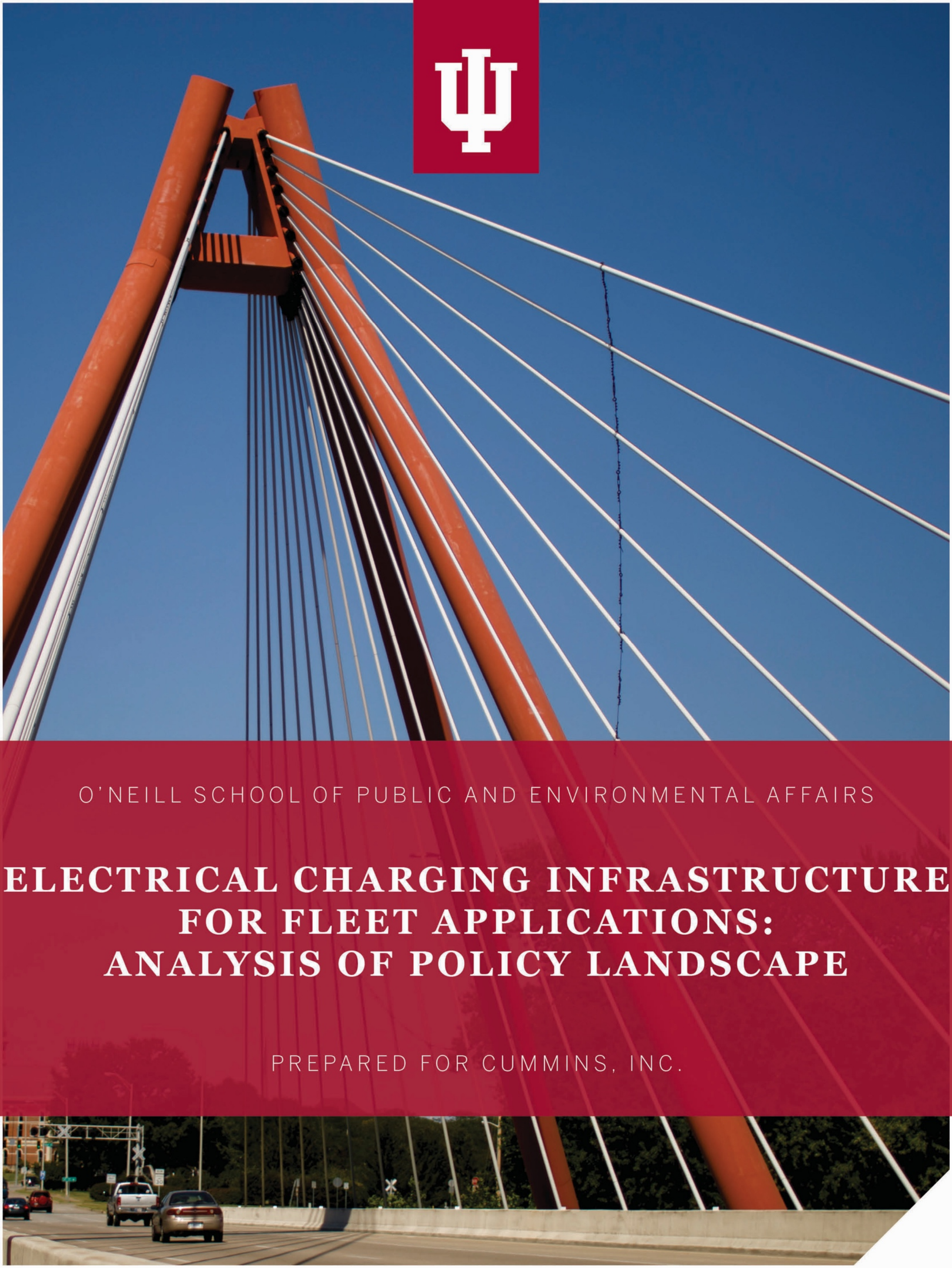

O'NEILL SCHOOL OF PUBLIC AND ENVIRONMENTAL AFFAIRS

ELECTRICAL CHARGING INFRASTRUCTURE FOR FLEET APPLICATIONS: ANALYSIS OF POLICY LANDSCAPE

PREPARED FOR CUMMINS, INC.

Electrical Charging Infrastructure for Fleet Applications: Analysis of Policy Landscape

Final Report
(abridged version)

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Submitted: April 25, 2019

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List of Acronyms

CommEV - Commercial Electric Vehicle. Refers to electrical vehicles for commercial use that are not passenger vehicles, such as fleet trucks, buses, etc.

CPCs - Commercial Private Companies. Refers to companies that operate large commercial fleets in municipalities. Examples include FedEx, UPS, and food delivery trucks.

CSR - Corporate Social Responsibility. A type of private business self-regulation akin to a corporate ethics strategy; typically emphasizes a balance between social, environmental, and financial well-being.

HOV Lane - High Occupancy Vehicle Lane. An extra highway lane for vehicles with multiple passengers used to incentivize carpooling.

LCOE - Levelized Cost of Electricity

NAAQS - National Ambient Air Quality Standards. Standards for air quality pollutants, established by the EPA under the Clean Air Act.

PassEV - Passenger Electric Vehicle. Refers to consumer electric vehicles for daily use, such as a Nissan Leaf or Chevy Volt.

PUC - Public Utility Commission

RPS - Renewable Portfolio Standards. Regulatory mandates designed to increase production of energy from renewable sources.

RTO/ISO - Regional Transmission Operator/Independent System Operator

TCO - Total Cost of Ownership. A determination of the direct and indirect costs associated with a purchase.

TOU - Time of Use Pricing

ZEV - Zero Emissions Vehicle. A state mandate modeled after California standard.

Introduction

This report contains the results of a study on the possible policies and other measures that Cummins could pursue to enhance the deployment of a charging infrastructure for medium duty commercial electric-powered vehicles in urban and suburban settings. It was prepared by Master of Public Affairs and Master of Science in Environmental Science candidates at the O'Neill School of Public and Environmental Affairs, Indiana University – Bloomington.

The goal of this capstone course is to identify and assess the evolving issues associated with the development of the charging infrastructure needed to ensure that electricity will be available to charge Cummins-powered commercial EVs operating within and near municipalities. To do this, public policies and other measures that could enhance the deployment of a charging infrastructure for medium-duty electric-powered vehicles in urban and suburban settings were identified, assessed, and ranked in order of importance. To evaluate the public policies, the research effort was divided into three subject areas: electricity supply, infrastructure, and social welfare.

Background

Widespread adaptation of all types of electric vehicles (EVs) in the United States faces a variety of challenges including sociopolitical, infrastructure, and energy capacity. EV readiness depends on collaboration between consumers, government bodies, and utility providers. It is location-specific to areas with favorable charging infrastructure, consumer incentives, and clean energy policies (Tal et al., 2013). Passenger electric vehicles (PassEVs) have been in use for much longer than commercial electric vehicles (CommEVs), and therefore, the required infrastructure and public policies for their effective use are more widely understood and documented. Many of the factors influencing EV utilization are common between PassEVs and CommEVs. Therefore, policies supporting PassEVs can be an indicator of criteria that both cities and buyers need to consider when implementing a CommEV charging infrastructure.

To understand why businesses and municipalities might consider purchasing CommEVs, it is important to understand the factors that drive retail consumers to purchase PassEVs. Consumers switch from internal combustion engines to EVs for the lifestyle, economic, and environmental aspects associated with EVs (Green Car Institute 2003; Rolim et al., 2012). Consumer incentive policies for EV adoption vary between state and municipal governments, therefore differences are important to consider when determining EV readiness of a given city. Incentives such as tax rebates, subsidies, and driver privileges are plausible reasons why a purchaser would pay a price premium for an electric vehicle versus another type of vehicle; however, more research is needed to understand charging behavior self-selection (Tal et al., 2013).

The geographic location of charging infrastructure, as well as driver awareness of the system and willingness to use it, all impact charging and driving behaviors (Boston & Werthman, 2016; Tal et al., 2013). Many studies conclude that individuals experience "range anxiety" when operating EVs due to the low EV distance rates and the fear of running out of battery without access to a nearby charging station. In general, many of the factors and concerns that promote and inhibit consumers acquiring and using passenger EVs are also drivers for companies and municipalities considering owning and operating commercial EVs (Boston & Werthman, 2016).

Burnham, et. al. (2017) outline the overall need for direct current (DC) fast charging stations that can provide full power to EVs in the shortest amount of time. Such a system could help to reduce EV users' concerns about required charging times but, subsequently may lead to increases in the cost of electricity supplied. The study recommends public-private partnerships be established between the sectors to facilitate the development of high-voltage DC charging systems. The study also addresses the challenge that charging infrastructure development is inhibited by non-uniform adapters among EV charging systems. A variety of adapters cause compatibility and safety issues for charging stations, and the study highlights a need for standardized charging stations and uniform adapters among utilities (Burnham et al., 2017).

