, LPG) in 2025, with the full fleet corresponding to 100% to meet the total national vmt demand with power from the local grid, as shown in **Table 17**.

Table 17. FS Demand by Fuel Type in Bn-vmt and Percentage (*ETSAP, 2023)*

Fuel to meet Demand	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	Demand vmt					
Gasoline	2,187.12	2,182.27	2,132.80	2,079.03	2,069.21	1960.2
Gasoline/Electric	101.81	159.91	223.62	282.58	328.39	362.7
Diesel	20.53	23.99	24.74	27.4	29.62	31.93
Electric	376.19	464.14	570.04	661.36	721.83	906.68
Ethanol	369.92	335.92	307.81	295.57	296.61	301.83
CNG	1.07	0.47	0.48	0.49	0.51	0.53
LPG	0.14	0.19	0.25	0.3	0.36	0.43
Total	3,056.78	3,166.89	3,259.74	3,346.73	3,446.53	3,564.30
Fuel to meet Demand	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	Demand %					
Gasoline	72	69	65	62	60	55
Gasoline/Electric	3	5	7	8	10	10
Diesel	0.672	0.758	0.759	0.819	0.859	0.896
Electric	12	15	17	20	21	25
Ethanol	12	11	9	9	9	8
CNG	0.035	0.015	0.015	0.015	0.015	0.015
LPG	0.005	0.006	0.008	0.009	0.010	0.012
Total	100	100	100	100	100	100

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Chapter 4: Results and Discussion

The following paragraphs present the results of the social component and the emission analysis. As discussed in Chapter 2, URCs responded similarly to those accounted for in previous studies. In other areas, their responses are quite different. Pollutant emission scenarios, BCS and FS, indicated a substantial reduction of emissions starting in 2035.

Social Science Component

The social science component provided valuable insights into consumer perception, opinions, and knowledge in URCs. The analysis of this information could positively contribute to the changes needed to improve EV public perception. Consequently, the widespread diffusion and adoption of EVs, including ChSs and ERWs in URCs, could become an attainable reality for URCs. As stated earlier, this component comprised three focus group sessions and a survey conducted in URCs in the El Paso region. Study topics included local AQ, EVs, EV-ChSs, and ERWs.

Selection of the Communities

The communities selected for the focus group were Chihuahuita, Montana Vista, and Anthony, TX. Additionally, based on the communities' demographics, Segundo Barrio and Central El Paso were also included in the survey. A brief description of these communities is given in **Table 18** while **Figure 19** shows their locations.

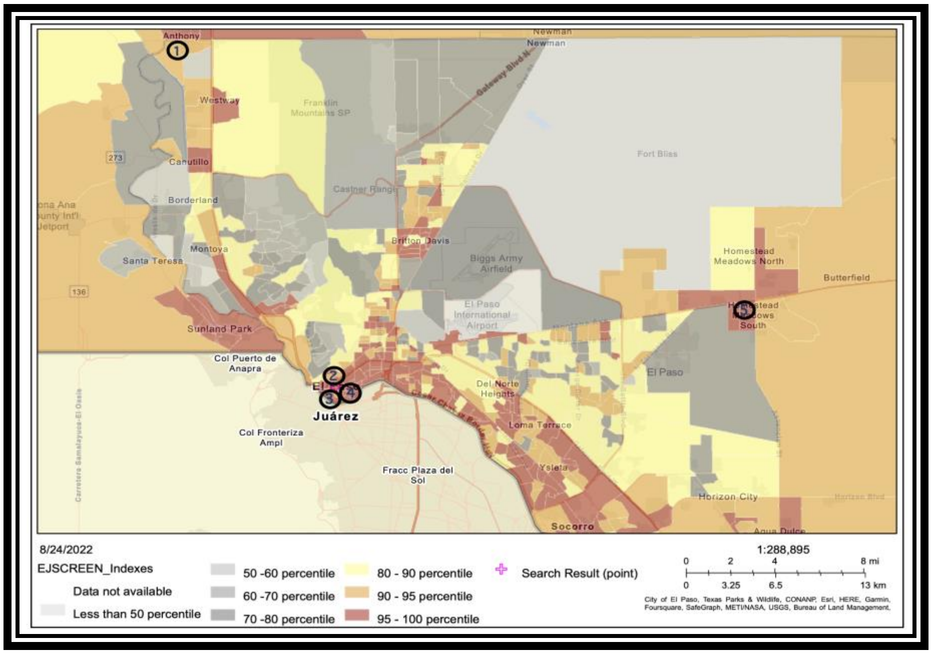


Figure 19. Communities' location *(EPA, 2022)*
1: Anthony, TX, 2: Central El Paso, 3: Chihuahuita, 4: Segundo Barrio, 5: Montana Vista.

Chihuahuita.

Chihuahuita is a historic district in south downtown El Paso on the borderline between Mexico and the United States. It is the oldest neighborhood in the city. Most members have lived there for over twenty or thirty years *(TxDot, 2018)*. This community is vulnerable to multiple environmental hazards. These include traffic pollution from the commercial areas of the nearby downtown area and the urban bus terminal. Also, from the US 62 Paisano drive located few blocks away, from the Loop 375 state highway passing above the community, and the commercial railroad that dissects the community and blocks the only entry/exit point to/from the community when the train travels through. Other key pollution sources include the neighboring Mexican border Juarez city, which is located immediately south of the neighborhood, and the Santa Fe international port of entry, which operates 24 hours a day, seven days a week. As a historic district, this community has specific design guidelines established by the city for restoration and/or new construction in the neighborhood that could modify or affect its original historic construction and preservation *(City of El Paso, 1988)*. This, in turn, prevents the residents and the city from adding or modifying any contemporary construction, such as EV-ChSs or ERWs.

EV perception from most members of this community was highly positive. They considered that EVs could significantly improve air quality as they face pollution from different sources. Nevertheless, they considered EVs out of their reach mainly due to upfront costs. However, participants' interest increased when learning about government incentives and tax rebates, something they had never heard of. This generated participants to inquire about the type of incentives available and whether those are applicable to them. Thus, increasing their interest in acquiring EVs.

Regarding EV ChSs and ERWs, the design guidelines of their historic district were perceived as a disadvantage, as ChSs and ERWs could not be installed in their neighborhood. This created a decreased interest in EV adoption since they were unaware how far they would need to drive to reach a ChS. Chihuahuita community members did not realize that their neighborhood has access to EV public charging stations within less than a mile of their homes. This, is due to their location near downtown, as opposed to rural communities Montana Vista and Anthony, which lack nearby charging stations. Lastly, electrified roadways were a completely new theme to the participants. Although they considered them a great resource if they eliminated the need to drive to a charging station, they still highlighted that most of their community members could not afford an EV. Thus, ERWs would not be useful for them.

Montana Vista.

Montana Vista is an unincorporated rural community located far east in El Paso County and part of the metropolitan statistical area *(U.S. Census Bureau, 2023)*. Some participants have lived in the neighborhood for less than three years, while others have lived in the neighborhood for over 10 years. Although Montana Vista has a power plant nearby and the highly commuted US 62/180 highway (Montana Ave.) going through their neighborhood, the community members do not consider themselves as facing big environmental issues.

Participants of this middle-aged working-class community were in favor of EV technology. Although they perceived it as costly, they showed great interest when they considered the benefits that the technology could provide for their job activities. These activities included long-distance transportation of construction materials and heavy machinery. Their main EV inquiries included the availability of heavy-duty pick-ups, maximum payload capacity, and maximum vehicle miles traveled per charge on full load. Regarding ChSs, they knew El Paso has public ChSs in service and that they are located far from their community, which was perceived as a disadvantage regarding EV adoption.

With respect to ERWs, these community members were fully unaware of the technology. They perceived ERWs as useful if they could eliminate ChSs and EV range anxiety. Nonetheless, they considered them unnecessary for now as EVs are not widely used. Withal, the topic of ERWs generated particular interest in the effects of electrification on human health, the safety of users, construction and maintenance costs, and its effects on their community power supply.

Anthony, TX.

This rural community is also an unincorporated neighborhood located far west in the county of El Paso *(U.S. Census Bureau, 2023)*. It is comprised mostly of retirees, who perceived EVs as highly beneficial as they could help provide better air quality and are cost-effective compared to regular vehicles' fuel expenses. The community is vulnerable to nearby traffic pollution from the I-10 interstate, commercial areas, gas stations with trailer rest travel areas, and a local elementary school. The members of this community were particularly interested in what EVs could offer them in terms of safety, comfort, and monetary savings. Their primary inquiries focused on safety regarding the new technologies EV offer. For example, movement and vehicle detection to prevent accidents or whether EVs can drive autonomously if the driver experiences a heart attack. They also inquired were unaware of incentives or tax rebates available for EV purchases, which increased their interest when learning about the topic.

Regarding ChSs, this community knew about existing stations in the city, although they did not know much about the locations or an approximate number the city has provided. Thus, they perceived having charging stations installed in their neighborhood as beneficial if it eliminates the need to drive to a station and the anxiety of running out of charge. As per ERWs, this community did not know about the technology. While their perception of this technology was positive, they expressed concerns about the ERWs' construction and maintenance process that may cause traffic issues and affect their community’s power supply. **Table 18** presents the makeup of the three communities and their perception of EV technology.

Table 18. Overview of the Selected Communities (City of El Paso, 1988; TxDot, 2018; U.S. Census Bureau, 2023)

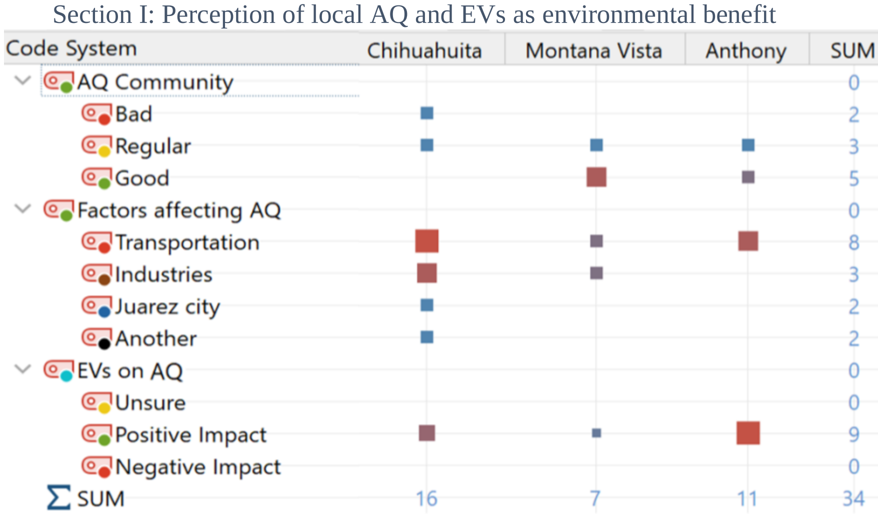
Community	Group Age	Education Level	Annual Household Income	Technology Perception	Neighborhood Overview
Chihuahuita	35-65 years	Some high school Associate degree	$17 - $38K	*Advantages:* Could potentially help enhance their community's air quality *Disadvantages/Concerns:* EV initial cost, having historic district design restrictions keeps them from having EV ChSs and ERWs installed	Affected by pollution from bus station and downtown commercial areas nearby, the 62 and 375 state highways, the commercial rail road going through the neighbor and blocks the one entry/exit to/from the community, the Mexican neighboring border city, and the daily commuted Santa Fe international port of entry. Did not know their downtown location has close access to current EV ChSs. Never heard about EV purchase incentives and ERWs before.
Montana Vista	25-55 years	High school and College	$38K - $75K	*Advantages:* EV could potentially facilitate work activities especially electric pick-ups. Showed special interest in home EV charging stations *Disadvantages/Concerns:* EV initial cost. Will ERWs increase taxes? Who will assume ERWs construction and maintenance costs? Can ERWs cause community power outage?	Rural middle age working community located far east. An unincorporated community in El Paso County, affected by pollution from the US 62 and electric plant nearby. Perceived EVs as useful for their work. They had knowledge of local EV ChSs in service and locations. Never heard of EV incentives and ERWs
Anthony	45- 65 years	High school and College	$49K - $75K	*Advantages:* Highly beneficial to cleaner air and cost effective as compared to fuel expenses from ICEVs *Disadvantages/Concerns:* EV initial cost. What new technology do EVs offer to help drivers prevent accidents? Will ERWs cause traffic congestion or community power outage?	An unincorporated far west town in El Paso County. Mostly retirees. Community affected by pollution from the commercial areas nearby, the interstate 1-10 including gas station stops and rest areas. Found EVs beneficial. No knowledge about EV incentives. Never heard of ERWs.

Focus Groups

The study performed a total of three focus group sessions, one of each of the following communities: Chihuahuita, Montana Vista, and Anthony. The focus group sessions aimed to understand the perceptions, knowledge, and opinions regarding EV technology, and identify key barriers to public perception and adoption to help promote and diffuse the technology as equitable. Participants were not provided with or required specific responses besides their personal perceptions and ideas. The analysis of these three sessions is presented in **Table 19**. The responses of each community are shown and summarized vertically. Responses among communities can be compared and summarized horizontally. The sentiment is represented with a square, varying in size according to the feeling intensity. The larger the square, the greater the feeling or emotion respondents expressed to each question. No square indicates that responses were not given.

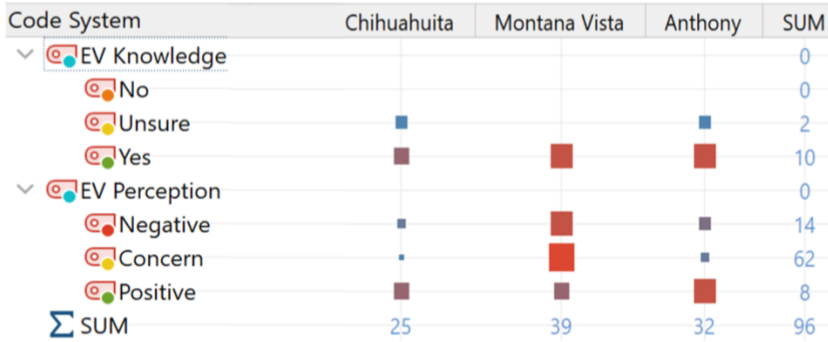
Table 19. Focus Group Sentiment Analysis by Section

Section I: Perception of local AQ and EVs as environmental benefit



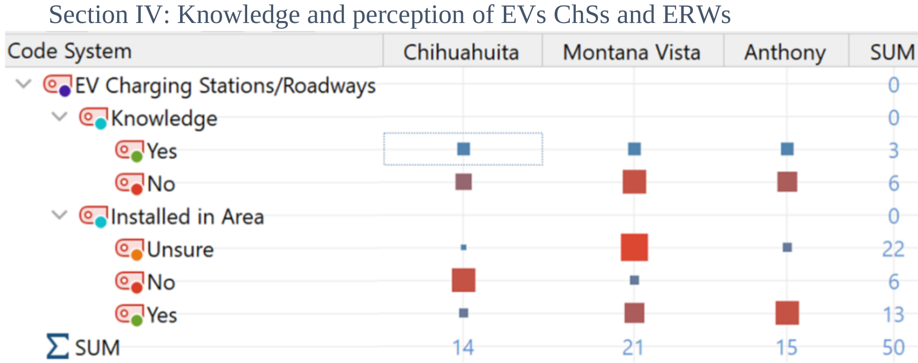
Code System	Chihuahuita	Montana Vista	Anthony	SUM
AQ Community				0
Bad	■			2
Regular	■	■	■	3
Good		■	■	5
Factors affecting AQ				0
Transportation	■	■	■	8
Industries	■	■		3
Juarez city	■			2
Another	■			2
EVs on AQ				0
Unsure				0
Positive Impact	■	■	■	9
Negative Impact				0
Σ SUM	16	7	11	34

Section II: Knowledge and perception of EVs



Section III: Knowledge and perception of purchasing EVs and incentives

Section IV: Knowledge and perception of EVs ChSs and ERWs



Section I: Perception of local AQ and EVs as an environmental benefit

The focus group sessions included questions on perceptions, opinions, and knowledge regarding major factors that affect the community's local AQ, AQ improvement needs, and EVs as beneficial factors to improve local AQ.

Participants from Montana Vista in the far east of El Paso considered their AQ to be good and clean. In contrast, participants from Chihuahuita expressed more concerns about pollution and fumes in their community, attributing these issues to the interstate highway traffic, commercial railroad, the neighboring Ciudad Juárez, Mexico, and associated traffic emissions from the International Paso del Norte Port of Entry. Participants from Anthony indicated their major AQ concerns stemmed from the nearby interstate highway (I-10) traffic, gas stations, trailer rest areas, commercial areas, and school traffic.

The three communities identified EVs as a technology that can improve their AQ positively. Of the three communities, the residents in Anthony reflected the most positive perception toward EVs. In Chihuahuita, residents, despite having more factors affecting the AQ, the upfront provided the least positive perception toward EVs. Meanwhile, the residents of Montana Vista, although recognizing the potential AQ benefits of EVs, provided the least positive feedback as they did not perceive AQ concerns in their community. Both Chihuahuita and Montana Vista communities agreed that replacing current ICEVs transiting their areas' interstates with EVs would benefit the overall local AQ.

Section II: Knowledge and Perception of EVs

The focus group sessions evaluated EV perception, opinions, and knowledge in URCs to identify possible factors influencing consumer preferences and behavior toward EV adoption in low-income minority populations.

The three groups showed some degree of EV knowledge, although they felt unsure if it was accurate. They knew that EVs are available in the market, they help the environment and human health by reducing fuel emissions, and EVs are more expensive than ICEVs. Participants from Montana Vista had knowledge about different EVs in the market, although they did not know them by their names, but as cars that “use electricity only” (BEVs) or “use electricity and fuel” (HEVs). However, they did not know about PHEVs and their different components or characteristics nor about home EV chargers. Whereas, participants from Anthony knew about EVs as a new and cost-effective technology that could save them fuel expenses.

The three communities perceived the upfront cost as the first disadvantage of EVs. They stated that the cost limits equal access for all as opposed to ICEVs’ more accessible cost. The following factors were also perceived as detrimental disadvantages: not knowing about EV driving range under normal conditions or during a traffic jam, charging time and associated costs, vehicle maintenance costs, and ChSs location. These factors limited their ability to make informed decisions about buying EVs. Participants from the Chihuahuita community also expressed that as a historical district, the city’s design guidelines would not allow infrastructure modifications in their neighborhood. Not being able to have a CHS in their neighborhood was perceived as a disadvantage of EV use.

Regarding EV benefits, the three communities expressed only two opinions: EVs help the environment by reducing fuel emissions and can be a form of cost-effective technology due to possible savings from fuel expenses. However, they wanted to learn more about the actual monetary benefits and the time frame for the return on investment.

Beyond considering any advantages or disadvantages of EV adoption, the participants from the three communities expressed concerns and doubts about EVs, given that this topic was new to them and they were unaware of other underlying issues that may exist. Safety drew particular interest from participants. Their main questions focused on the general effects of EV charging. For example, whether it is safe to charge more than one vehicle at home, and whether it is safe for one’s health to spend long periods of time inside an EV while charging. Regarding battery safety, the main concerns included how elevated or low temperatures could affect battery performance and lifespan, specifically, whether batteries are safe and will not "explode" under the extreme heat temperatures in El Paso. They also asked if the close proximity of EV batteries to humans has a long-term effect on human health, whether batteries are safe for pacemaker users, and whether batteries can affect cellular phones or vice versa.

General EV questions from the three communities included the different charging options in the market and their cost, maintenance, safety, and environmental benefits. Regarding vehicle types available in the market, they wanted to know why EVs cost more than ICEVs and what components or features make different EVs cost more than others. Participants also asked about the availability of EV repair shops are available in the city. Specific questions included: whether repairs are only serviced by EV dealerships, EV maintenance frequency, and if EV repairs and insurance cost more than ICEVs' maintenance and insurance. They also inquired about EV batteries, types, maintenance required, lifespan, and replacement cost. With respect to home chargers, the main concerns included levels of charging available, purchase and installation cost, life span, electricity consumption rate, cost, and whether a regular electrician can install the home ChSs or if a specialized electrician is required. They also asked if home ChSs were safer and faster than public ChSs and what happens to home ChSs and batteries once they complete their life span.

Other similar concerns included EV safety at high speed or in collisions compared to ICEVs and whether EVs are at a lower risk of explosion in an accident compared to ICEVs. Participants wanted to know what new EV technologies are available. These included: contact and movement sensors to help prevent accidents and whether EVs can be driven autonomously in the case the driver passes out or has a heart attack. Lastly, given that EVs are quiet, they inquired how safe EVs are for blind and deaf pedestrians.

Section III: Knowledge and perception of purchasing EVs and incentives

Concerning EV purchase, Montana Vista and Anthony participants felt unsure about EVs mainly because of the high upfront cost and the lack of information regarding the different EV technology options and benefits. Of the three communities, Chihuahuita residents showed the most interest in EVs. Nevertheless, they lost interest, due to upfront cost and to their district design regulations not allowing the installation of public ChS. However, members of Chihuahuita did not know that, although their community may not be permitted to install a ChS, their community has access to public ChSs in less than one mile due to their proximity to downtown. This information regenerated their interest in EV acquisition.

Regarding EVs, the Montana Vista participants had questions about the availability of electric heavy-duty pick-ups in the market. They asked about the upfront cost and the availability of insurance and road assistance. They also wanted to know the trucks' maximum payload/towing capacity and the maximum distance trucks can drive on a single charge at full payload capacity. Participants from the three groups also wanted to learn how to calculate the actual cost-benefit of owning an EV and savings from fuel expenses, especially on long-distance work trips.

Residents of the three communities considered upfront cost a key limitation to purchasing an EV. They asked if ICEVs can be traded in for EVs purchase and if used EVs are available for purchase similarly to ICEVs. Participants did not know about federal tax credits, state and local incentives, and rebates for EV purchases, which generated significant interest among all the participants. As they learned, their perception of EVs improved. They felt the vehicles could be more affordable for them with the assistance of incentives and rebates. and whether. Their inquiries regarding incentives included what the maximum incentive amount is, what it is based on, and how it is applied. They also wanted to know whether incentives are applicable for retirees, whether more than one incentive can be grated per household, and which vehicle gets the maximum amount.

Section IV: Knowledge and Perception of EV ChSs and ERWs

EV-ChSs and ERWs were the last topics discussed during the focus group sessions. Although the three communities knew about public ChSs in El Paso, participants from Anthony and Chihuahuita did not know any of the station's location or approximate number of stations in town. Only the participants from Montana Vista knew of some locations and that they were far from their homes. Participants from the three communities also did not know about the ChSs charging levels (Level 2 or DC fast charging) currently available in El Paso. They were also unaware of charging time, costs, or internet applications or search engines to locate ChSs.

Perceptions and opinions about having ChSs installed in their neighborhoods varied. Participants from the rural communities of Anthony and Montana Vista, located far west and far east of El Paso, respectively, were receptive. They perceived a benefit in having ChSs installed in their neighborhood since they do not currently have any nearby. They felt this could keep them from driving long distances to charge EVs if they chose to purchase one, and it could promote EV adoption in their communities, contributing to decreasing traffic pollution as EV adoption increases. Their concerns about ChSs included who would cover the station installation and maintenance cost, how often new stations would be installed, and whether the community would face electricity supply issues.

The participants from Montana Vista asked if ChSs would result in more emissions from electricity generation at the power plant near their homes. On the other hand, participants from Anthony were concerned whether having ChSs in their neighborhoods could cause more traffic issues since they already face heavy traffic from the interstate, gas stations, trailer rest stops, commercial areas, and schools nearby. Participants from Chihuahuita, due to upfront cost and the impossibility of having a station due to their historic district restrictions, still expressed that EVs are unaffordable to most members of their community. They also felt uncomfortable or unsafe about having "random strangers" coming to their small neighborhood to use the station, especially at night.

The last topic regarding ERWs drew the most significant interest. As motioned in Chapter One, ERWs aim to substitute charging stations. This, using inductive embedded charging elements in the pavement, allows vehicles to charge wirelessly as they drive or park on electrified roadways *(ASPIRE, 2023)*. This last section evaluated URCs' perceptions, opinions, and knowledge of ERWs and their willingness to install this technology in their neighborhoods. None of the groups had previously heard about ERWs. The group discussion generated diverse results with perceptions and concerns specific to the needs of each group.

The general perception of ERWs was positive if they were able to eliminate the need for public ChSs, and with it, driving range anxiety, although not for the present moment. The three communities agreed that promoting and making EVs accessible to all, including their URCs, should be prioritized before investing resources in roadway electrification, considering the actual low percentage of EVs in the market compared to ICEVs. The participants expressed concerns about the cost, health effects, and safety of ERWs. Most concerns related to cost focused on who will assume the construction and maintenance cost of ERWs, whether ERWs' construction will increase property taxes, and whether ERWs will be freely accessible or will include a usage fee. Health concerns consisted of questions regarding the impacts of electrification on human health and safety, such as how safe ERWs will be for users, specifically for cancer survivors, people undergoing chemotherapy, people with pacemakers, and pregnant or lactating women. Safety concerns focused on ERWs under rainstorms, flooding, and extreme heat/freezing temperatures. Other concerns included the lifespan of ERWs, whether electrification might damage fuel vehicles, and whether fuel vehicles like cranes or ambulances can safely circulate ERWs to assist in road accidents.

Regarding EWRs installed in their neighborhoods, participants from Chihuahuita considered them unnecessary due to their residents being unable to afford an EV and their historic district restrictions over new development. Participants from Montana Vista and Anthony showed mixed attitudes toward EWRs. They expressed concerns about electrification, such as whether it would cause community electricity outages and whether its construction and maintenance would take a long time, thus causing roadway closure and traffic congestion as the highway extension currently does. Participants from Montana Vista considered ERWs a good technology; however, they suggested that until the number of EVs in El Paso increases considerably, and then electrification could begin with highways and main roads alone.

Surveys

The social component also included a survey instrument applied in five URCs in El Paso to understand their perceptions, knowledge, and opinions regarding the electrified technology, identify critical barriers to public perception and adoption, and help diffuse the technology as equitable. The communities included Chihuahuita, Montana Vista, Anthony TX., Segundo Barrio, and Central El Paso. Participation was entirely voluntary, and responses were strictly confidential. Key participants included current residents of the selected communities who were considered the best candidates to convey their experience and perspectives for their residency in the neighborhoods, including being at least 18 years of age. The survey content by section is illustrated in **Table 14.** The full survey document is included in **Appendix A,** along with the tables of the questions in **Appendix B.**

Data Analysis

The chi-square test of independence was utilized to examine how perception, knowledge, and opinion varied among the participants. The test evaluated the statistical associations and the relationship between the variables by testing the null hypothesis of no association. The survey had a 95% confidence interval based on a sample size of 221 participants from a population of 18,200 residents. The following paragraphs summarize the results of the surveys and the relation between responses from the different categories.

Sample Demographics

The survey sample (n=221) showed close participation between males (45%) and females (54%), predominantly Hispanics (87%), with a minor percentage of Whites (8%) and some Asians (1.5%) and American Indians (0.5%). Most of the survey sample participants were between the age group of 18 to 24 (40%) and 25 to 34 (27%), whereas the lowest participation bracket was from males and females in the age group of 56 to 64 (3%). The highest level of education came from respondents having some college, meaning they attended college and did not graduate or are still attending college (32%), followed by high school graduates (18%) and those with associate's degrees (16%). Regarding annual household income, most of the sample indicated a range between $25k to $49k (26%) and $50k to $ 74k (23%). Those with less than $25k (16%) and $75k to $99k reflected medium percentages (13%,) including those who preferred not to answer (14%). The fewest responses showed household incomes between $100-$149K (7%) and more than $150K (1%). The sample demographics are presented in Figures 20-22 below and **Table 20**.

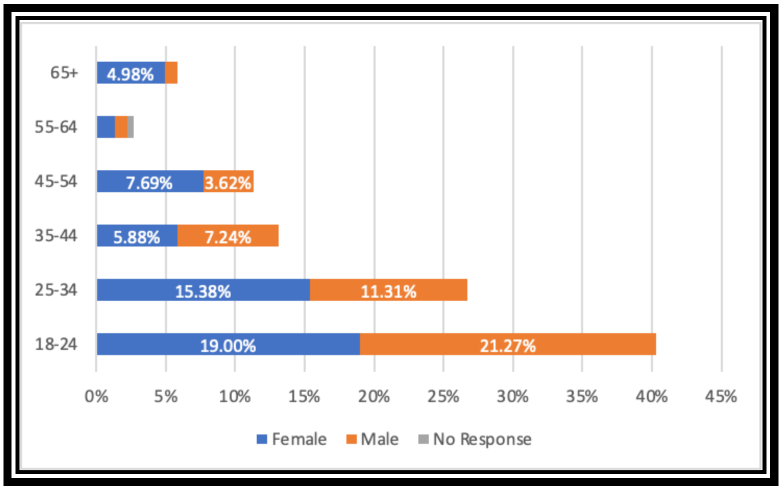


Figure 20. Sample age group and gender

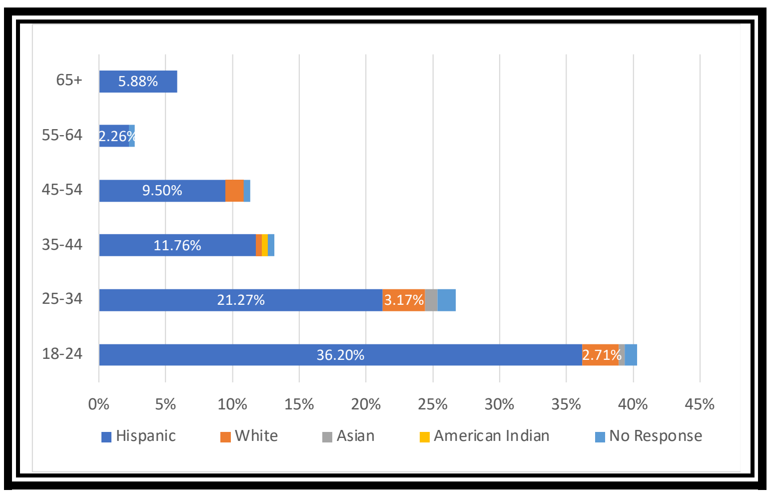


Figure 21. Sample age group and race

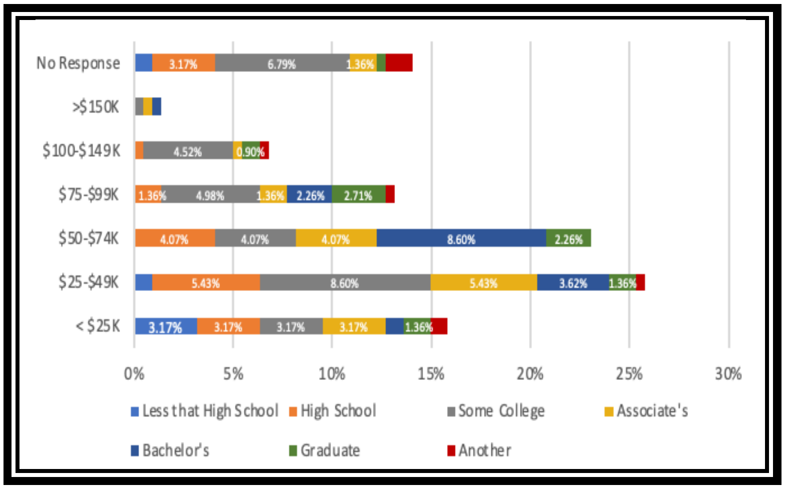


Figure 22. Sample household income and education level

Perception of Environment

Familiarity and concern were rated on a 5-point Likert scale from 1 (not at all familiar/concerned) to 5 (extremely familiar/concerned). **Figure 23** and **Table 21** include Participants' responses on the health impacts of air pollution (AP) and their concern with their neighborhood's air quality (AQ).

Results showed that most respondents felt slightly (20%) to somewhat familiar (43%) with the health impacts of AP. The lowest percentages were those who felt not at all familiar (4%) or extremely familiar (16%). Chi-square analysis showed a significant difference between familiarity with AP health impacts based on education (Q_p =37.255, df=24, p=0.0413) and household income (Q_p =36.862, df=24, p=0.0452), suggesting that individuals with a college degree felt more familiar than those with lower degrees of education. Additionally, respondents with household incomes between $25k and $49k registered were more familiar with AP health impacts than those with higher incomes. No significant differences were observed based on gender (Q_p=7.664, df=8, p=0.4670) and age (Q_p=28.371, df=20, p=0.1009).