Qin, et. al. (2016) found that EV bus fleets face barriers in market penetration due to high costs incurred by using high voltage charging systems. They investigated optimal charging strategies to minimize costs and found that frequent charging at battery levels of 60 to 64 percent saved an estimated $1,586-$2,703 in lower and upper demand charges per month. The researchers extrapolated this figure for a typical 12-year bus service life and estimated up to $168,000 in savings. While more frequent charging at less than a full charge may be an inconvenience to bus operators, and depends largely on the buses' distance rates from a 100 percent to 60 percent battery charge, the cost savings are attractive to both public and private bus systems. Employing a battery swapping system for when the active battery reaches the threshold of 60 to 64 percent would save time on the frequent charges, however, other research suggests individuals and organizations prefer plug in charging over battery swapping (Chen et al., 2018). This preference is due to the convenience of charging batteries, rather than manually replacing them with a battery of unknown charge level. Additionally, battery swapping stations could require individuals to be knowledgeable of their vehicle underpinnings and how to safely swap batteries. However, battery swapping may be optimal for minimizing electricity costs for public transportation fleets if drivers are properly trained in the battery swapping process (Chen at al., 2018).

A recent white paper argues that the growing adoption of EVs will cause problems with the energy grid as it is currently constrained. The study recommends power utilities to: (1) embed analytics throughout the EV ecosystem, (2) involve information technology in EV planning at an early stage, (3) adopt a flexible approach to EV technology infrastructure, (4) match business model inflection points with technology developments, and (5) incorporate forecasting, scenario analysis and predictive analytics into the project lifecycle process (Ravens, 2018). Long (2018) argues that EV manufacturers and operators need to develop new and close working relationships with utility companies because EV charging is dependent on infrastructure as well as cost of energy, load management, and reliability.

Other research suggests that if energy grid constraints are minimized, utility companies will welcome the benefits of EV implementation. EVs have potential to offset the reduction of electricity demand to utility companies caused by the implementation of energy efficiency technologies and programs. Electric utilities can play an important role in growing the EV market as fuel providers (Salisbury, 2016). Additionally, EVs are becoming a crucial distributed energy resource (DER) for balancing the grid supply and demand, supporting energy needs during outages, and providing ancillary services (Chandler, 2018).

Electric vehicle implementation is also gaining momentum as an economically and technologically feasible means of reducing greenhouse gas emissions from transportation. This emission reduction is only successful in areas with a fuel mix lower in fossil fuels, and EVs have consequently been more successful in states with Renewable Portfolio Standards (RPS) (Forrest, 2016). The existing and future energy mix of utilities or Regional Transmission Organization (RTOs) is therefore important to consider in EV readiness assessments.

Many of these factors and considerations described above are potentially common between passenger and commercial EVs. Therefore, some of these policies and behaviors were used to guide the research areas outlined in the following section.

Approach

In order to effectively research and analyze these questions, this research effort was divided into three subject areas: electricity supply, charging infrastructure, and social welfare. The following section will outline the areas of focus for each of these research areas.

The Electricity Supply team identified and assessed policy aspects of the electricity supply systems and controls needed to power a charging infrastructure for commercial EVs. The team focused on understanding current and possible public sector actions that will influence electricity supply. The team developed a list of factors that are influential in the deployment of electric vehicle charging infrastructures, including the role of state Public Utility Commissions (PUCs), grid management entities, portfolio fuel mixes, utility companies, the cost of electricity, and state and local EV policies.

The Infrastructure team identified policy aspects of charging infrastructure required as defined in Cummins's Phase II electrification plan. The team focused on understanding current and possible actions in the public sector that could influence infrastructure development including municipal finances, zoning and planning, electric government fleet vehicles, and commercial EVs.

The Social Welfare team was responsible for understanding the social-behavioral barriers to electric vehicle adoption for municipalities and commercial private companies. The team conducted qualitative analyses to identify these challenges and assess how they may influence electricity supply and infrastructure development.

Twenty-three cities were ranked and analyzed for charging infrastructure for commercial EVs. Throughout this report, this suite of select cities will be referred to as "the cities."

With the goal of identifying and assessing the evolving policy and related issues constraining the development of a commercial EV charging infrastructure, the primary research question was framed as: what factors influence the development of an effective commercial electric vehicle charging infrastructure in a municipality? Secondarily, how do these factors interact and influence one another within a state or municipality? Finally, which cities of interest to Cummins are the most and least likely to be able to implement a commercial EV charging infrastructure based on these factors? The following section describes the methodologies used to address these questions and the resultant conclusions that were derived, along with a set of recommendations for promoting the implementation of effective charging systems for commercial vehicles.

Methodology

Much of what has been implemented by various entities to support electric vehicles has been done in support of passenger electric vehicles, but not necessarily commercial electric vehicles. The capstone team sought to understand which elements or potential drivers for PassEVs were broad enough in applicability that the factors could support CommEVs. These criteria included grid capabilities, labor needs, commercial technical needs, how electricity distribution and transmission would be impacted by CommEV infrastructure, what infrastructure already exists within municipalities, and which social elements impact the adoption of CommEVs.

Based on these factors, it was determined that challenges were divisible into three broad subject areas: electrical supply, infrastructure development, and social welfare. To address the research questions, working groups were established to research and assess the criteria and the relationships between criteria that impact the development of a charging infrastructure for commercial vehicles.

An initial list of cities was created by the Electricity Supply and Infrastructure teams based on preliminary research, and additional cities of interest were contributed by Cummins. Factors that contributed to selection included: regional climate, ZEV and non-ZEV states, cities in states both with and without renewable portfolio standards, the general electricity production mix of that city, surface level drivers towards electrification, perceived progressiveness of the city, and the inclusion of cities that are critical to logistics and transportation.

The groups internally researched, discussed, and crafted evaluative criteria based on how each might influence the development of high-powered charging infrastructure for CommEVs. These fundamental criteria were then researched further, primarily from the academic literature to provide justification for including these criteria. Lastly, sub-criteria were constructed based on their support for creating a favorable atmosphere for CommEV charging infrastructure development. The Electricity Supply group identified fourteen criteria, and the Infrastructure team identified twenty. Based on an examination of the criteria examined by the Social Welfare team, all but two of the approximately twelve criteria were not scored and weighted due to their qualitative and non-geographically specific nature. The two criteria that were included for this subject area included regulatory compliance and municipal branding in terms of environmental progressiveness. A more detailed description of the processes used to assess criteria in the three subject areas can be found in Appendix A.

The importance and/or influence of a given criterion on facilitating the development of a charging infrastructure was determined by weighting each criterion (in rows) using the Cause and Effect Matrix. The matrix contained five evaluative categories (in columns) that were common in two of the three groups. The shared categories were “Ease of Implementation,” “Environment,” “Certainty,” “Impact to EV Adoption,” and “Impact to Cost.” The categories were weighted independently by the Electricity Supply and Infrastructure teams, depending on the relevance to each team. The weights of the importance of these categories were selected to form differences between the criteria (see Appendix B). Following the procedure of assigning weights within the C&E matrix, a value of 0, 1, 3, or 9 was assigned to each criterion based on its level of importance or influence to evaluative categories. A total score for each criterion was generated by multiplying the assigned weighted value by the weight of the category. Weighted criteria were then used to generate scores to evaluate the cities' readiness to implement a CommEv charging infrastructure. Some criteria were evaluated using a binary score (e.g. "ZEV State"), while others used scalar values (e.g. EV Definition). Scalar values were set from 0 to a maximum value, derived from the total possible score for each criterion. Scales varied by criteria and were set to reflect the differences in the importance of each criteria.

Finally, each city was scored, and the summation of the scores for each city was compared to one another to create a ranked list of the cities. Rankings were determined by the highest to lowest scores for CommEV infrastructure preparedness. Cities that numerically ranked as the five highest and lowest were assessed by the research team to rectify outliers. The final list of highest and lowest ranked cities was determined based on both numerical scores and discussion (Table 1).

Results

The three teams, Electricity Supply, Infrastructure, and Social Welfare conducted their analysis based on the criteria identified to be the most influential in developing high-powered charging infrastructure. Appendix C includes the final scores and rankings for each of the three research teams. The following results are presented by subject area with reporting of key findings and attention brought to particularly insightful results. Implications of these findings will follow in the Discussion and Application section.

Electricity Supply

Several common themes were seen in the cities that ranked highly for EV implementation. Cities whose utility providers and Public Utility Commissions (PUCs) have developed programs to expand and support electrification of EVs present a more amenable policy environment for the development outlined in Cummins' Electrified Power Business Plan. Many cities with a strong RPS also have a strong track record of alignment between state, city, PUC, and utility policies that show a positive EV growth policy trend. Additionally, results indicate that coastal cities have a higher likelihood of adoption of EVs and supporting infrastructure. Cities that lie near coastal regions, and those that have higher populations, are better prepared for EVs due to existing significant electrical infrastructure and the large industrial and commercial customer base of utility companies.

Cities that lie within Regional Transmission Operator (RTO) footprints and utility service territories that have a higher percentage of renewable energy in their fuel mix are effective areas to implement EVs because their fuel sources come from green technologies. Urban metropolitan areas that lie in electric retail service territories with time-of-use pricing and demand-side management programs will be better suited to help meet Cummins' electricity supply and cost policy needs as this allows them to better control their electricity costs for charging. Additionally, an analysis of the levelized cost of electricity (LCOE) of each city is dependent on geographical factors and other variables. However, cities with lower LCOE will be more suitable for Cummins' first two stages of electrification.