Regarding neighborhood AQ, most participants responded somewhat concerned (32%), followed by neutral (26%), while slightly (16%) and not at all concerned (5%) received the least of responses. Chi-square analysis showed an association in neighborhood AQ concerns based on household income (Qp=37.012, df=24, p=0.0436) and age (=36.634, df=20, p=0.0129). Younger individuals (age 25-35) with lower household incomes ($25k - $49k) were more likely to express concern about their local AQ than older individuals with higher incomes. This suggests that age and household income might impact the public perception of environmental pollution and its health impacts in URCs. No significant association was identified between education (Qp=23.082, df=24, p=0.5149) and gender (Qp=37.503, df=8, p=0.0000). Results are somewhat different from previous studies *(Sovacool et al., 2019)*, where women seemed to feel more concerned about the environmental effects of EVs than men, independently of their age and household income.

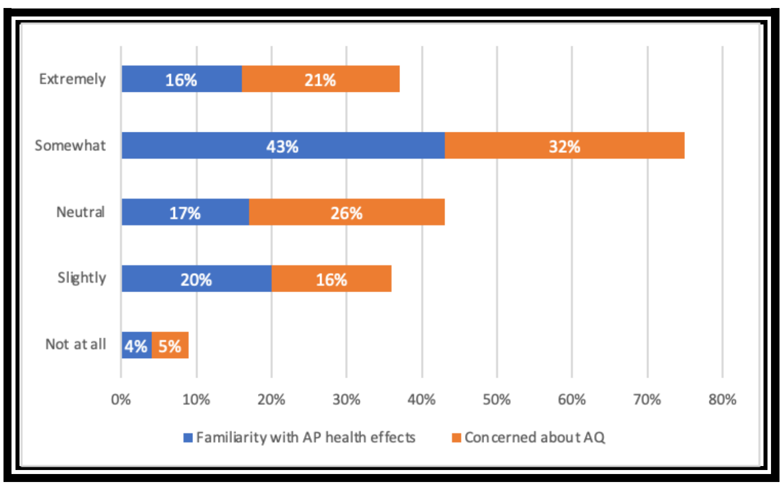


Figure 23. Familiarity with AP health impacts and concerns with AQ

Driving and Transportation Habits

Participants shared their driving and transportation habits, including approximate weekly vehicle miles traveled (vmt), monthly fuel expenses, and whether they use public transport. **Figure 24**, **Figure** 25, and **Figure 26** show their responses. For more information, refer to **Table 22**.

When considering their driving frequency, most of the sample indicated driving daily (76%) or more than three times per week (12%). In comparison, those with less driving time reported by the sample drove 2 to 3 times per week (4%), once a week (2%), rarely drove (2%), or drove once a month (0.5%). Weekly distances of 20-60 vmt, 60-120 vmt, and more than 120 vmt were reported by most respondents, and the lowest vmt was less than 20 miles. Chi-square tests identified a significant relationship statistically between driving frequency and education (Qp=70.637, df=36, p=0.0005), gender (Qp=29.749, df=12, p=0.0030), and age (Qp=57.427, df=30, p=0.0019). This suggests that younger female participants in URCs with a college degree tend to drive longer distances than those with less education.

Regarding fuel expenses, almost a third of the sample reported monthly expenses of $60-$99 (32.5%) or $100-$199 (29%). The next bracket of expenses consisted of $40-$59 (13%) or more than $200 (13%). The lowest expenses were $20-$39 (4%), and less than $20 (2%) had the lowest responses. The remaining sample reported not knowing their approximate fuel expenses (2%) or not having a vehicle (4%). Parallelly, Chi-square analysis reflected a significant association between monthly expenses, education (Qp=64.363, df=42, p=0.0148), gender (Qp=35.868, df=14, p-0.0011), and age (Qp=55.340, df=35, p=0.0157). The analysis results show that young individuals (ages 18-24) enrolled in college or have a college degree tended to drive more often and thus spend more on fuel than older participants with less education. Female participants were likelier to drive and spend more on fuel than males. No statistical significance was identified with driving frequency (Qp=50.782, df=36, p=0.0521) and fuel expenses based on income (Qp=50.690, df=42, p=0.1682).

Most of the sample indicated never (72%) or rarely (20%) using public transport; a small sample indicated sometimes (6%) or often (2%) using public transport. These results differ somewhat from previous studies *(*Vassileva & Campillo, 2016; *Ouyang et al., 2018; Sovacool et al., 2019)* applied to higher education and income markets. Men seemed to drive more often and longer distances than women as opposed to this study's results. The use of public transportation also differs. Respondents from larger cities tended to use public transportation more where access was readily available. This is not always the case for URCs. Thus, this may highlight URCs as a potential market for EVs where public transportation tends to be scarcer due to their communities' location in relation to the main depot, as in the case of the rural Montana Vista and Anthony communities.

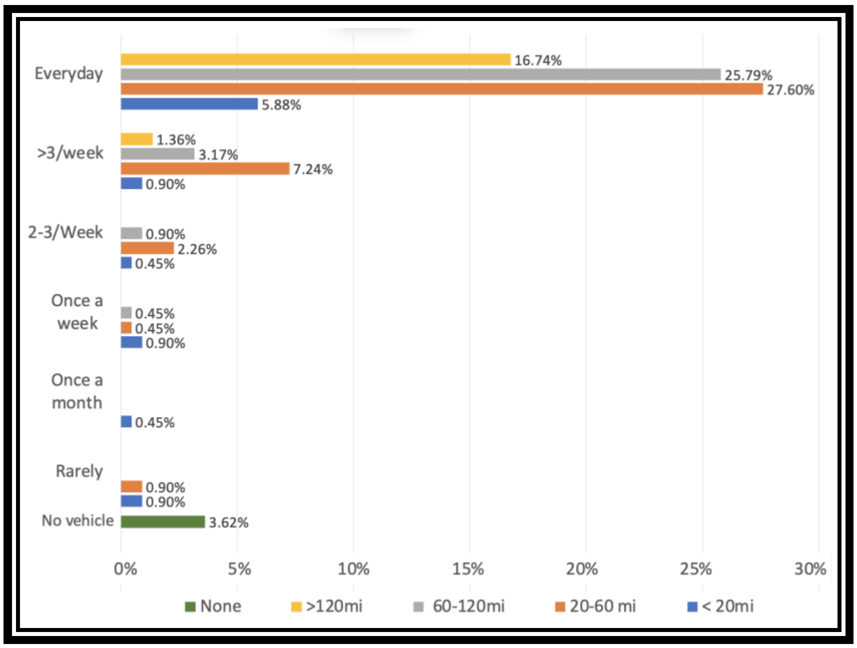


Figure 24. Driving frequency and weekly miles traveled

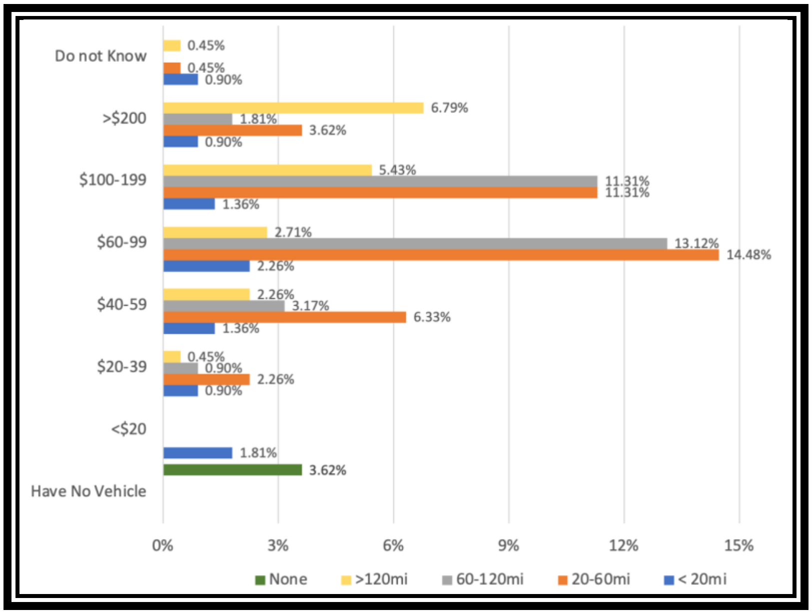


Figure 25. Weekly miles traveled and monthly fuel expenses

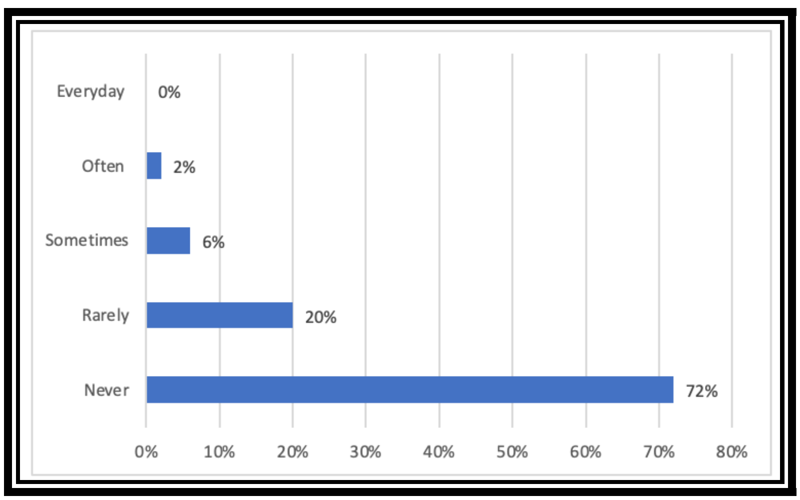


Figure 26. Use of public transport

Knowledge of the EV Technology

Participants shared their knowledge of ICEVs and EVs, including their familiarity with both vehicle types, prior driving experience, EV driving range, and the vehicle type they believed offered the best benefits. Participants also mentioned the sources they would use to gain further insight into the technology. Familiarity with the vehicles was rated on a scale from 1 (not familiar) to 5 (extremely familiar). Results are presented in **Figure 27** and **Table 23**.

Almost half of the participants (52%) indicated they were extremely familiar with the ICEVs. However, for EVs, most participants felt somewhat familiar with the BEVs (30.5%) and HEVs (25%) and the least familiar with the PHEVs (30%). For the ICEVs, the analysis showed significant statistical differences based on education (Qp=69.665, df=24, p=0.0001), gender (Qp=22.513, df=8, p=0.0040), and age (Qp=67.952, df=20, p=0.0001) where young (ages 18-24) female respondents enrolled in college or have a college degree tended to be more familiar with ICEVs than male participants with some college experience. No statistically significant differences based on income were observed. EV analysis identified significant differences between participants being familiar with the BEVs (Qp=40.883, df=20, p=0.0039) and the HEVs (Qp=36.780, df=20, p=0.0124) based also on age, indicative that younger individuals (age 18-24) enrolled in college or have a college degree tended to feel more familiar with the BEVs and HEVs than older participants with less or higher education. This was independent of the other demographic attributes, as no significant differences were observed. Results showed that URCs tended to be generally more familiar with the BEVs and less with the HEVs or PHEVs. This differs from other studies *(Egbue & Long, 2012; Larson et al., 2014)* where higher-income markets were assessed, and the public tended to be more familiar with HEVs and PHEVs. These studies also showed that education and income might impact the public's knowledge about the different EVs in the market.

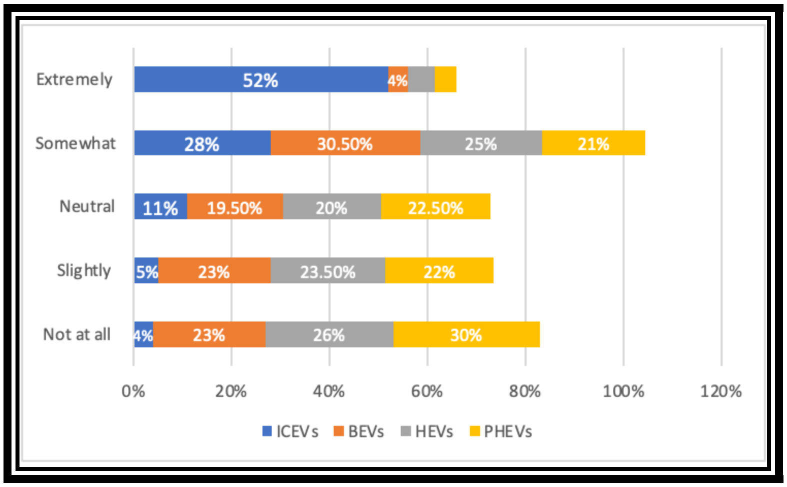


Figure 27. Familiarity with EVs and ICEVs

Most of the sample demonstrated experience driving ICEVs (91%). A few participants indicated experience driving the HEVs (13.5%), the PHEVs (7%), and the least the BEVs (6%); see **Figure 28** and **Table 24.** The chi-square analysis results showed significant differences in experience driving ICEVs based on gender (Qp=11.79, df=2, p=0.0028) and age (Qp=41.006, df=5, p=0.0000) and education (Qp=15.173, df=5, p=0.019). The data suggests that young females (ages 18-24) enrolled in college or have a college degree were more likely than males (ages 18-24) enrolled in college or have a college degree to indicate experience driving ICEVs. According to income (Qp=6.378, df=6, p=0.3822) and education (Qp=15.173, df=6, p=0.190), no significant differences were reflected from the analysis. Regarding EVs, the analysis showed no significant statistical relationship between driving experience and the demographic variables (age, education level, gender, income household).

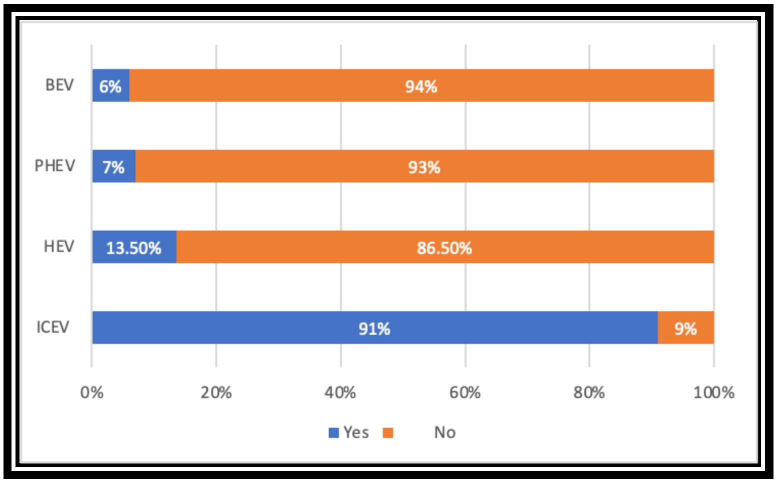


Figure 28. Driving Experience

Participants indicated their understanding of EV driving range. Responses ranged from 1 (less than 100 miles) to 5 (More than 300 miles) or 6 (I do not know). The results are shown in **Figure 29** and **Table 25**.

A driving range of 100 miles but < 200 (25%) received the most responses, while the option of < 100 miles (7%) was the least selected. The analysis showed statistically significant associations in driving range estimates based on age (Qp=36.630, df=20, p-0.0056) and education level (Qp=52.757, df=24, p-0.0006). Younger participants (ages 18-24) enrolled in college or have a college degree were more likely to have knowledge about EV driving range than older participants with lower education, regardless of gender (Qp=3.763, df=8, p=0.8778) and household income (Qp=25.029, df=24, p=0.4042). The results are similar to studies *(Egbue & Long, 2012; Kester et al., 2019; Noel et al., 2018)* performed on higher income markets and education levels where participants shared range anxiety as a concern when considering acquiring an EV. This shows that range anxiety remains a common concern in the general public regardless of their household income or education levels. This concern could be attributed to the general lack of EV information, which limits the public familiarity and acceptance of the vehicles and not necessarily to the EV's actual driving range.