Infrastructure

Examination of the proposed and existing policy structures of the cities demonstrate a trend in some cities towards adopting policies that support vehicle electrification programs. This includes deploying government EV fleets, increased financing opportunities and strategies, and PassEV policies. In some cases, PassEV policies may serve as proxies for policies that incentivize CommEV development programs.

The establishment and allocation of public charging systems and purchasing incentives are the highest weighted criteria for PassEVs, because the availability of public charging infrastructure will be required to overcome range and inconvenience barriers (Slowik et al., 2017). All of the cities that were evaluated highly already have some form of publicly available charging infrastructure (usually exclusively for PassEVs). High Occupancy Vehicle (HOV) lane access can help EV drivers to reduce travel time, and contribute to reduced energy consumption for electric vehicles (Clark-Sutton et al, 2016). Of the cities, sixteen have PassEV access to HOV lanes (Lutsey et al., 2016). Also, most of the cities have parking benefits for PassEVs (Slowik et al., 2017). While these particular incentives may not exactly align with the needs of a CommEV fleet, the presence of HOV access could serve as a significant incentive to deployment.

Consumer purchasing incentives can potentially bring down the upfront costs of EVs to make them more competitive with traditional vehicles. Seventeen cities have new and used vehicle purchase incentives for consumers, which include tax credits or rebates that state or city governments offer for consumers to purchase EVs (Frades et al., 2014). Such incentives increase consumer awareness and reduce initial cost barriers, contributing to expanding EV consumption (Haddadian et al., 2016).

City Policies

Many of the cities have, or are moving towards, an electric vehicle fleet. Eighteen of the cities already have or had an electric government fleet, and seventeen of those cities have government-owned depot-style charging stations. is the only city that has a charging station infrastructure for government fleets that was developed by a third party. For cities without existing electric fleets, several cities have clear plans to purchase an electric fleet or move towards carbon-neutral fleets.

Twenty-one of the cities have some mention of electric vehicles and their associated infrastructure either in city code, ordinance, or various city-generated publications. Only fourteen of the cities explicitly define electric vehicles in their code or mention them on their government website. Eighteen cities regulate where and/or by whom electric vehicle charging stations can be placed within the municipalities. are among ten of the eighteen cities that provide the most specific regulatory schemes for charging infrastructure. Additionally, the team evaluated policies and codes surrounding gasoline filling stations, with the assumption that an electric charging infrastructure or charging station could potentially be developed using similar zoning and permitting structures. To that end, seventeen cities have city codes specific to gas station ownership, construction, and regulation. Some of the most innovative or comprehensive city codes and websites regarding electric vehicles were in cities such as.

Public Finance

Six states have tax rebate and credit programs for the purchase of EVs. In order of tax rebate and credit volume, they are: California, Oregon, Texas, Tennessee, Washington, D.C., and Pennsylvania. While other states have tax rebates and credits, these policies are more directed towards PassEVs. Additionally, many of the cities do not yet have plans in place to significantly incentivize or reduce the cost of creating high-power charging infrastructure. Two of the cities have grant programs available for private corporations, public agencies, or public-private partnerships to subsidize the cost of building high-power charging infrastructure. Ten of the cities reduce total ownership costs in the form of reduced registration fees or exemptions from emissions testing, and nine of the cities charge annual fees to electric vehicle owners to compensate for the loss in gas tax revenue.

Social Welfare

Because of the fact that social challenges are, in many cases, centered on beliefs, behaviors, and perceptions of problems, the criteria evaluated by the Social Welfare group were significantly more qualitative than those identified and evaluated by the other two topical areas.

The most important social welfare criteria for municipal adoption of CommEVs are roughly devisable into two categories: regulatory compliance and social feasibility. Examples of these include: perceptions of cost savings (total cost of ownership), need for regulatory compliance, environmentally-progressive city branding initiatives, emissions savings/reduction goals, and beliefs about maintenance benefits. The top issues identified to be barriers for municipal adoption of CommEVs are concerns and perceptions about: upfront costs, infrastructure costs, charging duration, and grid capacity.

Municipal adoption of CommEVs from a “regulatory compliance” or “city branding” perspective was examined to determine the rationale behind an entity’s adoption of CommEV charging infrastructure. “Regulatory compliance” refers to cities adopting electric vehicles as an option to reduce air emissions and achieve attainment with National Ambient Air Quality Standards (NAAQS). “City branding” refers to a city’s desire for CommEV adoption as part of an overall environmentally-progressive perspective. These cities, while not facing significant air quality issues, want to position themselves as environmentally-progressive, and also may be attempting to adopt climate adaptation strategies.

City Ranking

Based on the outcomes of the scoring process of the cities, a ranked list of all of the cities was generated in each of the three research areas. These were then combined to create an overall ranked listing of the twenty-three cities assessed. Those cities that ranked at the top and bottom five for deployment of a CommEV infrastructure were determined. The top and bottom ranking was not strictly based on a summation of scores across groups; instead, it was based on the ranking that each research team came to independently, followed by a discussion of those cities that were close but not in the top or bottom. It was then determined, based on shared commonalities, which were either best- or least-suited for the implementation of CommEV charging infrastructure. The results of this process are illustrated in Table 1 which shows those cities that achieved their position in the top or bottom of the ranking by numerical score alone, and those that were close, but achieved their position in the ranking through a combination of numerical score and discussion.

Discussion and Application

The following section will outline the implications of the results of the previous Results section. These results were integrated to determine the most likely cities for the implementation of CommEV charging infrastructure.

Electricity Supply

When analyzing the ranked list of cities from the perspective of electricity supply, the criteria selected prove to be useful, as using them generates results that show a clear distinction between the top five from the rest of the cities. The main commonalities that put at the top of the list were their high scores in key criteria that were had high weightings of significance. These components include: the presence of a Zero-Emission Vehicle (ZEV) program within the state, the presence of a Time-of-use (TOU) pricing mechanism at the utility level, and strong policy track records at the PUC/utility level. The price of electricity is also a highly-weighted criteria. There was some variation in the scoring between the top five cities, but they all performed relatively high in this criteria as well.

Although the bottom-ranked cities were not as clearly defined as the top-ranked cities, there are still commonalities that explain their low rankings. All bottom-ranked cities received a score of zero for failing to have a ZEV program within their state. Additionally, with the exception of, none of the other four cities had the true presence of a Regional Transmission Organization. All five cities ranked only moderate or weak for the fuel mix of the RTO or utility that represents them.

There are mixed results across cities for policy trends and policy track records for these bottom five cities. However, the majority of the policy scores given to the other four bottom cities received moderate and/or neutral scores as opposed to positive and/or strong designations in the categories of policy trends and track records. These findings show that positive and/or strong policy scores on a number of factors were not consistently achieved in these five cities. This is a stark contrast to the top five ranked cities which all consistently scored perfectly across the seven policy sections of 'state government level policy track record,' 'city government level policy track record,' 'PUC/utility level policy track record,' 'state government level policy trends,' 'city government level policy trends,' 'PUC level policy trends,' and 'utility level policy trends.' This is significant because the seven policy-related criteria represent half of the Electricity Supply team's fourteen total criteria.

Some important assumptions were made about several of the most highly weighted criteria that were used in the Electricity Supply team's Cause and Effect matrix. These assumptions are important to address because these criteria are what ultimately determined the order ranking of the cities list. When assigning values for an RTO presence, were given a different score than the original 'zero or three' binary value. They were given a score of one because, although neither city technically falls under the jurisdiction of an RTO, they are regulated by the Tennessee Valley Authority (TVA). The TVA operates as a 'sub-RTO/super-utility entity.'

In regard to TOU pricing, cities were given the full score of ten for having any TOU pricing mechanism in place, and all do. This is based on research which found that TOU pricing mechanisms apply to residential pricing. It is also already known that a majority of utilities do have some form of a commercial TOU pricing rates. It is assumed that if a city or utility company has TOU pricing for the residential sector, then they will also have one for the commercial/industrial sectors that could be tailored to a CommEV charging system because it is inferred that it is more difficult to implement and manage such a mechanism at the residential level. A third key assumption was made during the categorization process of the RTO/Utility Fuel Mix. It was decided that the strong, moderate, or weak designations of a fuel mix would be based off the percent of coal in that fuel mix. While it is understood that the percent of coal does not fully account for or encompass the entire 'cleanliness' of a fuel mix, the proportion of coal in the mix was used as the proxy for 'cleanliness' to simplify the analysis.

Infrastructure

When evaluating the cities' fiscal policies, the differences between the top and bottom cities were evident. Two of the most heavily weighted criteria in this section were tax rebates and tax credits. Financial incentives can strongly encourage cities to implement an EV charging infrastructure. is the only one of the top cities to offer tax credits, while four of the five top cities offer green bonds and three of the top cities offer relevant grants. None of the bottom five cities offered tax rebates, tax credits, green bonds programs, relevant grants, or funding for purchase. These financial incentives are essential to encouraging municipal governments to implement EV policies and procedures, so it is a logical conclusion that the cities that put an emphasis on implementing fiscal incentives are also the most ready to implement a charging infrastructure.