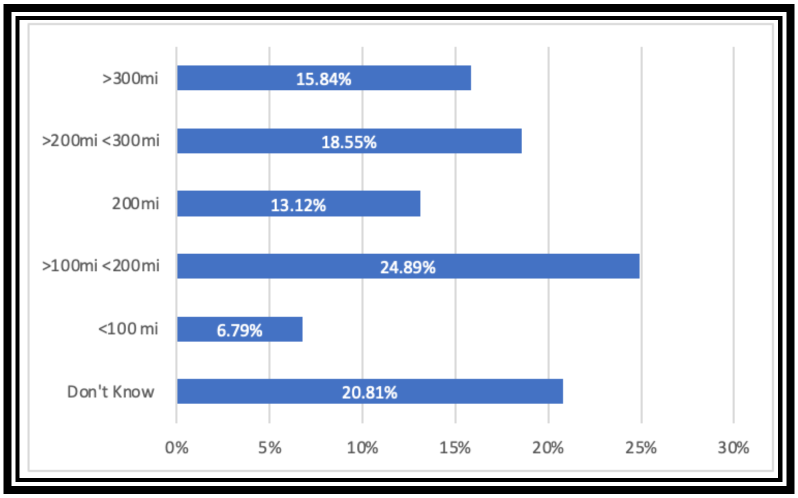


Figure 29. EV Driving Range Estimates

Respondents' data shows that they perceived EVs as the most beneficial for the environment because they improve AQ by reducing pollution (84%). Some also considered EVs to be safer to drive (34%). ICEVs, on the other hand, were perceived as the most beneficial by providing longer driving distances (57%) and lower upfront costs (56%); see results in **Figure 30** and **Table 26**.

The results from the analysis showed statistically significant associations in the belief that EVs provide a safer driving environment based on age (Qp=20.531, df=5, p-0.0010). Younger participants (ages 18-24) perceived EVs as safer than older participants, regardless of the other demographic variables. No significant associations were found in EVs reducing pollution and improving AQ and the other demographic variables.

The ICEV analysis results showed significant statistical associations in the vehicles providing lower upfront cost based on gender (Qp=10.699, df=2, p-0.0048) and providing longer driving distance based on gender (Qp=7.330, df=2, p-0.0256). No significant associations were found between age, education, or household income variables. This may indicate that women were likelier to perceive more benefits or preferred ICEVs than men, differently from other research assessed *(Larson et al., 2014; Ouyang et al., 2018; Sovacool et al., 2019),* where aspects such as vehicle driving distance and initial cost were considered important by men more than by women.

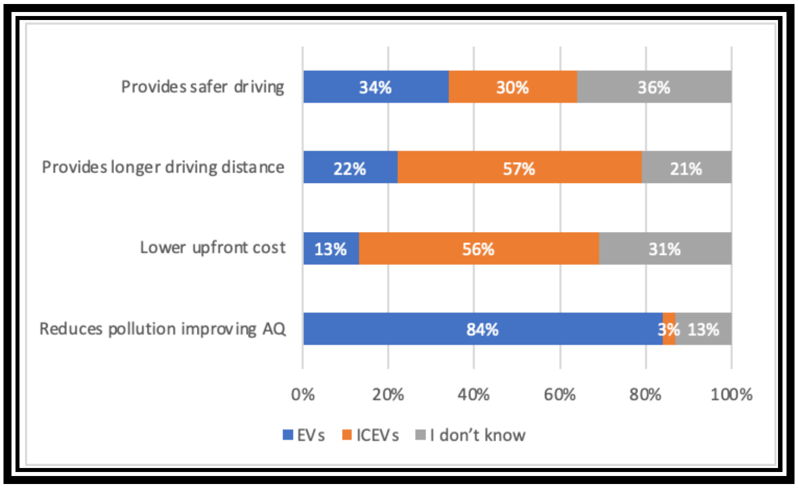


Figure 30. Most Perceived Benefits EVs vs ICEVs

Regarding purchasing EVs, participants rated the main disadvantages keeping them from purchasing a vehicle with options from 1 (slightly disagree) to 5 (strongly agree) and 6 (I don't know), as presented in **Figure 31** and **Table 27.**

Most participants (34%) strongly agreed that not having enough nearby ChSs (34%) was perceived as a prominent disadvantage for owning EVs. The difficulty of finding a mechanic shop (25%) and EV upfront cost (22%) were also considered key disadvantages. A short driving range (20%) and long charging time (13.5%) were other important factors participants considered as a disadvantage to owning an EV. The analysis showed significant differences between the disadvantage of not having enough ChSs nearby based on age (Qp=49.390, df=25, p=0.002) and education (Qp=103.515, df=30, p=0.000); also, with the difficulty of finding a mechanic based on age (Qp=71.448, df=25, p=0.000) and education (p=66.835, df=30, p=0.000), suggesting that individuals in the ages of 18 to 24 enrolled in college or have a college degree tended to prioritize more the location of a ChS and having a mechanic shop when considering the purchase on an EV than older individuals with less or higher education, independently of their income or gender, as no statistically significant differences were observed with these variables. In reference to previous research *(Larson et al., 2014; Ouyang et al., 2018; Sovacool et al., 2019),* upfront cost and driving range still remain a major concern regarding EV acquisition, whereas in URCs, highly prioritized having a ChS nearby and a shop for vehicle maintenance. URCs considered vehicle longevity and maintenance as highly important in owning an EV. Most URC households tend to own a single vehicle to meet all family members' transportation needs long term. Opposite to higher-income households where having more than one vehicle is more common.

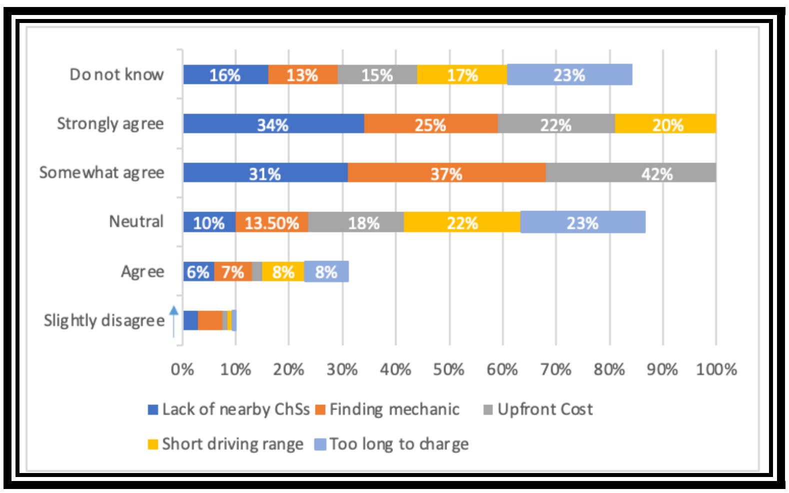


Figure 31. Main perceived EV disadvantages

Participants also responded that if they wanted to learn more about EVs, they could rely on the Internet (63%), have in-person visits with local dealerships (13%), and read online EV reviews (11.5%). Other learning options mentioned by participants are listed in **Figure 32** and **Table 28.** Additionally, some URCs members own EVs and depend on personal interests and specific needs as deciding factors to acquire an EV. This is because public sources of information or community engagement programs had not been made available to them. The results are similar to studies *(Vassileva & Campillo, 2016; W. Li et al., 2017)* where public EV interest depended more on demographics, personal perceptions, personal experiences, and users' emotions or a combination of these factors. Public interest was not fully dependent on the specific benefits of EV technology or community engagement programs to inform the public. Opposed to URCs, where EV technology development generated interest, particularly in elder residents. They asked if EVs can assist them, for example, if they experience a heart attack while driving or if an EV can help them prevent a collision.

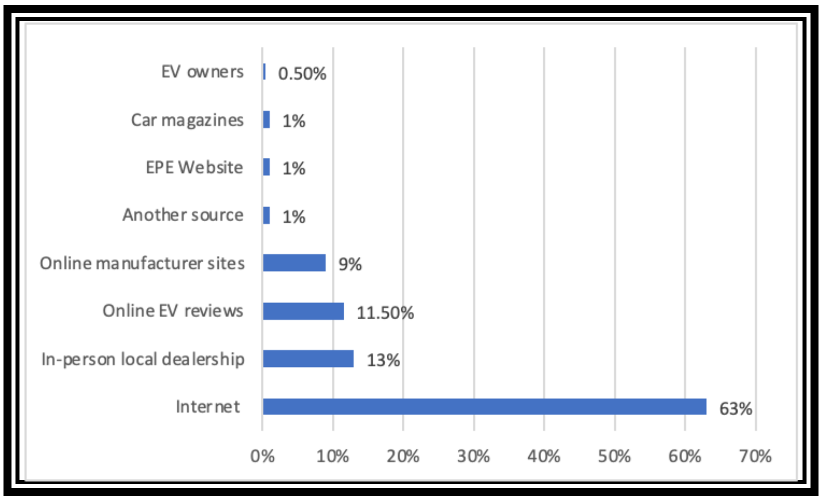


Figure 32. Sources to learn more about EVs

Vehicle Ownership

This section focused on the factors the participants considered important before purchasing a vehicle and their interest in purchasing EVs with the availability of home charging incentives. Respondents were also allowed to include other factors they consider important and not listed in the survey. Participants used a 5-point scale to rate their answers, from 1 (not important) to 5 (highly important), as presented in **Figure 33** and **Table 29**.

Participants considered upfront cost (71%) the most important factor (5) to consider for the purchase of a vehicle. Saving on fuel expenses (67%) and financing availability (62%) were considered equally important as upfront cost. The size of the vehicle (56%), style (44%), and the noise of the engine (43%) were other factors considered. The least important factor participants considered was vehicle emissions (35.29%).

Chi-square analysis reflected a similar importance for upfront cost based on age (Qp=49.881, df=20, p=0.0002) and education (Qp=49.072, df=24, Qp=0.0019), as well as financing, size, and style. Other significant factors were saving on fuel expenses and vehicle emissions according to gender and vehicle size according to household income. The results suggest that individuals between the ages of 18-24 enrolled in college or have a college degree tended to consider factors such as cost, financing, and style before purchasing a vehicle. In contrast, women prioritized savings and emissions more than men. Further, individuals with household incomes between \$25k – \$49k paid more attention to the vehicle size than individuals with higher household incomes. Vehicle noise was important only for individuals in the 18-24 age group.

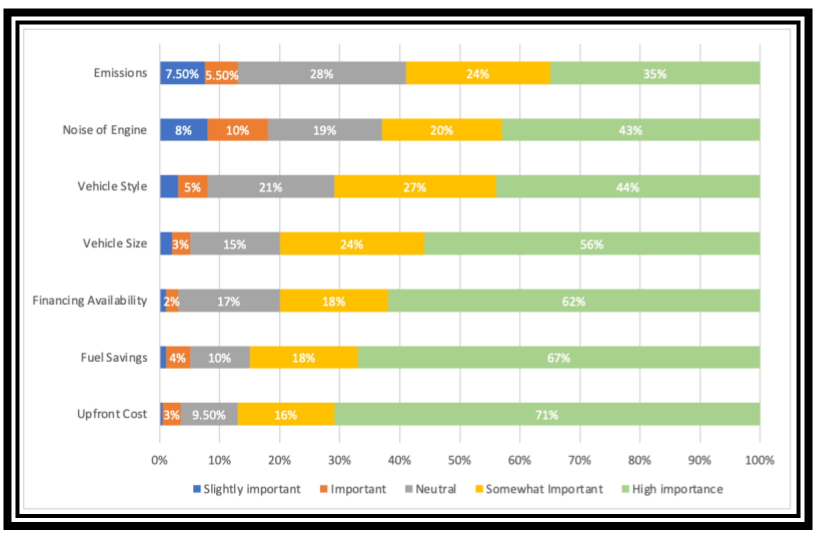


Figure 33. Important factors to consider when purchasing a vehicle

Other factors that participants provided when deciding to purchase an EV are found in **Figure 34** and **Table 30**. Nearby availability of charging stations was the most important factor respondents indicated (96%). Fuel expenses savings (charge cost vs fuel cost) (95%), upfront cost (purchase/maintenance) (94%), and battery warranty (94%). Vehicle size (79%), vehicle style (74%), and noise of the engine (73%) fell to a lower level of importance. It is particularly important to highlight that that although EV cost was a top factor to consider by respondents when purchasing an EV, and the most important factor regarding ICEV purchase, the availability of a nearby ChS was the most important factor regarding the purchase of EVs. This shows that URCs are genuinely interested in EVs, and their concerns go beyond upfront cost and driving range. Although these considerations were different regarding ICEVs. These findings may be somewhat similar to previous studies *(Vassileva & Campillo, 2016; Hardman et al., 2018; Ouyang et al., 2018), showing that driving patterns, the availability, and the* distance of charging infrastructure played an important role in public EV perception.

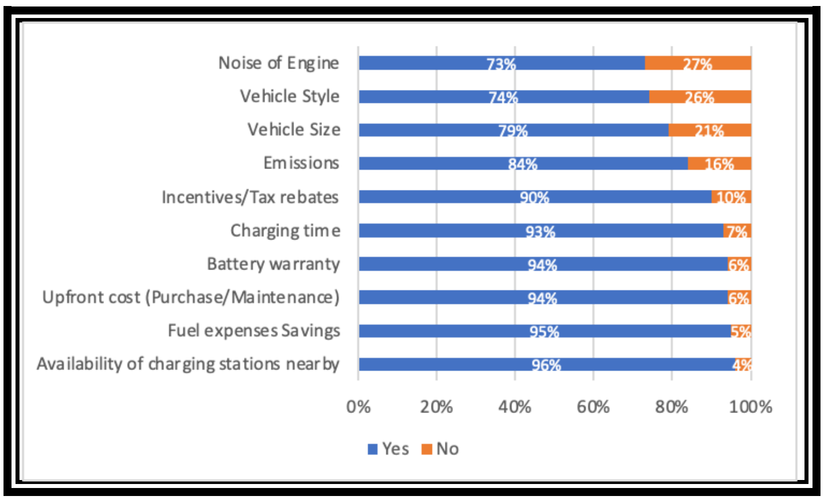


Figure 34. Important factors to consider for EV purchase

When asked about the participants' interest in purchasing an EV, HEVs received the highest interest (45%), followed by the BEVs (38%) and the PHEVs (38%), both with an equal number of responses. Regarding interest in EV purchase with the availability of home ChSs incentives, more than half of the sample (65%) agreed they would consider the purchase of an EV. A few participants felt unsure (21%), while fewer were uninterested in purchasing an EV (14%), even with available incentives. See the results in **Figure 35** and **Table 31**.

To balance ICEV and EV purchase interest, participants were asked which vehicle they felt more inclined to purchase. The only statistical associations reflected by the analysis's results included the interest for ICEVs based on age (Qp=18.164, df=5, p=0.002) and the interest for PHEVs (Qp=14.436, df=6, p=0.025) based on household. No significant associations were found for the interest of the rest of the vehicles and the demographic variables. Individuals aged 18-24 demonstrated more interest in ICEVs than older respondents. In contrast, PHEVs received more interest from participants with household incomes between $25k-$49k. These participants considered that hybrids ease the anxiety of running out of charge while still providing savings from fuel expenses.

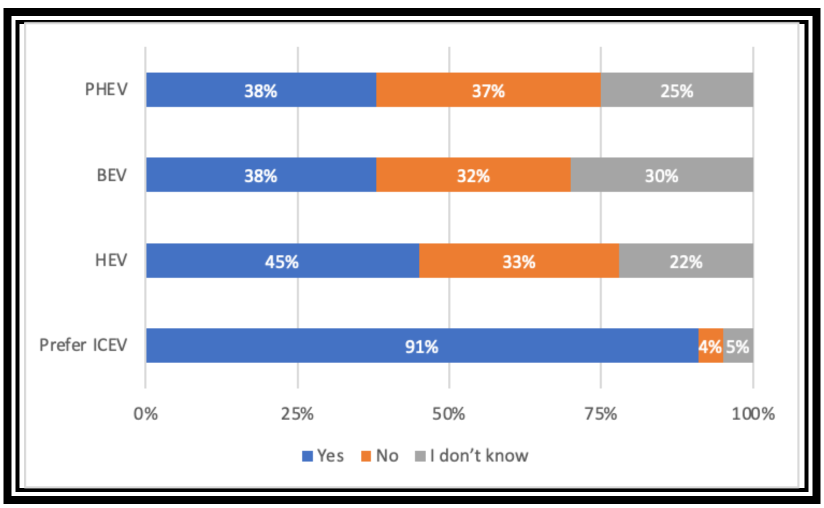


Figure 35. Interest in EV purchase with home ChS incentives available

Lastly, respondents shared additional factors they would consider if purchasing an EV. Although the sample acknowledged cost when considering EV purchases, the results indicate that other aspects are more important for them. Participants questioned the cleanness and the environmental impacts of the electricity used in the USA to produce EVs and batteries to claim that EVs help with climate change. They also inquired about home ChSs, household electricity costs, and the dispositions of EV batteries when they no longer work. Also, if EV battery recycling is promoted, as in the case of ICEVs'. Additionally, participants asked whether an energy crisis would affect their EV driving ability as with the previous gasoline shortage that occurred in the early 1970s. Participants also wanted to know the availability of maintenance and spare parts for EVs or whether to rely solely on the EV agency. The vehicle manufacturer and their standards contributed to the participants' confidence if they were to purchase an EV. Other inquiries were whether EVs are available in manual transmissions and if vehicle modifications can be made. Some respondents indicated they would consider EVs only when no option is left.

Charging Stations

The last section of the survey asked respondents about EV ChSs. Questions addressed their perception of having a ChS installed in their neighborhood and associated factors. Perception was rated with options from 1 (slightly disagree) to 5 (strongly agree) and 6 (I don't know), as shown in **Figure 36** and **Table 32**.

Some respondents felt neutral about whether a ChS would improve their neighborhood (29%). Others felt it could be a nuisance (41%) or would feel worried about its health effects (38%). The lowest number of respondents strongly agreed that installing a charging station could either be a nuisance (4%) or would raise concerns about its health effects (4%). Chi-square analysis results showed a relationship between the perception of a ChS improving the neighborhood according to age ($Q_p=60.364$, $df=25$, $p=0.0001$) and raising health concerns according to gender ($Q_p=33.603$, $df=10$, $p=0.0002$). Participants between 18 and 24 perceived ChSs in their area as beneficial, while women in the same age group also considered possible health impacts regardless of their education level or household income. Participants also mentioned that most residents in their area could not afford an EV, thus, a ChS would not be necessary at this time, however, perhaps in the near future. Another factor mentioned was whether ChSs would generate more traffic or cause issues with the local energy supply. The results show that URCs perceive the benefit of ChSs more as a community gain than a personal benefit. URCs residents identified possible health effects as an important factor to consider for the community at large, unlike other research on public EV perception where respondents focused more on station location according to their personal driving patterns *(Vassileva & Campillo, 2016; Hardman et al., 2018; Ouyang et al., 2018)*.

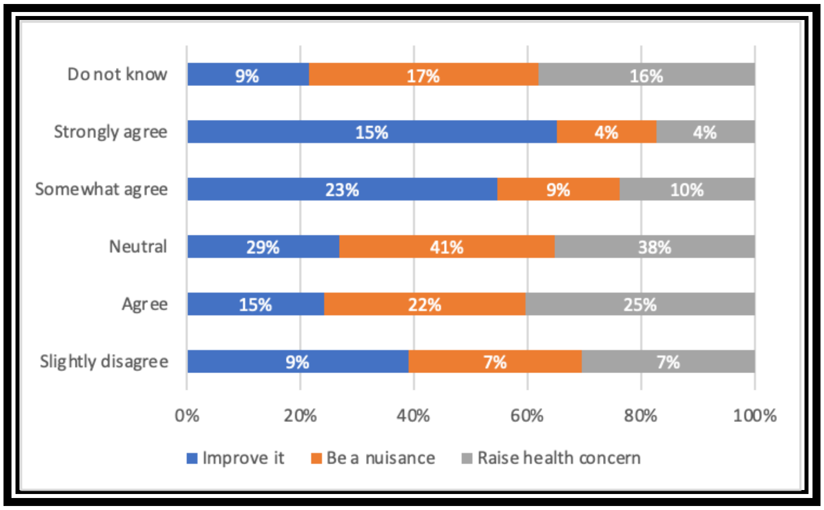


Figure 36.Perception of having ChSs installed in the neighborhood

Lastly, regarding having ChSs installed in their neighborhoods, URC members perceived ChSs as a community gain. Residents shared locations where they considered stations would be most useful for all residents and that a location should be of easy access. They also inquired whether a ChS could cause traffic issues for their community or affect their power supply and, overall, the safety of all community members. Most participants agreed on having ChSs along with gas stations (65%), shopping malls (14.93%), or public parking lots (9.95%). These and the rest of the responses are presented in **Figure 37** and **Table 33.** It is important to note that the participants prioritized the community's best interest over a personal benefit regarding a ChS installation. This perception was equally expressed by the members of each community, not survey-driven when asked about their general perception of having ChSs in their neighborhood. This notion of community gain may be unique to URCs as no previous research studies have identified a similar perception by respondents.

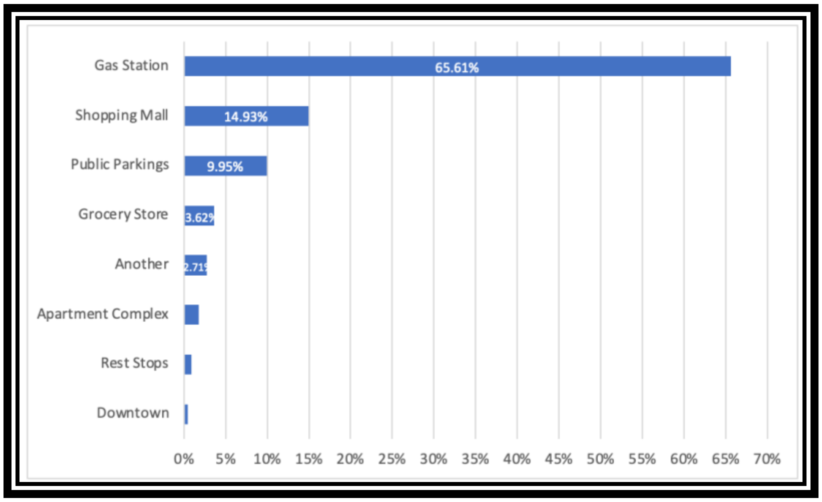


Figure 37. ChSs suggested locations

Modeling

The following paragraphs present the BCS and FS projection results. Both scenarios showed a decrease in pollutant emissions starting in 2035. However, FS shows a distinct reduction in emissions due to an increased EV market penetration through 2050, including alternative fuel vehicles. Emission results are presented by region and also as total national emissions.

BCS and FS Outcomes

BCS and FS results are presented parallelly to assess emission differences. The outcome of both scenarios is presented in Figures 38 through 43 by region for the LDV market penetration. General demand and fleet distribution on energy consumption for both scenarios, BCS and FS are presented in **Table 16** and **Table 17**. For both scenarios, ICEVs remain the dominant choice of vehicle use throughout the entire time period, where EVs do win a share of

5% by 2035 in the BCS. This is mainly a result of compact vehicles' affordability and CAFÉ regulations. In FS, ICEVs (gasoline and diesel) market penetration decreased from 72% in 2025 to 55% by 2050. EVs (BEVs and HEVs) will increase from 15% to 35% of the national fleet by 2050. Alternative fuel vehicles (Ethanol, CNG, and LPG) account for 9% of the vehicle market by 2050, with a slight decrease of 4% through the time frame. As stated earlier, this study does not address policies that would be necessary to increase EV market penetration to a higher level, which could produce more significant emission changes. Instead, based on the BCS assumption, after 2035 most EV adoption barriers will have been successfully addressed to include stronger policies applied to decrease dependency on fossil fuels. Similarly, incentive and subsidy programs will have increased, and EV charging infrastructure availability will remain constant through 2050. Regional results in the projections show a similar tendency due to the same vehicle types entering at the start of the model and also leaving after 2035. However, due to market penetration, changes are observed. The changes implemented in the FS are reflected in a decreasing trend in all the emission graphs, which will be further analyzed below.

It is important to consider that the vehicle fleet distribution is the same for all nine regions of the model. For this reason, emissions tend to follow the same decreasing tendency throughout the entire time frame.

CO2 Emissions

CO_2 emissions are presented in **Figure 38.** See also **Table 35** and **Table 41** in **Appendix D**. CO_2 emissions remain the largest pollutant coming from fossil fuel use through the entire time frame of the scenario. The BCS shows a promising trend, decreasing from 2025 to 2030 and increasing from 2035 to 2050. However, the FS shows emissions consistently decrease from 662.57 to 584.55 kT/Bn-vmt, a significant decrease of 12% from 2025 to 2050. This substantial change is also a direct result of the influx of alternative fuels and electric vehicles implemented in this scenario, which offers a hopeful outlook for emissions reduction. Additionally, as seen in **Table 17**, the FS shows ICEVs decreasing in a larger percentage than in the BCS. In the FS, from 2025 to 2050, ICEVs decreased a total of 17%, EVs increased by 20% for while alternative fuel vehicles remained almost the same, but decreased 4%. Certain vehicles in the FS model become obsolete from 2030 to 2050. EVs are expected to replace them, contributing to the reduction of emissions compared to the fluctuation in emissions that the BCS shows.

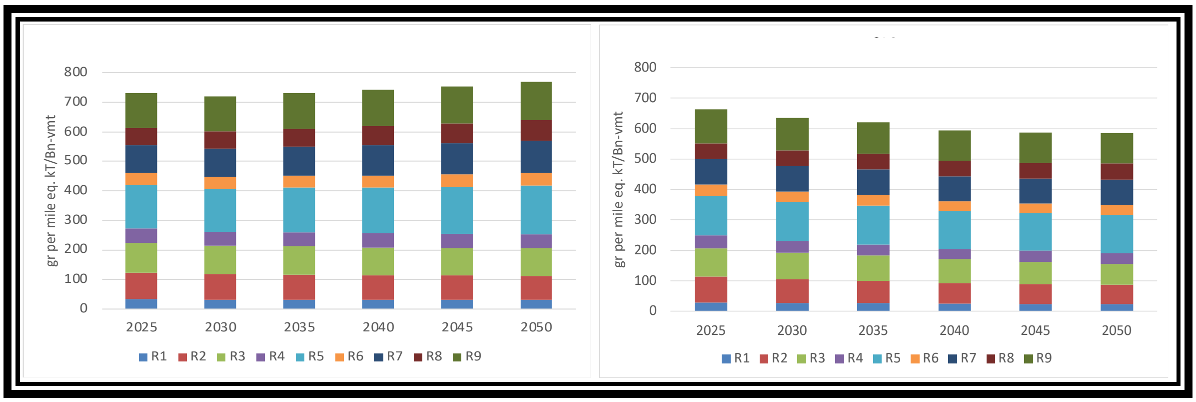


Figure 38. BCS left, and FS right CO2 Emissions by Region

CH4 Emissions

In the BCS, CH_4 emissions decreased by 37.5%. This is from 31.95 to 19.94 kT/Bn-vmt from 2025 to 2035 while increasing by 1.35% from 2040 to 2050. In the FS, emissions decreased at a steeper pace, a remarkable decrease of 37.46% from 2025 to 2035 and a further decrease of slightly more than 4% from 2040 to 2050. Most of CH_4 emissions come from the use of alternative fuels. The technology mix still shows a higher market penetration for the ICEVs. However, ethanol vehicles represent a good share to meet a greater part of the user demand, which, in comparison to ICEVs, allows for a favorable decrease in emissions. See **Figure 39**, **Table 36**, and **Table 42** in **Appendix D**.

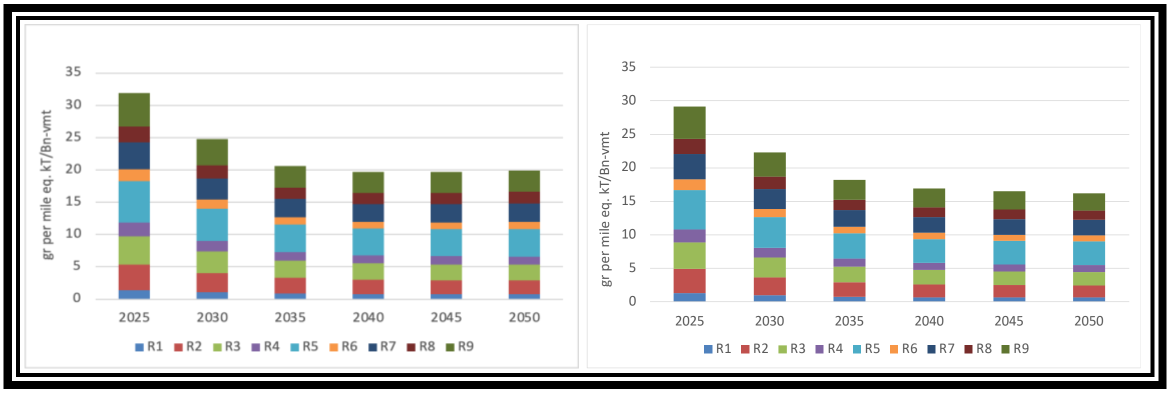


Figure 39. BCS left, and FS right CH_4 Emissions by Region

NO2 Emissions

NO_2 emissions follow a similar trend in the BCS and FS where emissions do decrease but at a slower rate of reduction. This is partly due to some vehicles that are no longer capable of meeting attainable inspection and efficiency standards, thus being removed from the market. However, there is a remarkable decrease from 19.45 to 19.14 kT/Bn-vmt from 2025 to 2030 but an increase from 2035 to 2050 from 19.25 to 20.28 kT/Bn-vmt. In the FS, there is a 9.9% decrease from 2025 to 2050, with no increase in emissions at any point in the scenario. Emissions tend to remain almost constant. The technology mix also includes ethanol, CNG, and HEVs, which are the most popular vehicles on the market. **Figure 40** shows NO_2 emission by region for both scenarios. See also **Table 37** and **Table 43** in **Appendix D**.

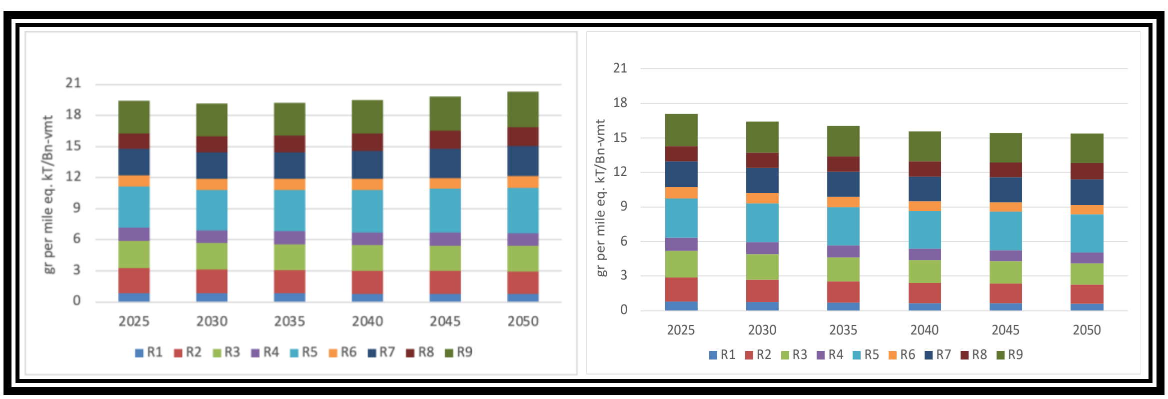


Figure 40. BCS left, and FS right NO_2 Emissions by Region

PM 10 and PM 2.5

PM10 emissions are presented in **Figure 41.** See also **Table 38** and **Table 44** in **Appendix D**. The trend in the BCS varies, decreasing from 2025 to 2035 and increasing from 2040 to 2050. The trend in the FS follows a similar behavior to the previous FS scenarios for other contaminants decreasing from 2025 to 2050. The emissions decreased by 10.34 % from 114.93 to 103.04 kT/Bn-vmt.

PM2.5 Emissions can be seen in **Figure 42.** See also **Table 39** and **Table 45** in **Appendix D**. The BCS model emissions have a more evident downward trend than other emissions in this model. From 2025 to 2035, the decrease is about 17.98%, and a 3.55% increase from 2035 to 2050. In the FS, the starting emissions are 10% lower than those from the BCS model. The emissions in the FS will steadily decrease from 2025 to 2050.