The prevalence of fiscal policies intended to encourage the use of electric vehicles among the top cities distinguishes the highest and lowest-ranked cities in this category. Similar to the usage of PassEV policies as a proxy for willingness to implement CommEV policies, fiscal policies that encourage consumers to purchase EVs may also indicate a willingness of municipalities to establish policies to encourage businesses to purchase CommEVs in the future. Whether or not a city requires electric vehicles to undergo the same required inspections of other vehicles may result in small monetary saving per year or per vehicle, if electric vehicles are exempted. Additionally, many cities have implemented fees for electric vehicles, which are meant to supplement the gas tax that would have been generated had those vehicles used gasoline as fuel. This criterion applies to those places that have not implemented this type of fee, so the vehicle owners are truly "exempt" from paying a gas tax. offer both exemptions, and. has only a gas tax exemption. The other two top cities have neither. All of the bottom cities, with the exception of, offered a gas tax exemption, while only offered an emissions inspection exemption.

When considering zoning and planning, there were also clear differences between the top and bottom cities. The most heavily weighted criteria in this section were electric vehicle definitions in city code and the existence of a government EV fleet. Defining electric vehicles in city code could be an indicator of comfort with electric vehicles or willingness to regulate them on a city-level, meaning these cities might be more likely to implement a CommEV charging infrastructure. Therefore, cities that already distinctly consider and define electric vehicles, and related terms, in their codes are thought to be more likely candidates for promulgating polices in support of a CommEV charging infrastructure. While three of the bottom five cities fully defined electric vehicles in their city code, it is important to consider that all five of the top cities did. This commonality demonstrates that cities that define EVs are more likely to be ready to implement charging infrastructure.

Cities with higher specificity in their regulation of electric charging stations were also considered to be more ready to implement a CommEV charging infrastructure, as they have the regulatory schemes in place to support such a system. All five of the top cities regulate charging stations at the highest level., two of the bottom five cities, both regulate charging stations at the highest evaluated level. regulate charging stations at a middle level, and does not at all.

Cities who have a clearly developed process for the ownership, inspection, and regulation of gasoline or service stations may be able to translate those policies into policies related to CommEV charging infrastructures. Gas station ownership regulation and processes are at varying levels across the five bottom cities, while three of the top five cities regulate at the highest evaluated level. All cities regulate service and gas station inspection processes. This criterion was used as an indicator of the ways in which a city might choose to regulate a CommEV charging infrastructure, with the goal being rapid service and access for CommEVs, similar to the usage of gasoline filling stations for traditional vehicles. One of the most notable distinctions between the top and bottom cities is that all top five cities have a government EV fleet and charge those vehicles at depots, while only one of the bottom cities does, which it charges at EV charging stations. Investing in an EV fleet for the government may demonstrate that these cities are more willing to consider the implementation of a CommEV charging infrastructure.

Regulations related to PassEVs were also evaluated as a means of measuring the city's likely willingness and readiness to utilize EVs in a commercial context. The most heavily weighted criteria in this section were purchasing incentives and publicly available charging. Similar to financial incentives for governments, financial incentives for consumers can encourage the adoption of EVs. All of the top cities have new and used purchasing incentives, while only two cities in the bottom five do. All of the cities across both lists have publicly available charging, with the exception of. Three of the cities in both the top and bottom rankings offer a city PassEV parking benefit. All cities regulate workplace charging, and all of the top cities offer direct sales to the customer. The ability for companies to sell vehicles directly to customers is a criterion that is considered as an indicator of the general attitude towards EVs; however, this is also a less important criterion (Clark-Sutton et al., 2016). One important distinction in this category is that all of the top cities have a PassEV car sharing program, but only do from the list of bottom cities. Car sharing programs offers more opportunities for residents to experience EVs, and is indicative of a city's general attitude in support of EVs. While the differences are not as distinct in the PassEV category between the top and bottom cities, this may simply reflect the increasing comfort with PassEVs across the country. However, this criterion is intended as only an indicator of possible willingness to implement CommEVs.

Social Welfare

In addressing social welfare aspects that need to be considered relative to implementation of a CommEV charging infrastructure, while some criteria could be quantified, such as degree and type of regulatory compliance, but many of the criteria in this area can only be assessed qualitatively because they relate to perceptions, beliefs and behaviors. Therefore, the evaluation in this area relied primarily on qualitative data and assessment methods. Ultimately it was determined that most criteria in this area are both non-specific to a given geographic locality and are generally highly subjective.

Some cities are often assumed a priori to be front runners in the adoption of CommEVs were thought to be top contenders because of their political leanings and overall progressiveness. While were found to conform with the more progressive nature of much of the, is commonly viewed as a progressive cluster located within an otherwise conservative state. An assessment of several environmental indices revealed that was not ranked one of the “greenest” cities, which ran counter to original assumptions. Similarly, though. are known to be innovative and progressive cities, originally, they were not included on the preliminary list of assumed “green” cities.

The top cities for adoption of CommEVs from a “regulatory compliance” perspective were found to be geographically quite diverse. But these rankings did not run counter to the initial educated thoughts, given the known air quality issues that California cities have attempted to combat. Moreover, given manufacturing and metalworking history, it follows that they are a top ranked city for complying with air quality metrics.

Criteria Interactions

The top five cities were ranked as the most amenable to implementing an infrastructure to support the charging of CommEVs based on their numerical scores from the C&E matrix, but an examination of the interplay between contributing factors (criteria) is also important. Several of the key criteria that were weighted heavily in Electricity Supply or Infrastructure C&E matrixes have interactions that are worthy of noting. These interactions are extensive and complex and therefore quite difficult to assess. The results of these interactions may be constructive, meaning they build upon each other to generate a synergistic outcome or, they could actually have a destructive interference that inhibits or even prohibits the desired positive goal of policy incentivization.

Two aspects of the possible interactions between criteria assessed in the C&E matrixes are important to consider: the hierarchy of criteria and their contingency upon one another. Conceptually, the degree of importance or hierarchical interaction of criteria relative to each other was taken into account by assigning varying weights to different criteria depending on their perceived importance. However, even if individual criteria are hierarchically related and weighted accordingly, when they interact synergistically, the product of their interaction may be greater than the impact determined by the strict summation of their individual weights or scores.

The degree of dependency or contingent interaction is a subjective assessment. Tables 2 and 3 attempt to display some of the factors that may have worked together in order to assess the city's overall readiness for a CommEV charging infrastructure. These tables demonstrate the shared criteria rankings among the top and bottom cities. Many of these criteria are compounding factors that may make a city a stronger or weaker candidate for CommEV infrastructure implementation if the criteria are already in place and working together to make adding new criteria easier. These criteria include whether or not the city is in a ZEV state, its policy track record, the presence of an RTO, use of green bonds, defining EVs in city codes and statutes, presence of a municipal EV fleet, being in non-attainment for at least one criteria pollutant, and being a "Green" city. As evidenced in the tables, the top cities and bottom cities have the same responses to almost all of these criteria. Since these are only some of the criterion addressed through the analysis, this commonality may imply that these factors work together in a way that makes them stronger than each individual criterion on its own. Examples of how these criteria may interact with each other to compound their overall positive impact follows the tables.

Top 5 Cities	**Electricity Supply**			**Infrastructure**			**Social Welfare**	
Criteria	*ZEV State*	*Perfect Score for "Policy track records and trends"*	*True RTO Presence*	*Green Bonds*	*EVs defined in Code*	*Gov't has an EV fleet*	*In non-attainment for 1+ criteria pollutant*	*Green City*
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Yes	Yes	Yes	No	Yes	Yes	No	Yes
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 2. Comparison of criteria that are common for all of the top ranked cities.

Bottom 5 Cities	**Electricity Supply**	**Infrastructure**	**Social Welfare**

Criteria	*ZEV State*	*Perfect Score for "Policy track records and trends"*	*True RTO Presence*	*Green Bonds*	*EVs defined in Code*	*Gov't has an EV fleet*	*In non-Attainment for 1+ criteria pollutant*	*Green city*
,	No	No	No	No	No	No	Yes	No
	No	No	Yes	No	Yes	No	Yes	No
	No	No	No	No	Yes	No	No	No
	No	No	No	No	Yes	No	Yes	No
	No	No	No	No	Somewhat	Yes	Yes	No

Table 3. Comparison of criteria that are common for all of the bottom ranked cities.

The distinct definition of EVs in municipal policies is considered to be a necessary precursor to actions that support adoption, such as the purchase of a government fleet. In order for cities to implement fiscal policies related to EVs, they must first define EVs and their related terms in their code. Cities that do not have electric vehicles incorporated into their codes will likely struggle to readily adopt medium-size commercial electric fleet vehicles, because this will not allow for additional criteria that could build synergistically on this basic required foundation.

Considering the possible interactions of the criteria that are common to the top cities, whether or not the city is in a ZEV state may have the most significant impact. Because ZEV program standards are set and managed by the California Air Resources Board (CARB), states cannot develop their own independent standards. Currently in the US, nine states have adopted California's ZEV program, and four other states,., are following the standards but have not officially adopted the program. If a city is located in a ZEV state, and is compliant with the NAAQS, then the city is more likely to have a green bond program that could incentivize CommEV development. The synergy between the three factors will have a larger net impact than each factor on its own because together each factor enhances a positive feedback system. While a municipal green bond program is not strictly predicated on a state's EV goals or national air quality standards, when a state EV goal is in place and a municipality complies with air quality standards, together it incentivizes a municipality to invest in greener infrastructure. Six of the cities fell under a ZEV program.