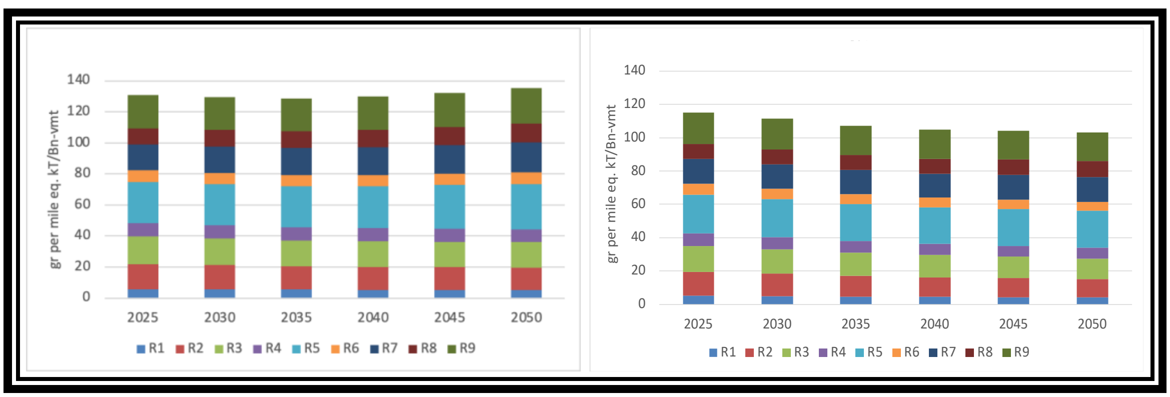


Figure 41. BCS left, and FS right PM1O Emissions by Region

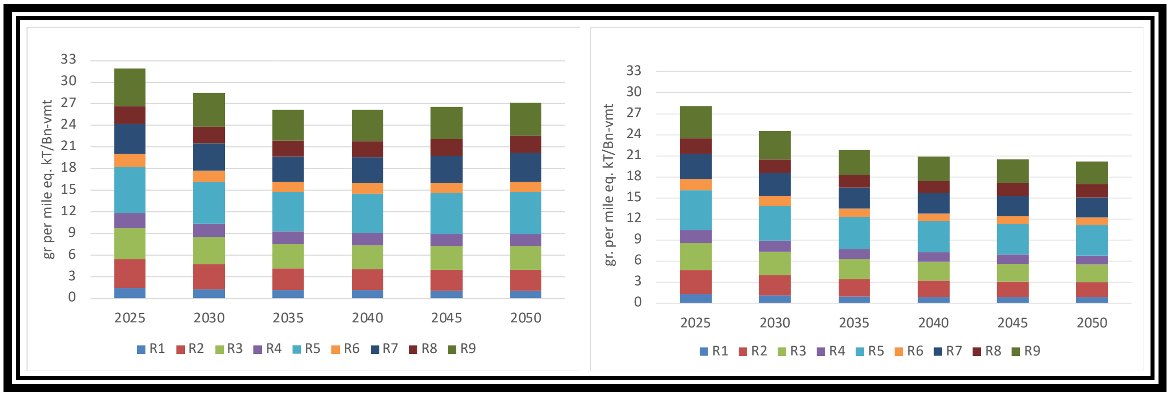


Figure 42. BCS left, and FS right PM2.5 Emissions by Region

Total National Emissions

Looking at a national overview, **Figure 43** presents the total U.S. emissions as a whole. See also **Table 40** and **Table 46** in **Appendix D**. CO_2 remains the largest pollutant due to ICEVs dominating the market throughout the entire time frame for both scenarios. However, apart from the increased use of EVs, CNG and LPG contribute significantly to decreasing CH_4 and PM 2.5. Overall, in the FS, CO_2 emissions will produce the largest environmental impact, followed by PM_{10} as a pollutant emitter. All pollutant emissions in the FS have a decline from 2025 to 2050, unlike the BCS, where, for some time periods, emissions decrease and then increase as they approach 2050.

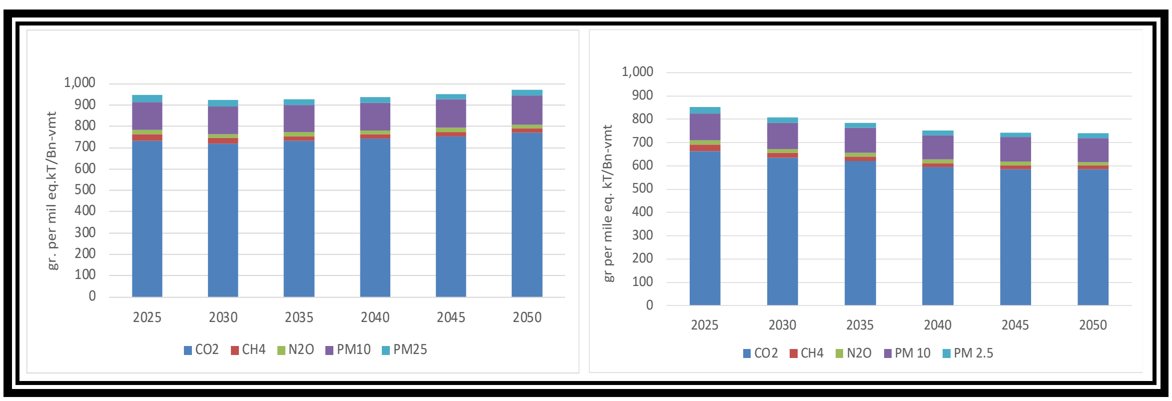


Figure 43. BCS left, and FS right National Total Emissions

Chapter 5: Conclusion

The study advances the understanding of key barriers that URC members believe and perceive regarding the adoption of EVs. This was achieved by evaluating URC residents' perceptions, opinions, and knowledge of EVs, public ChSs, and EWRs in urban and rural URCs in the El Paso region through survey and focus group sessions. The results provided valuable information to help assess and foster equity and inclusion to bridge engineering challenges with social and environmental justice in the EV market.

Incorporating these findings will greatly enhance future design and marketing criteria to include URCs to utilize the latest forms of mobility technology. To increase public interest in EV adoption, the needs and concerns of the communities must be understood and addressed through community engagement and education efforts. Additionally, this study contributes to the discussion of possible foundation locations for deploying electrified technology (ChSs and ERWs) based on the power grid's resilience while considering the public perception of infrastructure development and accessibility.

The study found that URCs are remarkably interested in EVs, ChSs, and ERWs. An acceptable measure of knowledge regarding the electrified technology in URCs was identified, mainly due to the personal interest of the residents, far beyond what was first estimated at the start of this work. Most participants demonstrated some knowledge about EVs, to a lesser degree of ChSs, and no knowledge of ERWs. The main barrier identified to electrified technology was a lack of knowledge regarding the technology, which impeded widespread diffusion and adoption of EVs. The study also found that the markets in each URC are all different, and fundamental considerations with respect to EVs, ChSs, and EWRs are diverse and specific to the needs of each community. Main corners included:

- EVs:
    - Learning about the different types of available vehicles in the market
    - Learning about the different benefits from vehicle to vehicle
    - Learning vehicle upfront, insurance, and maintenance costs
    - Learning battery span life and replacement process and cost
- ChSs:
    - Provide easy access information on public ChSs locations, fees, and charging timing
    - Provide easy access information of home ChSs, cost, life span, installation, and maintenance process
    - Provide easy access information on ChS effect on human health and on the local power grid, for example, whether it could lead to an outage and tax increase
- Incentives:
    - Designing more equitable incentives and rebates based on household location, income, number of members, and number of current vehicles
    - Increase diffusion of incentives and rebates availability in new markets in a way that is accessible to all
    - Diffuse specific information regarding who qualifies and how to apply. For information on availability and the application process, refer to **Appendix E.**
- ERWs
    - Learning about construction and maintenance costs and timing

  - Learning about electrification safety requirements and health effects
  - Learning about electrification's effect on the power grid, whether it could lead to an outage and tax increase

Although EV driving range and upfront costs were important for URCs, other factors contributed to the likelihood of purchasing an EV. For example, having a ChS nearby and the availability of vehicle maintenance shops were more important to the participants. URCs considered vehicle longevity and maintenance to be highly important in owning an EV. Most URCs possess only one vehicle to meet the needs of all family members in the long term. This is opposed to the results of higher-income household studies, where having multiple vehicles is more common.

URCs also prioritized electrification's health effects and safety. For example, they asked about how safe electrification is for cancer survivors, pacemaker users, people undergoing chemotherapy, and pregnant or lactating women. Safety concerns focused on ERWs under rainstorms, flooding, and extreme heat/freezing temperatures. Other concerns included the lifespan of ERWs, whether electrification might damage fuel vehicles, and whether fuel vehicles like cranes or ambulances can safely circulate ERWs to assist in road accidents. Similarly, ChS location and proximity, including domestic ChS availability, were also significantly important to these communities. ChSs locations were prioritized where they benefitted the most people, such as gas stations and shopping centers.

The results of this work suggest that additional information is needed at this juncture to continue to address concerns expressed by the participants. Due to steep upfront costs, EVs might not be a realistic option for URCs at this time. For this technology to be suitable as a means of transportation for these communities right now, comprehensive outreach and education that is clearly understandable, easy to access, and tailored to each community must be provided, as not one size fits all. Improving the understanding and mindset of future EV owners could significantly increase EV public perception and market penetration in URCs. Survey and focus group sessions results displayed great interest from the residents, particularly after learning about the availability of purchase incentives and tax rebates, something they had never heard about. When considering other consumers, improving awareness of these incentives seems instrumental to perception and increasing possible purchases.

This work also evaluated how EVs in the LDV sector can help reduce the environmental impacts emitted by the transportation sector. This was based on a projected increase in EV market penetration in URCs, which could possibly reduce GHG emissions. Emission evaluation results showed that EVs can positively impact the reduction of GHG emissions. However, alternative fuels still play an important role in reducing pollutant emissions. The projections using the MARKAL model still addressed an alternative fuel fix during the entire time period while assessing emissions.

Results also showed that nationally, the regions with the highest percentage of Hispanic URC populations could benefit more from an increased EV adoption rate, such as regions 7 and 9. Similarly, the regions with a larger demand for vmt, such as Regions 3 and 5, could benefit from an EV adoption increase regardless of their territory or population size.

The study also highlights technological innovation's importance in decreasing future emissions to generate an environmental benefit as transportation emissions decrease. However, a larger degree of EV market penetration, beyond the 21% projections in this study, is necessary to achieve a considerable improvement in emission reduction. Policy development also plays an important role in future emissions reductions. Increasing the efficiency of vehicles while fossil fuels remain on the market or reducing the permitted limit for their consumption as energy production increases to meet future vmt demand. Joint collaboration from policymakers, technology and infrastructure developers, and the community is crucial to achieving an environmental and social benefit through EV technology.

In conclusion, this study enhances the discussion pertinent to public perception and key barriers for an appropriate EV widespread diffusion and promoting adoption by URCs. By doing so, decision-making and stakeholders can apply to select viable alternatives and equitable locations of ChSs and ERWs.

Chapter 6: Future Work

Providing knowledge and understanding of the electrified technology to historically minoritized populations is essential in advocating this topic as an equitable technology. This helps address the main public acceptance barriers and increases their interest and adoption rates. Similarly, it prepares the market for the future of electrified infrastructure. These steps also raise awareness in bridging the gap between engineering and community outreach when planning and developing equitable transportation infrastructure, including ChSs and ERWs. This methodology shows that fostering equity and social and environmental justice in engineering, considering the public perceptions and needs of underrepresented groups while planning and developing public transportation infrastructure, is extremely important.

The study identified that mitigating the lack of essential knowledge of the electrified technology in URCs, is a basic step in fostering its adoption in new markets, such as historically minoritized populations. Each market in URC is different, including its concerns, which are diverse and based on the specific needs of each community thus, areas for future research include:

- *Community engagement and education efforts.*

  It is crucial to develop easy-to-access learning resources for community members. This helps promote technology benefits and innovation, increasing public interest, as not everyone in URCs can access the Internet or commute to information resources outside their community. Resources should also be tailored to the needs of each community, for most of their interests are based on the specific needs of each group.

- *Develop and promote inclusive and diverse local, state, and national incentives.*
  Government EV/Home ChSs incentives, subsidies, and tax rebates should be designed according to the area where resources will be allocated for the needs of rural communities, which differ widely from those of urban communities regarding access to transportation systems and mobility patterns. Household income and the number of members should also be considered, as they are vital factors in public EV diffusion and adoption. URC households typically rely on a single and older vehicle to supply all family members' transportation needs.
- *Foster relationships with infrastructure developers, vehicle manufacturers, policymakers, and the community.*
  This ensures that the community's input is considered when developing new infrastructure, policy, and EV technology. This approach helps promote the current resources, such as EV infrastructure and incentives available amongst URCs, so members acknowledge their existing resources and learn how to take advantage of them. It also paves the way for promoting technological innovation and environmental benefits, which can increase public interest.
- *Explore alternative fuels in electricity production and distribution.*
  To reduce GHG emissions in the LDV sector with increased use of EVs, new sources of electricity generation must be considered to achieve higher environmental benefits, as electricity production still depends on fossil fuels.
- *Development of new policy to promote electric mobility transition.*
  As travel demands continue to increase, new policies that assess vehicle efficiency and establish fossil use limits must be developed to decrease the

dependency on fossil fuels. This aspect supports the Biden administration's effort to promote the electric mobility transition, prevent future emissions, and provide cleaner air and better public well-being.

It is important to note that the URCs residents prioritized the community's best interest over a personal benefit regarding a ChS and ERWs installation. This perception was equally expressed by the members of each community and not study-driven when asked about their perception of having ChSs and ERWs in their neighborhood. This data may be unique to URCs as no previous research addresses this perception. This aspect may be important for future research to evaluate the potential of the URCs market to diffuse and increase EV technology as an equitable technology.

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Appendix A

Survey

Section 1: Demographic information

Please select your gender
1. Male
2. Female
3. Prefer not to answer

Please select your race/ethnicity
1. White
2. African American/Black
3. American Indian or Alaska Native
4. Asian
5. Native Hawaiian or Other Pacific Islander
6. Hispanic or Latino
7. Other
8. Prefer not to say

Please select is your age range
1. 18-24
2. 25-34
3. 35-44
4. 45-54
5. 55-64
6. 65 +

Please select your highest degree attained
1. Less than High School
2. High school graduate (includes equivalency)
3. Some college, no degree
4. Associate’s degree
5. Bachelor’s degree
6. Graduate or professional degree
7. Other __________

Which of the following best describes your household's total annual income?
1. Under $25,000
2. $25,000 to $49,999
3. $50,000 to $74,999
4. $75,000 to $99,000
5. $100,000 to $149,999
6. More than $150,000
7. I prefer not to answer

Section 2: Perception of environment.

How familiar are you with the following?

	Not at all	Slightly	Neutral	Somewhat	Extremely
Climate change	❑	❑	❑	❑	❑
Health impacts of air pollution	❑	❑	❑	❑	❑
Health impacts due to traffic	❑	❑	❑	❑	❑

How concerned are you about the following?

	Not at all	Slightly	Neutral	Somewhat	Extremely
The air quality in your neighborhoods	❑	❑	❑	❑	❑
The air quality in the City of El Paso	❑	❑	❑	❑	❑

Section 3: Driving/Transportation Habits.

To respond the following questions, please consider your typical behavior before COVID-19 restrictions.

How often do you use your car?

1. Rarely/few times a year
2. Once a month
3. 2-3 times a month
4. Once a week
5. 2-3 times a week
6. more than 3 times per week
7. Always/Every day
8. I do not own a car

How many miles do you drive weekly on average?

1. Less than 20 miles
2. 20 to 60 miles
3. 60 to 120 miles
4. over 120 miles
5. Other ___________

How much do you spend on gasoline per month?

1. Less than $20
2. $20 to $39.99
3. $40 to $59.99
4. $60 to $99.99
5. $100 to $199.99
6. More than $200
7. I do not know

How often do you use public transportation?

1. Never
2. Rarely, a few times a year
3. Sometimes, once in a while
4. Often, 3-5 times per week
5. Always, Every day

Section 4: Knowledge of technology.

How familiar are you with the following technologies?