All of the "Green Cities" that have a presence of a state-wide ZEV program, also have shown high levels of environmental progressiveness and cohesiveness in electric vehicle policies and policy trends, issue green bonds, define EVs in their code, and have an EV government fleet, with the exception of Boston which does not offer green bonds. This may demonstrate that these are important factors may work together to positively influence a city's green image and contributed to its status as “Green City” amenable to EV development. Cities that aim to be viewed as “green” are likely to have a municipal RPS (that may act in harmony with the state RPS), offer green bonds and tax incentives for both electric vehicles and charging infrastructure, and own an EV government fleet. With this in mind, it is possible that cities who are concerned with an environmentally-progressive image, are more likely to implement policies that provide fiscal incentives and purchase government property that reflects that goal, such as city fleet EVs.

Two additional criteria that seem to interact with each other in a positive manner are city public finance policies and total cost of ownership. While TCO for electric vehicles is lower than that of internal combustion engines, cities cannot reach this lower TCO without public finance policies that support the heavy upfront cost of EVs. However, TCO was not a quantifiable criterion for the analysis, and therefore did not contribute to city rankings.

Moving forward, building upon the ranking of the cities based on the summation of criteria scores by assessing possible interactions of select criteria could be used as a means to further evaluate a city’s readiness to implement a CommEV charging structure. Considering the results of the quantitative city ranking along with evaluating how some of the criteria may positively interact to support CommEV development, the cities mostly to support a successful implementation of a CommEV charging infrastructure could be determined.

Conclusions

The greatest policy challenges facing successful CommEV implementation relate to a set of factors or criteria that lie in three domains: dynamics of the electricity supply, availability of charging infrastructures, and the social feasibility in the development region. This research identified and assessed the impact of a series of criteria found in these three domains. As the policies and practices that promote and support PassEV development are more fully documented and evaluated, it is inferred that the presence of these factors in a given municipality will also, in some but not all cases, be supportive of CommEV development.

Each research domain assessed the criteria, assigned levels of importance to them using a cause and effect matrix, determined their weighted impacts, and summarized the aggregated score to generate a ranked set of twenty-three cities as to their readiness for a commercial electric vehicle deployment.

The strongest contenders for EV readiness showed a trend in each of the cities toward environmentally supportive policies and alternative energy initiatives. The top five were considered to have a green brand, which was reflected in their progressive policies required for EV development. All five of the top cities are located in ZEV and RPS states, and all five had a fuel mix in their generation portfolios dominated by non-coal powered energy sources. A reduction in CO_2 emissions from internal combustion engines is a major driver for EVs, and these cities all shared the goal of reducing carbon emissions. Cities with a history of poor air quality or other means of environmental degradation ranked higher on the list, as environmental compliance was also a strong incentive toward adopting EVs. Because of these mandates, in many of these cities a robust development of PassEV support will pave the way for CommEV deployment.

The top five cities also shared a variety of financial incentives for EV adaptation under all three criteria sectors. Four out of five top cities offer green bonds. offers tax credits to EV owners. The two top cities offer direct funding for EV purchases. Financial incentives for purchases encourage municipalities to install a charging infrastructure to support the increase in EVs and reduce range anxiety, and these cities are more capable of supporting CommEVs. All cities offered time of use pricing for electricity, which was crucial in the electricity supply list because TOU was found to incentivize EVs more than a lower LCOE. We concluded that TOU pricing encourages EV adoption more than a low LCOE because it gives consumers more control in managing their electricity costs. The top five cities had higher LCOE and TOU pricing, supported this conclusion.

The top five cities also contained a higher level of EV presence in municipal, state, and RTO policies. This presence, including a higher level of specificity in their charging station regulations, showed cities were prepared to implement EVs through their political realm. The top cities regulated charging stations at the highest level, and all had the strongest scores among state, city, and PUC/Utility policy records and trends. Policy strengths play a role in the reliability of electricity, availability of charging stations, and social feasibility categories that determined city rankings.

While the criteria for each category were determined independently, when considered together, some of these factors aligned and positively interacted to enhance a city's overall preparedness for the development of commercial electric vehicles. Any future study of CommEV readiness in a given city could use the rankings and weighting of the criteria in each of the three research categories, coupled with a more detailed evaluation of criteria interactions, to inform decision-makers on how new environmental initiatives, financial incentives, and policies could favorably support CommEV development.

Recommendations

There are a great deal of factors that are in play to influence EV infrastructure development, and therefore, this set of recommendations is based only on a preliminary assessment of cities' readiness for implementing a CommEV infrastructure. While these factors may change over time, based on this research and analysis, these areas of recommendations may be useful in determining likely locations to implement a CommEV charging infrastructure.

Based on the analysis and possible mechanisms to support EVs, the following actions are recommended for Cummins to consider:

Less Difficult to Implement:

- Prioritize CommEV development in municipalities with existing PassEV policies located in an RTO, and a state with an RPS, preferable also a city RPS
- Focus on cities located where air quality compliance is a concern (nonattainment areas)
- Explore refining commercial TOU pricing practices and policies to favor CommEV charging
- Prioritize TOU pricing policies over LCOE when comparing cities
- Explore public/private partnerships to support installation of charging infrastructures
- Prioritize cities with progressive green initiatives

More Difficult to Implement:

- Support public policies that subsidize CommEV charging infrastructure for a specific time period, providing regulatory certainty in the business environment
- Encourage cities to adopt more specific CommEV policies to conform with existing more rigorous PassEV regulations
- Encourage political state entities to favor policies that reduce carbon emissions

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Appendices

Appendix A. Description of Research Methodologies

Electricity Supply - Methodology

The Electricity Supply team analyzed the selected cities using the electric retail service provider as the unit of analysis for studying cost and supply. The service provider or utility company's relationship with its state and city regulator, membership in an RTO, fuel mix, and the presence of time of use or electric vehicle pricing schemes were all factors examined for each city. The presence (or lack thereof) or the degree of influence of each of the factors studied were categorized as either binary (e.g. presence in an RTO), or scalar (e.g. diversity of fuel mix) and then assigned a point value, so that maximum possible points for all factors when summed is 100.

The group studied trends in the electricity supply industry with respect to electric vehicles and identified utility company, RTO/ISO, and municipal policies and utility commission dockets for their favorability to Cummins' electricity supply goals and their outlooks on the same. Among the factors studied, current EV policies were researched with regards to city and state regulations and utility and PUC policies so to predict future trends, along with their current policy track record. Cities and regulators that have no current EV policies were given a weak score of zero, if they demonstrated at least one EV policy they were given a moderate score of three, and if five or more EV policies were present, the city was given a strong ranking of six. These categories made up six percent each of the city's final electricity supply score. Additionally, the current and future fuel mix of the cities studied were analyzed and scored for diversity based upon the percentage of coal in the footprint. Furthermore, the cost of electricity was scored using a tool that provided the levelized cost of electricity for each city.

Finally, the group performed a limited "well-to-wheels" analysis of the carbon dioxide emissions produced by the vehicles, and the energy used by them, as a function of the fuel mix of the electric utilities of the cities production of the studied. This limited life cycle analysis also factors into the scoring of the cities and helps to visualize the impact of the fuel mix of the utility providers of each city and whether they are aligned with Cummins' goals with respect to carbon dioxide emissions.

Rank	Criterion Name	Max Points
1	Price of Electricity	11
2	ZEV State	11
3	Time of Use Pricing (Utility)	10
4	PUC Level/Utility Level (PTR)	10
5	Utility Level (PT)	7
6	Strength of RPS	6
7	Alternative energy (RPS)	6
8	State Government Level (PTR)	6
9	City Government Level (PTR)	6
10	State Government Level (PT)	6
11	City Government Level (PT)	6
12	PUC Level (PT)	6
13	Fuel Mix (RTO or Utility)	6
14	RTO Presence	3

Figure 1: Electricity Supply Ranked Criteria. Table showing ranked criteria as a percent of total available. (PTR) Policy Track Record (PT) Policy Trends (RTO) Regional Transmission Operator (RPS) Renewable Portfolio Standards (ZEV) Zero Emission Vehicle (PUC) Public Utility Commission

Infrastructure - Methodology

The Infrastructure team researched academic literature to determine the policy drivers and associated factors that influence electric vehicles and charging infrastructure adoption in general, and particularly the charging infrastructure for CommEVs. Once this process was complete, the literature served as a guide to determine the higher-level categories on which to evaluate a municipality's policy readiness and/or ability to implement a network of high-powered charging infrastructure. From this topical area, the categories of Finance, Zoning and Planning, Government Readiness, and PassEVs were developed. The first three categories serve as a demonstration of a government's current policy and program capacity to handle a high-powered charging infrastructure. The PassEVs category was chosen as under the assumption that a city with rigorous PassEV programs and policies would be more capable of implementing a network of high-powered chargers favorable to the development of commercial electric vehicles like those in Cummins Phase II Electrification Plan.

After the development of categories, individual criteria were created and scored across each category for each city according to the 102-point scale. Originally, the scale was developed on a 100 point scale but due to rounding was increased to 102 points. Criteria were given different numerical values, or "points," in a given category depending on the level of influence in determining whether or not the infrastructure of a city is ready or able to implement an electric vehicle charging infrastructure. The point assignment was developed using the Cause and Effect matrix described above. The final score provided from the Infrastructure team represents a qualitative understanding of where each city currently stands in their capability to support or facilitate a high-powered charging infrastructure.