	Not at all	Slightly	Neutral	Somewhat	Extremely
Battery Electric Vehicles (BEVs): Powered by batteries that are recharged by plugging them into an electric power source.	❑	❑	❑	❑	❑
Hybrid Electric Vehicles (HEVs): Powered by an electric motor and a gasoline engine simultaneously. The engine uses gasoline to recharge the battery that powers the electric motor.	❑	❑	❑	❑	❑
Plug-in Hybrid Electric Vehicles (PHEVs): Powered by an electric motor and gasoline engine. The electric motor is powered by a battery that charges by plugging it into an electric power source and uses the gasoline engines as a backup.	❑	❑	❑	❑	❑
Internal Combustion Engine Vehicles (ICEVs): Gasoline/Diesel engine	❑	❑	❑	❑	❑

Have you ever driven these vehicles?

	Yes	No
Battery Electric Vehicles (BEVs): Powered by batteries that are recharged by plugging them to an electric power source.	❑	❑
Hybrid Electric Vehicles (HEVs): Powered by an electric motor and a gasoline engine simultaneously. Engine uses gasoline to recharge the battery that powers the electric motor.	❑	❑
Plug-in Hybrid Electric Vehicles (PHEVs): Powered by an electric motor and gasoline engine. Electric motor is powered by a battery that charges by plugging it to an electric power source and use the gasoline engines as a backup.	❑	❑
Internal Combustion Engine Vehicles (ICEVs): Gasoline/Diesel engine	❑	❑

What distance do you think EVs can drive on a fully charged battery electric vehicle (BEV)?

1. Less than 100 miles
2. More than 100 but less than 200 miles
3. 200 miles
4. More than 200 miles but less than 300 miles
5. More than 300 miles
6. I do not know

ICEVs' and EVs' most perceived benefit

	EVs	ICEVs	I do not know
Reduces pollution improving air quality in my community	❑	❑	❑
Lower upfront cost	❑	❑	❑
Provides longer driving distances	❑	❑	❑
Provides a safer driving	❑	❑	❑

What are the main disadvantages of purchasing an electric vehicle?

	Strongly disagree	Disagree	Neutral	Somewhat Agree	Strongly Agree	I do not know
Difficult to find a mechanic	❑	❑	❑	❑	❑	❑
Lack of nearby charging stations	❑	❑	❑	❑	❑	❑
Upfront Cost	❑	❑	❑	❑	❑	❑
Short driving charge	❑	❑	❑	❑	❑	❑
Charging takes too long	❑	❑	❑	❑	❑	❑

If you wanted to learn more about electric vehicles, where would you seek information? Select only one

1. Internet (google, yahoo, etc.)
2. Online for third-party reviews/recommendations
3. Online car manufacturer sites
4. In-person dealership
5. El Paso Electric website
6. Car magazines
7. EV Owners
8. Other __________

Section 5: Vehicle Ownership

How important are the following factors when purchasing a vehicle?

	Not at all important	Slightly important	Neutral	Somewhat important	Very important
Emissions	❑	❑	❑	❑	❑
Fuel savings	❑	❑	❑	❑	❑
Initial cost	❑	❑	❑	❑	❑
Long-term maintenance cost	❑	❑	❑	❑	❑
Vehicle size	❑	❑	❑	❑	❑
Vehicle style/appearance	❑	❑	❑	❑	❑
Financing available	❑	❑	❑	❑	❑
Noise of engine	❑	❑	❑	❑	❑

How important are the following factors when purchasing an EV?

	Yes	No
low/zero emissions	❑	❑
Noise of engine (e.g., tailpipe and noise emissions)	❑	❑
Battery warranty/reliability/lifetime	❑	❑
Availability of charging stations in my area	❑	❑
Reliability of charging stations in my area	❑	❑
Government incentive to reduce initial purchase cost	❑	❑
Initial Purchase and Long-term maintenance costs	❑	❑
Fuel savings (how much it costs to charge vs. fuel cost)	❑	❑
Efficiency (driving distance per charge)	❑	❑
Charging time	❑	❑
Vehicle size	❑	❑
Vehicle style/appearance	❑	❑

Would you consider purchasing a battery electric vehicle if there were incentives or rebates for purchasing and installing a home charging station?
1. Yes
2. No
3. I do not know

Section 6: Charging Stations
How do you feel about having a charging station for electric vehicles in your neighborhood?

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	I do not know
It will improve my neighborhood	❑	❑	❑	❑	❑	❑
It will be a nuisance	❑	❑	❑	❑	❑	❑
I am worried about health effects	❑	❑	❑	❑	❑	❑

Where would you prefer to find a charging station?
1. Gasoline station
2. Shopping mall/shopping centers/
3. Grocery stores
4. Public parking lots
5. Office buildings
6. Apartment complexes
7. Movie theaters
8. Rest stops
9. Other _________

Appendix B

Survey tables

Table 20. Overview of sample demographics

Attribute	Number of Responses	%	Attribute	Number of Responses	%
Gender			**Education Level**		
Female	120	54	Less than high school	11	5
Male	100	45	High school graduate	39	18
No Response	1	1	Some college	72	32
			Associate's	36	16
Ethnicity			Bachelor's	35	16
Hispanic	192	87	Graduate	20	9
White	17	8	Another	8	4
No Response	8	3			
Asian	3	1.5			
American Indian	1	0.5			
Age Group			**Household Income**		
18-24	89	40	< $25k	35	16
25-34	59	27	$25-$49k	57	26
35-44	29	13	$50-$74k	51	23
45-54	25	11	$75-$99k	29	13
55-64	6	3	$100-$149k	15	7
65+	13	6	>$150k	3	1
			No Answer	31	14

*Percentages were rounded to nearest tenth

Table 21. Familiarity with AP health impacts and concerns with AQ

Attribute	1 (Not at all)	2 (Slightly)	3 (Neutral)	4 (Somewhat)	5 (Extremely)	Mean (n=221)	Std. Dev. (n=221)
	Number of responses and %						
Familiar AP health effects	8 (4%)	44 (20%)	38 (17%)	95 (43%)	36 (16%)	3.48	3.14
Concern about AQ	11 (5%)	36 (16%)	58 (26%)	69 (32%)	47 (21%)	3.48	3.15

Table 22. Driving and transportation habits

Attribute	Number of Responses	%	Attribute	Number of Responses	%
Driving frequency			**Average weekly vmt**		
Every day	168	76	< 20 miles	21	10
> 3 times per week	28	12	20 to 60 miles	85	38
2-3 times per week	8	4	60 to 120 miles	67	17
Do not own a vehicle	8	4	> 120 miles	40	18
Once a week	4	2	Do not own a vehicle	8	4
Rarely	4	2			
Once monthly	1	1			
Monthly fuel expenses			**Use of Public transportation**		
< $20	4	2	Never	159	72
$20 to $39.99	10	4.5	Rarely	45	20
$40 to $59.99	29	13	Sometimes	13	6
$60 to $99.99	72	32.5	Often	4	2
$100 to $199	65	29	Everyday	0	0
> $200	29	13			
Do not know	4	2			
Do not own a vehicle	8	4			

Table 23. Familiarity with EVs and ICEVs

Familiarity with:	1 (Not at all)	2 (Slightly)	3 (Neutral)	4 (Somewhat)	5 (Extremely)	Mean (N=221)	SD (N=221)
			Number of responses and %*				
ICEVs	8 (4%)	12 (5%)	24 (11%)	62 (28%)	115 (52%)	4.19	1.065
BEVs	51 (23%)	52 (23%)	43 (19.5%)	67 (30.5%)	8 (4%)	2.68	1.226
HEVs	57 (26%)	52 (23.5%)	44 (20%)	56 (25%)	12 (5.5%)	2.61	1.259
PHEVs	67 (30%)	48 (22%)	50 (22.5%)	46 (21%)	10 (4.5%)	2.48	1.242

*Percentages may not equal 100 % as they were rounded to the nearest 10

Table 24. Driving Experience

Have driven:	Yes	No
	Number of responses and %	
ICEV	201(91%)	20 (9%)
HEV	30 (13.5%)	191 (86.5%)
PHEV	15 (7%)	206 (93%)
BEV	13 (6%)	208 (94%)

Table 25. EV driving range estimates

EV driving range on a full charge	Number of Responses	(%)
1-Less than 100 mi	15	7
2-100 mi but < 200 mi	55	25
3-200 mi	29	13
4- > 200 mi but < 300 mi	41	18
5- > 300 mi	35	16
6- I do not Know	46	21

Table 26. ICEVs and EVs' most perceived benefits

Attribute	EVs	ICEVs	I don't know
	Number of responses and %		
Reduces pollution improving AQ	185 (84%)	6 (3%)	30 (13%)
Lower upfront cost	28 (13%)	124 (56%)	69 (31%)
Provides longer driving distance	49 (22%)	126 (57%)	46 (21%)
Provides safer driving	74 (34%)	67 (30%)	80 (36%)

Table 27. Main perceived EV disadvantages

EV Main Disadvantages	1 (Slightly disagree)	2 (Agree)	3 (Neutral)	4 (Somewhat agree)	5 (Strongly agree)	6 (Do not know)	Mean (n=221)	SD (n=221)
			Number of responses and %					
Lack of nearby ChSs	6 (3%)	13 (6%)	22 (10%)	69 (31%)	75 (34%)	36 (16%)	4.37	1.19
Finding mechanic	10 (4.5%)	16 (7%)	30 (13.5%)	82 (37%)	54 (25%)	29 (13%)	4.09	1.26
Upfront Cost	2 (1%)	4 (2%)	39 (18%)	93 (42%)	49 (22%)	34 (15%)	4.29	1.04
Short driving range	2 (1%)	17 (8%)	49 (22%)	70 (32%)	45 (20%)	38 (17%)	4.14	1.21
Too long to charge	1 (0.5%)	17 (8%)	51 (23%)	71 (32%)	30 (13.5%)	51 (23%)	4.20	1.26

Table 28. Sources to learn more about EVs

Attribute	Number of responses	%
Internet	140	(63%)
In-person local dealership	27	(13%)
Online EV reviews	25	(11.5%)
Online manufacturer sites	20	(9%)
Another source	3	(1%)
EPE Website	3	(1%)
Car magazines	2	(1%)
EV owners	1	(0.5%)

Table 29. Important factors to consider when purchasing a vehicle

Factors	1 (Not at all important)	2 (Slightly important)	3 (Neutral)	4 (Somewhat Important)	5 (Highly important)	Mean (n=221)	SD (n=221)
			Number of responses and %				
Upfront cost	1 (0.5%)	7 (3%)	21(9.5%)	36 (16%)	156 (71%)	4.55	0.863
Savings on fuel	3 (1%)	8 (4%)	23 (10%)	40 (18%)	147 (67%)	4.45	0.914
Financing	3 (1%)	5 (2%)	37 (17%)	40 (18%)	136 (62%)	4.36	0.930
Vehicle Size	5 (2%)	6 (3%)	34 (15%)	53 (24%)	123 (56%)	4.28	0.972
Vehicle Style	7 (3%)	11 (5%)	47 (21%)	59 (27%)	97 (44%)	4.03	1.065
Noise of Engine	17(8%)	23 (10%)	41 (19%)	45 (20%)	95 (43%)	3.81	1.299
Vehicle Emissions	16 (7.5%)	12 (5.5%)	62 (28%)	53 (24%)	78 (35%)	3.75	1.199

Table 30. Important factors to consider for EV purchase

Factors	Yes	No
	Number of responses and %	
Availability of charging stations nearby	212 (96%)	9 (4%)
Fuel expenses Savings	211 (95%)	10 (5%)
Upfront cost (Purchase/Maintenance)	209 (94%)	12 (6%)
Battery warranty	208 (94%)	13 (6%)
Charging time	205 (93%)	16 (7%)
Incentives/Tax rebates	198 (90%)	23(10%)
Emissions	185 (84%)	36 (16%)
Vehicle Size	174 (79%)	47 (21%)
Vehicle Style	164 (74%)	57 (26%)
Noise of Engine	162 (73%)	59 (27%)

Table 31. Interest in EV purchase with home ChS incentives available

If home ChSs incentives are available, would you consider purchasing:	Yes	No	I don't know
	Number of responses and %		
ICEV?	201 (91%)	9 (4%)	11 (5%)
HEV?	100 (45%)	73 (33%)	48 (22%)
BEV?	85 (38%)	71 (32%)	65 (30%)
PHEV?	84 (38%)	81 (37%)	56 (25%)

Table 32. Perception of having ChSs installed in the neighborhood

Having ChSs in neighborhood will:	1 (Slightly disagree)	2 (Agree)	3 (Neutral)	4 (Somewhat agree)	5 (Strongly agree)	6 (Do not know)	Mean (n=221)	SD (n=221)
			Number of responses and %					
Improve it	19 (9%)	33 (15%)	64 (29%)	51 (23%)	34 (15%)	20 (9%)	3.49	1.384
Be a nuisance	15 (7%)	50 (22%)	90 (41%)	21 (9%)	9 (4%)	36 (17%)	3.30	1.459
Raise health concern	15 (7%)	56 (25%)	84 (38%)	21 (10%)	9 (4%)	36 (16%)	3.28	1.474

Table 33. Preferred location to have ChSs

Attribute	Number of Responses	%*
Gas stations	145	(65%)
Shopping mall	33	(15%)
Public Parking lots	22	(10%)
Grocery Stores	8	(4%)
Another	6	(3%)
Apartment complex	4	(2%)
Rest stops	2	(1%)
Downtown	1	(0.5%)

Appendix C

Hispanic Population in the U.S.