Rank	Criterion Name	Max Points
1	Tax Rebates (FI)	11
2	Tax Credit (FI)	9
3	EV Definition (Z&P)	9
4	Government EV Fleet (Gov)	8
5	Service Station Inspection & Regulation (Z&P)	7
6	Funding for Purchase (FI)	6
7	Gas Tax Exemption (FI)	6
8	Emissions Exemption (FI)	6
9	Charging Station Regulation (Z&P)	6
10	Government Fleet Charging Style (Gov)	6
11	Green Bond Program (FI)	4
12	Grants (FI)	4
13	New and Used Purchasing Incentives (Pass)	4
14	Publicly Available Sharing (Pass)	4
15	Gas Station Ownership Regulation (Z&P)	3
16	Carpool/HOV Lane Access (Pass)	3
17	City Parking Benefit (Pass)	2
18	EV Car Sharing Program (Pass)	2
19	Workplace Charging (Pass)	1
20	Direct Sales to Consumers (Pass)	1

Figure 2: Infrastructure Team Ranked Criteria. Table showing ranked criteria as a percent of total available. (FI) Finance (Z&P) Zoning and Planning (Pass) PassEVs (Gov) Government Fleet

Social Welfare - Methodology

The Social Welfare team researched both specific and broad barriers most commonly associated with the psychological and behavioral aspects of the adoption of EVs in general and to CommEVs specifically. This research explored reasons for attraction or aversion to adopting electrically powered vehicles but concentrated on those factors that serve to inhibit EV development. These included the comparatively shorter ranges when compared to ICEs, the burden of higher costs associated with new and developing technologies, battery lifespan shortcomings restrictions, concerns over charging duration, the low resale value, the current limitations of charging infrastructure and grid capacity in localities and regions across the United States, and other psychologically motivated resistance to adoption.

The team explored various sources of information were explored to find behavioral and psychological factors that might inhibit or prohibit the widespread adoption of a charging infrastructure of CommEVs. Once specific barriers were identified, the team found peer-reviewed articles that discussed reasons behind and potential solutions to these barriers were analyzed. The journal articles explored ways in which municipalities had approached incentivizing EV adoption, and ways in which they had worked with other entities to make adoption more feasible. Additionally, these articles highlighted routes method corporations have experimented with to try and overcome resistance to CommEV adoption.

The team considered all of the social welfare criteria from two perspectives: how they affect the decision-making process for municipalities or commercial private companies (CPCs). The municipality section was divided into two primary subdivisions; “Regulatory compliance” refers to cities adopting electric vehicles as one feasible option to reduce air emissions and achieve compliance with the National Ambient Air Quality Standards (NAAQS). “City branding” refers to a city’s desire for CommEV adoption as part of an overall progressive perspective. Total cost of ownership (TCO) and upfront cost were also identified to be significant factors for municipality decision-making. CPCs were also subdivided into TCO, branding, and risk aversion. All other factors were labeled “general factors” which applied to both municipalities and CPCs equally. These factors tend to be less influential and more difficult to measure. Examples include concerns by owners about battery longevity, overall reliability, charging time, and range anxiety. Because many of the criteria are not geographically differentiated (including all of the general factors, TCO, and risk aversion); these factors were determined to not be amenable to city-specific comparative analysis and were not considered in the city ranking process. The identified factors identified in the research process were then assessed and, in some cases, were eliminated as being significant barriers to CommEV adoption of charging infrastructure for entities considering adopting CommEV fleets. For example, public concern over the energy source (renewable vs. coal or natural gas based) was determined to not be a significant enough factor to derail either municipal or commercial efforts to invest in CommEV infrastructure. Therefore these factors were not included as determining features for decision-making and were left out of this analysis entirely. Some of these factors were given consideration, but ultimately most did not factor significantly in a weighting process such as used by the other two teams.

Once the pertinent social acceptability factors affecting the decision-making process, the criteria were sorted into distinct categories. For municipalities, these include regulatory compliance vs. city branding, total cost of ownership (TCO), and upfront cost. For commercial private companies they include: TCO, branding, and risk aversion. Other factors are represented in the "general" factor category. These are factors that influence both municipalities and commercial private companies equally. These factors tend to be less influential and more difficult to measure. Examples include concerns by owners about battery longevity, overall reliability, charging time, and range anxiety.

Because of the non-geographic nature of most of the criteria examined, it was determined that just two factors of the fifteen of the overall criteria identified were suitable to quantitative analysis. These factors pertain to municipalities specifically and are regulatory compliance and city branding. The team determined that the remaining factors were either lacking either in sufficient data, were too subjective, or were too situationally-specific to warrant quantification. For these reasons, the team decided not to use the C&E matrix to rank our cities. Instead, the team developed a point-attribution system independent from the matrix, which is outlined below.

First, the cities were ranked for regulatory compliance. This was determined by identifying how compliant each city was with the National Ambient Air Quality Standards (NAAQS). The regulatory compliance ranking is based off the number of air quality standards with which given city is in non-compliance. This number ranges from 0 to 6, six being that a city is in nonattainment with all six air quality standards, the maximum. The cities that are ranked highest are the cities that are have the most nonattainment issues. This indicates that the city has a "regulatory compliance" issue that needs to be addressed and may be alleviated by promoting the use of CommEVs in the city. We have identified high regulatory compliance issues as a driver for CommEV adoption.

The city branding ranking was determined by quantifying how "green" a city is. This was determined by aggregating eight independent lists from online sources. These articles included rankings of the "greenest cities in the United States," "the most sustainable cities in the United States," and "the most eco-friendly cities in America." Each city was awarded one point for appearing on the list and three points for appearing in the top five slots of the list. If a city appeared in a top five slot, that city was awarded three points total. Next, the cities were awarded two points for being a recipient of the Bloomberg American Cities Climate Challenge grant. Points were awarded to these cities because they have been identified as leading climate cities in the United States today. Finally, each city was given one point if they have a published Climate Action Plan or something similar. Notably, Orlando was the only city on our list without a Climate Action Plan (See Figure 3 below).

Finally, the list of cities was examined in order to rank the top five cities that are most amenable to CommEV adoption in reference to social welfare factors. The ranking also identified the bottom few cities, which need to develop greater social welfare before adopting CommEVs on a large scale. The two ranking lists—regulatory compliance and city branding lists were then aggregated together to create the final rankings. Total points available were 33 for both categories.

C&E Matrix for Electricity Supply								
	Criteria	Evaluative Categories					Total	Percent of Total
		Certainty	Impact to EV adoption	Ease of Implementation	Impact to Cost	Environmental Impact		
		Category Weight						
		3	6	9	10	4		
	Price of Electricity (Utility)	9	9	3	9	9	234	11%
	ZEV State	9	9	9	3	9	228	11%
	Time-of-use Pricing (Utility)	9	9	3	9	3	210	10%
	PUC/Utility policy track	3	3	9	9	3	210	10%
	Utility policy trends	3	3	9	3	3	150	7%
	State Gov policy track record	3	9	3	3	3	132	6%
	State Gov Policy Trends	3	9	3	3	3	132	6%
	Strength of RPS	9	1	3	3	9	126	6%
	RPS Presence	9	1	3	3	9	126	6%
	City Gov policy track record	3	9	3	3	3	132	6%
	PUC policy trends	3	9	3	3	3	132	6%
	City Gov Policy Trends	3	9	3	3	3	132	6%
	Fuel Mix of (RTO or Utility)	9	3	1	3	9	120	6%
	RTO Presence	9	0	3	1	1	68	3%
Electricity Supply							2132	

Figure 4. Cause and Effect Matrix for the Electrical Supply

C&E Matrix for Infrastructure								
	Criteria	Evaluative Categories					Total	Percent of Total
		Ease of Implementation	Environment Impact	Certainty	Impact to EV Adoption	Impact to Cost		
		Category Weight						
		10	4	7	7	9		
Finance	Tax Rebates	9	3	3	9	9	267	11%
	Tax Credits	9	3	3	3	9	225	9%
	Funding for Purchase	3	3	9	1	3	139	6%
	Gas Tax Exemption	9	3	3	3	1	153	6%
	Emissions Exemption	9	3	3	3	1	153	6%
	Green Bonds Programs	1	9	1	1	3	87	4%
	Grants	3	3	3	3	3	111	4%
Finance Total							1135	
Zoning and Planning	EV Definiton	9	1	9	9	0	220	9%
	Service Station Regulation	9	1	3	3	3	163	7%
	Charging Station Regulation	3	1	9	3	3	145	6%
	Gas Station Ownership Regulatio	3	0	3	3	1	81	3%
Z&P Total							609	
Government Fleet Vehicles	EV Fleet	9	3	3	3	9	186	8%
	Fleet Charging Style	9	1	1	9	3	149	6%
Gov. Fleet Total							335	
Passenger EVs	New and Used Purchasing Incenti	9	3	1	0	9	109	4%
	Publicly Available Charging	9	1	1	0	0	101	4%
	Carpool/HOV Lane Access	3	3	3	1	0	70	3%
	City Parking Benefit	3	3	0	0	3	42	2%
	EV Car Sharing Program	3	3	0	0	0	42	2%
	Workplace Charging	1	3	0	0	0	22	1%
	Direct Sales to Consumers	1	1	0	0	3	14	1%
Pass EV Totals							400	
							2479	