Table 34. U.S. Hispanic Population to vmt eq. *(U.S. Census Bureau,2023)*

Region	State	2022 Population by State	Number of Hispanics by State		Hispanics 18-65 years by State	65 % Hispanics Interested by State	% of Hhispanics into vmt by State (1 driver = 13,000 vmt)
1	Maine		2.10	%			
		1,385,340.00	29,092.14		184,648.00		
	New Hampshire		4.60	%			
		1,395,231.00	64,180.63		41,494.00		
	Vermont		2.30	%			
		647,064.00	14,882.47		10,400.00		
	Massachusetts		13.10	%			
		6,981,974.00	914,638.59		574,157.00		
	Connectitut		18.20	%			
		3,626,205.00	659,969.31		410,019.00		
	Rhode Island		17.60	%			
		1,093,734.00	192,497.18		119,718.00	65.00	13,000.00
	TOTALS =	15,129,548.00	1,875,260.33		1,340,436.00	871,283.40	11,326,684,200.00
2	New York		19.70	%			
		19,677,151.00	3,876,398.75		2,434,712.00		
	Pennsylvania		8.60	%			
		12,972,008.00	1,115,592.69		677,380.00		
	New Jersey		21.90	%			
		9,261,699.00	2,028,312.08		1,270,922.00	65.00	13,000.00
	TOTALS =	41,910,858.00	7,020,303.52		4,383,014.00	2,848,959.10	37,036,468,300.00
3	Michigan		5.70	%			
		10,034,113.00	571,944.44		427,841.00		
	Wisconsin		7.60	%			
		5,892,539.00	447,832.96		264,619.00		
	Illinois		18.30	%			
		12,582,032.00	2,302,511.86		1,452,502.00		
	Indiana		7.90	%			
		6,833,037.00	539,809.92		317,311.00		
	Ohio		4.50	%			
		11,756,058.00	529,022.61		305,922.00	65.00	13,000.00
	TOTALS =	47,097,779.00	4,391,121.79		2,768,195.00	1,799,326.75	23,391,247,750.00
4	North Dakota		4.60	%			
		779,261.00	35,846.01		20,568.00		
	South Dakota		4.90	%			
		909,824.00	44,581.38		23,087.00		
	Nebraska		12.30	%			
		1,967,923.00	242,054.53		137,390.00		
	Kansas		13.00	%			
		2,937,150.00	381,829.50		226,430.00		
	Missouri		4.80	%			
		6,177,957.00	296,541.94		175,967.00		
	Iowa		6.90	%			
		3,200,517.00	220,835.67		132,588.00		
	Minesota		6.00	%			
		5,717,184.00	343,031.04		203,963.00	65.00	13,000.00
	TOTALS =	21,689,816.00	1,564,720.06		919,993.00	597,995.45	7,773,940,850.00
5	Florida		27.10	%			
		22,244,823.00	6,028,347.03		3,875,113.00		
	Georgia		10.50	%			
		10,912,876.00	1,145,851.98		697,122.00		
	South Carolina		6.60	%			
		5,282,634.00	348,653.84		204,452.00		
	North Carolina		10.50	%			
		10,698,973.00	1,123,392.17		662,766.00		
	Virginia		10.50	%			
		8,683,619.00	911,780.00		573,802.00		
	West Virginia		21.20	%			
		1,775,156.00	376,333.07		20,839.00		
	Maryland		16.90	%			
		6,164,660.00	1,041,827.54		427,841.00		
	Daleware		20.80	%			
		1,018,396.00	211,826.37		61,813.00	65.00	13,000.00
	TOTALS =	66,781,137.00	11,188,012.00		6,523,748.00	4,240,436.20	55,125,670,600.00
6	Alabama		4.90	%			
		5,074,296.00	248,640.50		140,584.00		
	Mississippi		3.60	%			
		2,940,057.00	105,842.05		58,363.00		
	Tenessee		6.40	%			
		7,051,339.00	451,285.70		258,396.00		
	Kentucky		4.30	%			
		4,512,310.00	194,029.33		110,439.00	65.00	13,000.00
	TOTALS =	19,578,002.00	999,797.58		567,782.00	369,058.30	4,797,757,900.00
7	Texas		40.20	%			
		30,029,572.00	12,071,887.94		7,438,344.00		
	Oklahoma		12.10	%			
		4,019,800.00	486,395.80		281,904.00		
	Louisiana		5.80	%			
		4,590,241.00	266,233.98		154,899.00		
	Arkansas		8.60	%			
		3,045,637.00	261,924.78		152,920.00	65.00	13,000.00
	TOTALS =	41,685,250.00	13,086,442.50		8,028,067.00	5,218,243.55	67,837,166,150.00
8	Montana		4.50	%			
		1,122,867.00	50,529.02		29,431.00		
	Idaho		17.00	%			
		1,939,033.00	329,635.61		157,995.00		
	Wyoming		18.60	%			
		581,381.00	108,136.87		36,647.00		
	Nevada		30.30	%			
		3,177,772.00	962,864.92		604,934.00		
	Utah		12.00	%			
		3,380,800.00	405,696.00		306,937.00		
	Colorado		15.70	%			
		5,839,926.00	916,868.38		818,537.00		
	Arizona		32.50	%			
		7,359,197.00	2,391,739.03		1,485,871.00		
	New Mexico		50.20	%			
		2,113,344.00	1,060,898.69		640,123.00	65.00	13,000.00
	TOTALS =	25,514,320.00	6,226,368.50		4,080,475.00	2,652,308.75	34,480,013,750.00
9			14.00	%			
	Washington	7,785,786.00	1,090,010.04		658,166.00		
			14.40	%			
	Oregon	4,240,137.00	610,579.73		377,727.00		
			40.30	%			
	Califormia	39,029,342.00	15,728,824.83		9,970,569.00		
			7.70	%			
	Alaska	733,583.00	56,485.89		35,212.00		
			11.10				
	Hawaii	1,440,196.00	159,861.76		91,629.00	65.00	13,000.00
	TOTALS =	53,229,044.00	17,645,762.24		11,133,303.00	7,236,646.95	94,076,410,350.00

Appendix D

GHG Emission Tables

BCS Emissions by Region

Table 35. U.S. CO_2 Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	32.88	31.48	31.26	30.89	30.55	30.39
R2	90.85	86.60	85.43	83.98	82.64	81.82
R3	100.28	95.85	95.14	94.08	93.15	92.45
R4	48.23	46.98	47.26	47.41	47.66	48.04
R5	147.57	147.02	151.63	155.92	160.69	165.90
R6	41.37	40.24	40.44	40.52	40.70	41.12
R7	94.72	95.61	99.24	102.67	106.43	110.69
R8	57.25	58.11	60.91	63.66	66.67	70.15
R9	119.52	118.21	120.63	122.75	125.34	128.49
Total	732.68	720.10	731.92	741.89	753.83	769.06

Table 36. U.S. CH_4 Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	1.43	1.08	0.88	0.82	0.80	0.79
R2	3.96	2.98	2.41	2.23	2.16	2.12
R3	4.36	3.30	2.68	2.49	2.43	2.40
R4	2.11	1.62	1.33	1.26	1.25	1.25
R5	6.43	5.05	4.27	4.13	4.20	4.30
R6	1.81	1.38	1.14	1.07	1.06	1.07
R7	4.15	3.29	2.80	2.72	2.78	2.87
R8	2.50	2.00	1.72	1.69	1.74	1.82
R9	5.22	4.06	3.40	3.25	3.28	3.33
Total	31.95	24.76	20.63	19.67	19.70	19.94

Table 37. U.S. NO_2 Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	0.87	0.84	0.82	0.81	0.80	0.80
R2	2.41	2.30	2.25	2.21	2.17	2.16
R3	2.65	2.55	2.50	2.47	2.45	2.44
R4	1.28	1.25	1.24	1.25	1.25	1.27
R5	3.92	3.91	3.99	4.10	4.23	4.38
R6	1.10	1.07	1.06	1.06	1.07	1.08
R7	2.53	2.54	2.61	2.70	2.80	2.92
R8	1.52	1.54	1.60	1.67	1.75	1.85
R9	3.18	3.14	3.17	3.23	3.30	3.39
Total	19.45	19.14	19.25	19.49	19.84	20.28

Table 38. U.S. PM_{10} Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	5.84	5.66	5.49	5.42	5.36	5.35
R2	16.18	15.58	15.01	14.72	14.51	14.39
R3	17.82	17.24	16.72	16.49	16.35	16.26
R4	8.63	8.45	8.30	8.31	8.36	8.45
R5	26.33	26.45	26.65	27.33	28.20	29.18
R6	7.39	7.24	7.11	7.10	7.14	7.23
R7	17.01	17.20	17.44	18.00	18.68	19.47
R8	10.26	10.45	10.70	11.16	11.70	12.34
R9	21.38	21.26	21.20	21.52	22.00	22.60
Total	130.84	129.53	128.62	130.06	132.31	135.26

Table 39. U.S. $PM_{2.5}$ Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	1.43	1.25	1.12	1.09	1.08	1.07
R2	3.95	3.43	3.05	2.96	2.91	2.88
R3	4.35	3.79	3.40	3.32	3.28	3.26
R4	2.10	1.86	1.69	1.67	1.68	1.69
R5	6.42	5.82	5.42	5.50	5.65	5.85
R6	1.80	1.59	1.45	1.43	1.43	1.45
R7	4.15	3.79	3.55	3.62	3.74	3.90
R8	2.50	2.30	2.18	2.24	2.35	2.47
R9	5.21	4.68	4.31	4.33	4.41	4.53
Total	31.91	28.51	26.17	26.16	26.52	27.10

Table 40. U.S. Emissions Summary by Pollutant

Emissions	2025	2030	2035	2040	2045	2050
CO2	732.68	720.10	731.92	741.89	753.83	769.06
CH4	31.95	24.76	20.63	19.67	19.70	19.94
N2O	19.45	19.14	19.25	19.49	19.84	20.28
PM10	130.84	129.53	128.62	130.06	132.31	135.26
PM25	31.91	28.51	26.17	26.16	26.52	27.10

FS Emissions by Region

Table 41. U.S. CO_2 Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	29.24	27.40	26.36	24.63	23.52	23.02
R2	84.63	78.26	74.09	68.73	65.30	63.51
R3	93.23	86.28	82.16	76.60	73.19	68.03
R4	41.33	38.64	37.08	34.83	36.95	36.56
R5	131.12	127.99	127.88	124.30	123.72	125.62
R6	36.80	35.03	34.10	32.31	31.34	31.14
R7	84.19	83.23	83.69	81.85	81.94	83.81
R8	50.82	50.59	51.37	50.74	51.33	53.12
R9	111.20	106.72	104.55	100.38	99.02	99.73
Total	662.57	634.14	621.27	594.37	586.32	584.55

Table 42. U.S. CH_4 Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	1.30	0.98	0.78	0.70	0.67	0.66
R2	3.64	2.69	2.13	1.91	1.81	1.77
R3	3.97	2.97	2.37	2.14	2.05	2.00
R4	1.93	1.46	1.18	1.08	1.05	1.04
R5	5.82	4.56	3.77	3.55	3.53	3.59
R6	1.65	1.25	1.01	0.92	0.89	0.89
R7	3.79	2.96	2.47	2.34	2.34	2.29
R8	2.26	1.80	1.52	1.45	1.46	1.41
R9	4.76	3.67	3.00	2.80	2.75	2.58
Total	29.12	22.33	18.21	16.89	16.56	16.21

Table 43. U.S. N_2O Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	0.76	0.72	0.69	0.65	0.64	0.61
R2	2.11	1.98	1.87	1.76	1.71	1.64
R3	2.33	2.19	2.09	1.97	1.93	1.85
R4	1.13	1.07	1.04	0.99	0.99	0.96
R5	3.44	3.36	3.33	3.27	3.33	3.32
R6	0.96	0.92	0.89	0.85	0.84	0.82
R7	2.22	2.18	2.18	2.15	2.15	2.21
R8	1.34	1.33	1.34	1.33	1.31	1.40
R9	2.79	2.70	2.65	2.57	2.54	2.57
Total	17.07	16.44	16.05	15.55	15.43	15.38

Table 44. U.S. PM_{10} Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	5.13	4.87	4.58	4.36	4.22	4.07
R2	14.24	13.38	12.51	11.86	11.42	10.96
R3	15.66	14.81	13.93	13.29	12.87	12.39
R4	7.58	7.26	6.92	6.70	6.59	6.44
R5	23.12	22.72	22.21	22.02	22.21	22.23
R6	6.50	6.22	5.92	5.72	5.62	5.51
R7	14.93	14.78	14.53	14.50	14.71	14.83
R8	8.99	8.98	8.92	8.99	9.21	9.40
R9	18.78	18.27	17.67	17.33	17.32	17.22
Total	114.93	111.30	107.18	104.77	104.17	103.04

Table 45. U.S. $PM_{2.5}$ Emissions by Region

Region	2025	2030	2035	2040	2045	2050
R1	1.25	1.07	0.93	0.87	0.83	0.82
R2	3.48	2.95	2.55	2.37	2.25	2.20
R3	3.83	3.27	2.84	2.65	2.53	2.49
R4	1.85	1.60	1.41	1.34	1.30	1.29
R5	5.65	5.01	4.53	4.39	4.37	4.28
R6	1.59	1.37	1.21	1.14	1.11	1.11
R7	3.65	3.26	2.96	2.89	2.90	2.89
R8	2.20	1.98	1.82	1.79	1.81	1.89
R9	4.59	4.03	3.60	3.46	3.41	3.18
Total	28.08	24.55	21.86	20.91	20.51	20.15

Table 46. U.S. FS Total Emissions by Pollutant

Emission	2025	2030	2035	2040	2045	2050
CO2	662.57	634.14	621.27	594.37	586.32	584.55
CH4	29.12	22.33	18.21	16.89	16.56	16.21
N2O	17.07	16.44	16.05	15.55	15.43	15.38
PM 10	114.93	111.30	107.18	104.77	104.17	103.04
PM 2.5	28.08	24.55	21.86	20.91	20.51	20.15

Appendix E

EV Incentives Application

The TCEQ light duty motor vehicle purchase or lease program (LDPLIP) provides incentives for purchasing or leasing vehicles that use alternative fuels and those with conversion systems. It requires the following steps (*TCEQ, 2024):*

Eligibility

Incentives apply to individuals, corporations, government agencies, and business trusts. The vehicle must:

- Have been bought/rented new after September 2023
- Have title and registration
- Have four wheels
- Have at least a maximum speed of 55 miles per hour
- Comply with federal motor vehicle safety standards and state emission regulations
- The power train should be the original one, never been modified
- Be operated for at least twelve months
- Be up to 10,000 pounds or less
- Be propelled by:
    - Compressed natural gas (CNG)
    - Hydrogen fuel cell
    - Liquid petroleum gas (LPG)
    - Gas (propane)
    - Electricity

- Conversion system for compressed natural gas/propane

- EVs must have a motor powered by a hydrogen fuel cell or battery with a capacity not less than 4kW/hr and recharged from an external electric source

Application Process

- The program opens on October 23, 2023, and closes on March 22, 2024
- Grants depend on funds availability and quantity available (1k for CNG, LPG, PEVs, and PHEVs, and 2k for hydrogen fuel cell in this period)
- Applications are suspended Once the number of awards has been granted
- Funds are published by the TCEQ at www.terpgrants.org
- Application is found at www.terpgrants.org, must be filled and sent before 5p to LDPLIP-APPLY@tceq.texas.gov or by calling 1 800 919 8337 or by regular mail

  TCEQ Air Grants Division,

  LDPLIP, MC-204

  P.O. Box 13087

  Austin TX 78711-3087
- Documents required: IRS W-9, Driver's license, title, completed purchase proof

Grant Amounts

CNG and LPG

- Vehicle purchase or lease for 3 years or more = $5,000
- Vehicle lease 2 years or less than 3 years = $3,330 (66.6%)
- Vehicle lease 1 year or less than 2 years = $1,665 (33.3%)

Hydrogen fuel cell, PEVs, PHEVs

- Vehicle purchase or lease for 3 years or more = $2,500
- Vehicle lease 2 years or less than 3 years = $1,650 (66.6%)

- Vehicle lease 1 year or less than 2 years = $832.50 (33.3%)

Vehicle purchased/leased in 2022 or before. To claim IRS $7,500 Tax credit:

- Vehicle with battery at least 5kW/hr = $2,917
- For each kW after 5kW/hr = $417 extra
- Must be for own U.S. use not resale
- Have an external charging source
- 14,000 lbs or less
- Made by a manufacturer who hasn't sold more than 200k EVs in U.S

Vehicle purchased after August 16, 2022

- The same requirements, plus the final assembly must be in the U.S.
- Provide assembly location confirmation and vehicle VIN
- File form 8936 with the tax return
- Amendment return is available if missed to claim a tax credit for the year the vehicle was possessed

Vita

Liliana Lozada-Medellin is a Mexican female, first-generation Ph.D. She graduated from the Environmental Science and Engineering Doctoral program at the University of Texas at El Paso. She possesses a Master's degree in Construction Engineering and Management and a Bachelor's degree in Architecture. Most of her professional experience has been as a design architect in the private sector, research assistant, and teaching assistant.

During her start at UTEP graduate school, she conducted research for the Civil Engineering (CE) department regarding the use of Unmanned Aerial Vehicles (UAVs) where she wrote the conference paper "A Comprehensive Review of the Unmanned Air Vehicles (UAVs) Regulations In Mexico: Construction Industry Application" presented at the 6TH International Congress on Technology - Engineering in Kuala Lumpur, Malaysia in July 2018 (https://procedia.org/cpi/ICONTES-6-2111378), and a detailed literature review on the regulations, applications, and challenges of the technology in the Civil Engineering field, awarded the CONACYT Scholarship for Doctoral Studies Abroad 2019.

Further, she conducted research with the National Science Foundation's ASPIRE Engineering Research Center (https://aspire.usu.edu) and the US Department of Transportation's CARTEEH (Center for Advancing Research in Transportation Emissions, Energy, and Health) (https://www.carteeh.org) to advance knowledge of the environmental and social justice impacts of Electric Vehicles, Charging Stations, and Electrified Roadways, while promoting diversity and inclusion accounting for historically underrepresented minorities. Results were presented at the Transportation Research Board (TRB) Annual Meeting in Washington, D.C., U.S., January 2023. She also prepared a conference paper "Increasing Equity in Access to Electric Vehicles and Electrified Infrastructure through Perceptions, Opinions, and Knowledge of Underrepresented Communities in the Paso del Norte Region" (https://peer.asee.org/increasing-equity-in-access-to-electric-vehicles-and-electrified-infrastructure-through-perceptions-opinions-and-knowledge-of-underrepresented-communities-in-the-paso-del-norte-region) presented at the American Society of Engineering Education (ASEE) Annual Conference and Exposition, Baltimore, MA, U.S., in June 2023, and at the NSF's ASPIRE Engineering Research Center Annual Meeting in Logan, Utah, U.S., October 2022. Published by the ASEE, June 2023.

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