Figure 5. Cause and Effect Matrix for the Infrastructure

C&E Matrix for Social Welfare								
	Criteria	Evaluative Categories						Total
		Certainty	Impact to EV adoption	Ease of Implementation	Impact to Cost	Environmental Impact	Social Impact	
		Category Weight						
		1	6	9	10	5	4	
Municipalities	Total Cost of Ownership (M & CPC)	9	9	3	9	0	0	180
	Upfront Cost (M)	9	9	0	9	0	0	153
	Regulatory Compliance (M)	9	9	0	0	9	1	112
	City Branding (M)	3	3	3	0	9	3	105
	Municipalities Total							550
Commercial Private Companies	Total Cost of Ownership (CPC)	9	9	3	9	1	0	185
	Branding (CPC)	3	3	1	0	9	3	87
	Risk Aversion (CPC)	0	1	3	3	0	0	63
	CPC Total							335
General	Cost of Electricity	3	3	1	3	1	1	69
	Battery Longevity	3	3	0	3	3	0	66
	Maintenance Costs	1	1	0	3	1	0	42
	Overall Reliability	1	3	1	0	0	3	40
	Charging Time	3	3	0	0	1	1	30
	Resale Value	0	0	0	3	0	0	30
	Insurance Cost	1	0	0	1	0	0	11
	Range Anxiety	0	0	1	0	0	0	9
	General Total							297
Social Welfare Total								1182

Figure 6. Cause and Effect Matrix for the Social Welfare. Two criteria highlighted in yellow are the only ones numerically assessed for scoring cities.

Appendix C. Ranking and Result Tables for Each Research Group

Appendix D. Additional Social Welfare Criteria

Municipalities are in a unique entity position to the EV market because of their governing mechanisms, procurement process, and specific needs, as well as the fact that municipalities are not making decisions based on making a profit. Therefore, social welfare criteria and barriers to entry for private companies were analyzed under a separate perspective than for municipalities. Because of these differences, social welfare criteria for commercial private companies as well as the general social welfare criteria were not included in the results by this group. This restricted those social welfare criteria that were included in the city rankings to only two: regulatory compliance for air standards and city branding initiatives (as explained in the Methodology section of this paper).

<u>Municipal Government EV Programs Contributing to Regulatory Compliance</u>

Many municipalities and public authorities across the country have begun to adopt electric vehicle programs due to air quality issues, compliance with state-law, or changes in state energy policies such as the establishment of renewable portfolio standards (RPSs). The NAAQS is one driver for cities to adopt CommEVs. Having a nonattainment status with one or more criteria pollutants will likely drive a municipality to implement policies and practices to reduce air pollution. This is happening in as the city pushes to adopt CommEV bus and police fleets.

Many of the cities in this analysis are located in non-attainment areas for at least one criteria pollutant of the NAAQS. Ozone is the most common criteria pollutant for non-attainment, while nitrogen dioxide is the least common. Los Angeles is the only city in non-attainment for nitrogen dioxide. There are only six of the cities are in attainment status.

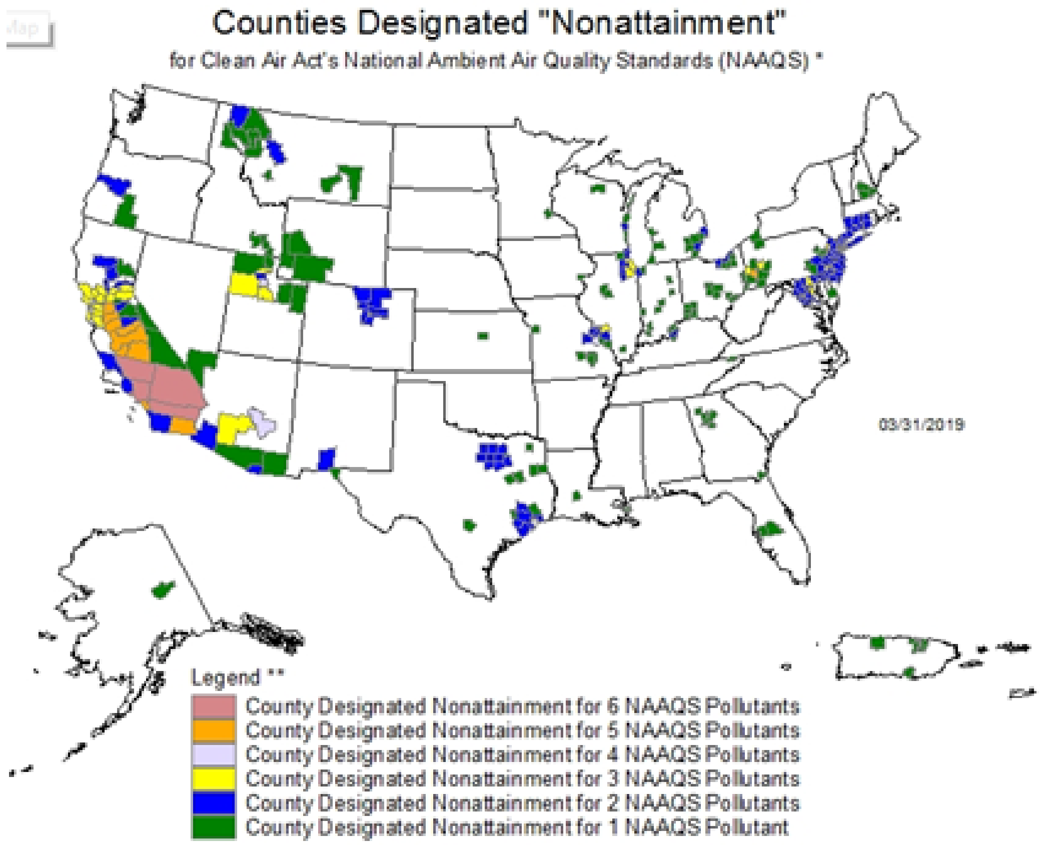

Figure 5: EPA Green Book project generated map of counties designated "nonattainment." The Green Book can be found at: https://www3.epa.gov/airquality/greenbook/mapnpoll.html .

Other programs, including the Zero-Emission Vehicles (ZEVs) program, establish a mandate requiring automakers in member states to manufacture and sell a certain percentage of their vehicles as electric. The ZEV mandate is currently active in ten states- Oregon, New Jersey, New York, Connecticut, Maine, Rhode Island, Vermont, Massachusetts and Maryland. Conceivably, the ZEV mandate could be modified to include CommEVs. In California, policies combine vehicle carbon dioxide or efficiency regulations, consumer incentives, and direct electric vehicle requirements. For example, Sacramento has been an EV lessee since 1994 when the city created a free parking program for EVs in city-owned garages. Since then, Sacramento has been working actively to provide public EV charging at city facilities and to support EVs in the community. Mandates like ZEVs illustrate a mandatory legal requirement for the city in a ZEV state to promote and facilitate EV adoption. States with ZEV mandates will likely be areas in which support for CommEV charging infrastructure is greater.

<u>Municipal Government EV Programs Contributing to Branding</u>

Transportation electrification is an economic choice made by vehicle manufacturers, corporations, municipalities, and consumers. Savvy cities and corporations recognize these trends and implement the appropriate open standards-based infrastructure to provide convenient charging experiences for all segments of transport. The goal of municipal branding initiatives often focuses on bridging the relationship between city branding and urban sustainability. Cities are increasingly undertaking local branding initiatives to increase or defend their competitive position as attractive places for citizens to reside and as a destination for visitors. In contrast with tourism branding, green/sustainable branding requires the support of residents because there must be a mechanism for cooperation between the residents and municipal government to move a branding initiative forward with common goals to maintain growth, development, and success for the city. These strategies will likely enhance social benefits for residents, including by reducing the effects of air pollution and noise pollution in underserved communities. This will work towards improving a given city's environmental justice objectives and pave the way for healthier, happier, equitable, and more durable municipalities.

Additionally, city branding incorporates a "demonstrated need" for a city to adopt CommEVs or other forward-thinking sustainability and climate change adaptation initiatives. For example, these cities are those which do not have regulatory compliance issues as a driver to adopt CommEVs but are incentivized to adopt fleets for municipal and commercial operations over other climate change concerns. Examples include cities that are at risk of losing property and lives due to storm surges, rising sea levels, water shortages due to worsening drought, increasingly severe wildfires, and with worsening air pollution, heat indexes, and noise pollution.

<u>Municipal Government, Total Cost of Ownership</u>

While the total cost of ownership (TCO) could be a potential driver for electric vehicle adoption, municipalities are often constrained by the capital costs of initial vehicle and infrastructure systems which serve as a major barrier to entry for these public organizations. Among the fleet manager community, it is well understood TCO is lower in an electric bus fleet. This cost-competitiveness with ICEs and lower overall total cost of ownership has also been well documented in research. This is because fuel and maintenance costs are one-third that of an equivalent diesel bus; electricity is cheaper than gasoline or diesel, and maintenance costs are lower due to the simpler engine. For example, a BYD electric bus costs $150,000 more than its diesel equivalent and the cost of building a charging infrastructure can be high. These upfront costs are insurmountable barriers for most municipalities, many of which struggle to identify funding sources and have competing social issues to address. Furthermore, many municipal vehicles are job specific and require custom construction, which can drive up total cost of ownership. Procurement guidelines drive all purchasing decisions for a municipality (Ernst 2016). Some may have an EV quota or environmental performance standards; these cities won't be as concerned about TCO. Vouchers and rebates help cover those high initial investment costs.

The most expensive difference between an EV and a legacy vehicle is often the cost of the battery. As the scale of production increases, electric vehicles will become even cheaper due to falling battery costs. Economists have stated that once EV batteries meet $100/kWh, they'll be cost competitive with internal combustion engines. In 2017, electric vehicle batteries were at $209/kWh according to a Bloomberg New Energy Finance report (Stevenson, 2017). Cities like Houston, TX and Loveland, CO have saved money compared to using gas-powered vehicles. And in 2015, battery-electric vehicles were slightly cheaper than gas-powered vehicles in Japan, the UK, California, and Texas, mostly due to government support in the form of subsidies and/or tax (Carrington, 2017).

True total cost of ownership, the long term cost of owning a piece of capital, is a driver for municipal fleet adoption of CommEVs. However, this benefit is outweighed by the lack of customization available and comparably high upfront costs to ICEs.

Private Companies, Total Cost of Ownership

In a corporate setting, total cost of ownership can also be called life-cycle analysis. According to Supply Technologies, a United Kingdom based supply chain consulting firm, private companies should take twelve considerations when calculating TCO. They are item value, minimum order quantities, material content, physical characteristics, method of delivery/lead time/logistics, source of supply, volatility of demand, product of life cycle, processing costs, application, program management costs, and opportunity costs). In terms of purchasing large assets, such as vehicles or large IT items, the main interests are budgeting and planning, asset life-cycle management, prioritizing capital purchase proposals, evaluating capital project proposals, vendor selections, and lease versus buy decisions. For a commercial private company to make the electric vehicle investment, there must be a lower total cost of ownership for electric vehicles than that of a traditional combustion engine vehicle.

Private Companies, CPC Branding

Private companies have long used branding as one of the most powerful tools to establish recognition within an industry and from consumers. Recently, the terms “sustainable branding” and “corporate social responsibility” (CSR) have gained popularity due to their importance to consumer loyalty and demonstrated positive impact on profits. A true sustainable brand is one that has successfully integrated environmental, economic, and social factors into its business operations.

Even with the private market shifting towards a focus on sustainability, there is still a great deal of growth to be had for companies willing to invest in CommEVs and CommEV infrastructure. For a CPC to seriously consider investing in EVs as a portion or all of their fleet there must be a compelling set of criteria to consider entering the CommEV industry. Many commercial companies now have CSR requirements, which may require an entity to meet specific “green” goals (among others). One way of achieving these CSR goals for vehicle-dependent business operations would be to adopt CommEV fleets. This would positively benefit consumers and employees by improving local air quality and reducing noise pollution. The business model overall would also benefit, adding name recognition and establishing the company as an innovative leader of industry. Finally, consumers want to know the companies they buy products from do so in a way that is environmentally and socially responsible. Conflating sustainable practices with name recognition is likely to increase sales for commercial private companies.

Private Companies, Risk Aversion

Commercial private companies are generally driven by the financial well-being of their business. This means that the potential risk of a purchase or investment is a significant factor in driving the investment actions of a company. High levels of risk averse behavior are expected when commercial entities are considering purchasing CommEV fleets due to the high uncertainty of the current CommEV and charging infrastructure markets. The payoff of adopting commercial vehicle fleets is uncertain compared to maintaining the status quo of ICE fleets. Risk aversion is exacerbated when looking at range anxiety of CommEV vehicles specifically. It can be concluded that a given company will need to be highly motivated by outside factors, such as cost savings, public demand, or mandated emissions reduction targets to overcome risk adversity in the decision-making process. For these reasons, risk aversion was identified as a significant barrier to commercial private companies investing in CommEVs on an impactful scale, especially for companies that are operating on smaller scales or whose business platform is defined by vehicle reliability. One notable solution to risk averse investors may be presenting opportunities for these companies to reduce risk through "renting" services, which could be provided by manufacturing companies like Cummins', who would assume the risk of buying the fleets.

General Social Welfare Factors

The following social factors were not numerically scored and yet are potentially important to consider relative to a given city's propensity to embrace CommEVs.

Battery longevity is a concern for many potential electric vehicle buyers. Although the batteries in electric vehicles, like any battery, will lose some of their capacity over extended use and cold weather applications, battery-storage technology, charging practices, and electric battery warranties are ways to alleviate battery longevity concerns.

EVs do not need as many components to operate and therefore, maintenance costs have been found to be lower than traditional internal-combustion engine vehicles (ICEs). For instance, engines in traditional ICEs contain dozens of moving parts while electric motors only have one. Fewer moving parts also means less fluids (ex. oil and transmission fluids). Because of this fact, reduced operation and maintenance budgets for maintenance may serve as an incentive for adoption.

In addition, the regenerative brake systems on EVs allow them to typically last longer than ICEs. Tires on EVs due to tend to wear quicker due to the regenerative braking systems and may need to be alternated and replaced more often than traditional ICEs. Lastly, the final potential drawback to EVs is collision repair costs. EVs house many fragile battery packs in areas that can be harmed in the event of a collision. If a collision occurs, these batteries may need to be replaced - and that could mean a big repair bill. However, similar to hybrid vehicles, insurance costs are higher with an electric vehicle due to a lack of data to inform premium calculations.

Overall reliability of electric vehicles is still under debate in the PassEV market. Consumer Reports ranked PassEV reliability "below average" or "poor" in their 2018 reliability survey.

However, Transport Evolved cites electric vehicles as being more reliable due to component simplicity. EV motors have one main moving part and complementary parts (the motor shaft, the rotor, and the stator), requiring less scheduled maintenance. The idea is that, with less part, and there are fewer mechanical systems to maintain or that could break down so EVs are subsequently more reliable.

Another obstacle to EV adoption in the commercial/municipal space is charging time. ICEs can be pulled into a gas station and filled up in less than five minutes. EVs can take anywhere from 20 minutes to multiple hours to reach full charge. Battery swapping may partially mitigate this concern. Faster EV charging technology is being explored and proliferating through the marketplace, but it remains a significant concern for potential CommEV fleet operators.

Range anxiety was at first thought to be a major barrier to CommEV adoption. However, this was mostly from a PassEV perspective. The group made a preliminary assumption that most vehicle owners would not be swayed to buy a vehicle that not only had a set range but would have a comparatively small window to recharge until it was able to be driven again. However, from a commercial and municipal perspective, these concerns are not as great. Considering that many commercial and municipal vehicles are on a fixed route with relatively low deviation, range anxiety was not considered as great of a contributing factor. Additionally, even if these vehicles were to deviate from a standard route, it may be the case that the deviation is not a significant enough mileage change to influence why or why not a city or commercial enterprise may elect to adopt electric vehicles.

Resale value is a part of the cost-decision framework of adopting CommEVs for both municipalities and commercial private companies as it factors in to total cost of ownership. Traditionally, municipalities have used fleet vehicles until they are no longer functional and have limited resale value, so it was not an important TCO factor. However, as local governments become more professionalized and new theories of management take hold, amortization schedules are going to be utilized more often to resell equipment at the optimal rate. In this case, resale value will become an important part of the benefit-cost analysis framework. Commercial vehicles may be capable of achieving greater resale value due to the historic use of amortization schedules. However, there is little data on the residual value of electric fleet vehicles due to fledging state of CommEV markets; most operators have not reached the optimal point of resale.

Social Welfare Conclusion

The general factors described were identified to be of some importance in the decision-making process for both municipalities and CPCs when considering CommEV systems adoption. However, general factors were not determined to be significant enough to overshadow the primary decision-making criteria of regulatory compliance, city branding, CPC branding, and TCO. Additionally, because of the qualitative properties of these factors, they were not quantified in the city rankings list. These factors should be acknowledged and investigated further within specific case studies of CommEV-ready cities.

Appendix E. GIS Analysis

Geographic Information System Analysis - Methodology

In order to compare the combined scores of the various cities in a graphical or geospatial manner, a geographic information system (GIS) analysis was conducted. GIS was used to graphically display the summed results and the individual team results against layers of interest. There was no further analysis done in the ArcGIS software. The spatial analysis was conducted using the ArcGIS software package, primarily in the ArcMap 10.6 program. The combined scores from the three research areas was applied over three different background layers (RTO areas, mean annual temperature and a map of the United States) to analyze for any potential geographic correlations relative to these factors. All layers were collected from reputable open source data portals like the United State Government or ESRI, developer of the ArcGIS software package. Additional attributes representing summed scores and team scores were added to the layers within ArcMap. The layers, mean temp 1901-2000 and ISOs, were chosen because these layers demonstrate two factors that were used when initially selecting cities for evaluation as well as part of the city evaluation. Specifically, the Mean Temperature 1901-2000 layer was used because battery efficiency can be impacted by the climate, and many professionals and laymen are not familiar with the geographic boundaries of the various independent system operators, so the ISO layer was utilized. While no additional geographic or spatial analysis was completed in this assessment, they could be used by future investigations to support the conclusion of the highest ranked cities and lowest ranked cities.