Metropolitan Council Electric Vehicles Planning Study: Analyses & Recommendations

MAY 2022

PRODUCED FOR THE METROPOLITAN COUNCIL
BY THE GREAT PLAINS INSTITUTE

GREAT PLAINS INSTITUTE

Acknowledgments

ABOUT THE GREAT PLAINS INSTITUTE

A nonpartisan, nonprofit organization, the Great Plains Institute works across the US to transform the energy system to benefit the economy and environment. Learn more at www.betterenergy.org.

ABOUT BELLWETHER CONSULTING

The mission of Bellwether Consulting is to build more equitable organizations and communities. We offer leadership-, organization-, and partnership development services to clients who are working toward a more just world. Bellwether Consulting is a woman-owned small business enterprise, certified by Minnesota Unified Certification Program, Central Certification Program, and the Minnesota Department of Administration.

WRITERS

- Elizabeth Abramson
- Allison Bell, Bellwether Consulting
- Katelyn Bocklund
- Rachel Brummel, Bellwether Consulting
- M. Moaz Uddin

EDITORS

- Jennifer Christensen
- Dane McFarlane

DESIGN

- Elizabeth Abramson
- Will Dunder
- Jessi Eidbo

Table of Contents

Executive Summary

Introduction

The Metropolitan Council hired the Great Plains Institute (GPI) and Bellwether Consulting in January 2021 to conduct an Electric Vehicles Planning Study with the following goals in mind:

- Summarize the current landscape related to electric vehicles (EVs)
- Evaluate and prioritize strategies for the Metropolitan Council as the region's Metropolitan Planning Organization to undertake that can accelerate the adoption of EVs as a means toward reducing greenhouse gas emissions
- Engage and inform staff and policymakers at the Metropolitan Council and partner agencies

This *Analyses & Recommendations* report addresses the second goal of the Electric Vehicles Planning Study, following the *Electric Vehicle Landscape Summary* published in December 2021.

Electric Vehicle Needs in the Twin Cities Metro Area

This report includes analyses of the current internal combustion engine vehicle fleets and future EV needs in the seven-county region. This includes a fleet analysis, residential and commercial use case analysis, and EV and charging scenario analysis for the seven-county region which consists of Anoka County, Hennepin County, Ramsey County, Washington County, Carver County, Scott County, and Dakota County.

The analyses help form a picture of the current vehicle fleet composition in the seven-county region. The analyses also forecast scenarios for EV growth and identify barriers and solutions for the transition to EVs.

Electric Vehicle Forecasting and Charger Assessment

EVs are beginning to take hold within the metro region. However, the region requires a major expansion of EV adoption and supportive infrastructure to eliminate emissions from surface transportation by midcentury. The project team completed an analysis to forecast levels of EV growth needed in the region to meet Metropolitan Council's goal of powering 20 percent of light-duty vehicles with electricity by 2030.This goal was set by Minnesota Department of Transportation, Minnesota Pollution Control Agency, and the Great Plains Institute in the 2019 study *Accelerating Electric Vehicle Adoption: A Vision for Minnesota.*

The analysis found that building out new charging stations and increasing charging capacity at existing stations will be critical to increasing EV adoption. The analysis also found that the region requires significant policy and market intervention to scale EV adoption to the necessary levels. Finally, the analysis found existing disparities in access to EVs and EV infrastructure that correlate with several demographic factors. These disparities underscore the importance of tailoring support to local contexts to ensure equitable access to the benefits of electrification across the region.

Travel Behavior Inventory and Residential Use Cases

The project team used the Travel Behavior Inventory to gather the residential use case analysis data.[1] This included data on the vehicle needs and travel patterns for the following use cases as a representative sample for the seven-county region:

- Urban apartment
- Urban house
- Suburban apartment
- Suburban house
- Rural house

The project team divided the five residential use cases by income and household size to understand each segment's vehicle needs and travel patterns. The project team determined that while the EV options in the seven-county region are limited, the current EVs on the market meet the minimum vehicle requirements and budgets for most residents.

The residential use case analysis includes a section that identifies barriers and solutions to the electrification of residential fleets in the region. The lack of access to EV charging is the main barrier to electrification. The residential use case analysis proposes solutions to help increase access to EV charging.

Fleet Analysis and Commercial Use Cases

The project team conducted surveys and interviews with fleet managers as part of a fleet analysis exercise. The analysis helped the team identify barriers and solutions to fleet electrification. The project team was also able to collect vital data on vehicle requirements and travel patterns for these fleets through the analysis.

The commercial use case analysis focused on seven commercial fleets to understand the vehicle needs and travel patterns for commercial fleets in the region:

- Urban delivery company
- Local government fleet
- Private company fleet
- Distribution delivery
- Transportation network company fleet
- Rental car fleet
- Repair and service fleet

The project team determined that commercial EVs are available on the market that can complete the typical duty cycles for these fleets in the region. While most commercial EVs are available at a reasonable price, there are exceptions, like local government fleets. Comparable electric versions of fleet vehicles used by local governments, particularly medium- and heavy-duty vehicles, are not as readily available and are often prohibitively expensive.

The commercial fleet analysis describes the lack of access to EV charging, the uncertainty about the total costs of installing charging infrastructure, and the uncertainty about energy costs

for running EVs as the main barriers to commercial fleet electrification. The analysis proposes solutions to help alleviate the concerns of fleet managers for each commercial use case.

Recommendations

The project team developed recommendations through input from state agencies and guidance from the technical advisory committee. The Metropolitan Council can play a leading role, partner with other organizations, or fund the work to help these recommendations materialize.

The team ranked the strategies in order of priority based on their effectiveness and urgency. While these strategies primarily reflect the role of the Metropolitan Council as the region's Metropolitan Planning Organization, a few under EV availability reflect the council's role as the region's largest transit operator. The following charts show the strategies nested under the relevant buckets.

Table ES-1. Strategies to support additional electric vehicle charging infrastructure

Lead	Partner	Fund
Generate, collect, and provide EV analysis, best practices, and data in the Transportation Policy Plan and Regional Development Guide	Connect cities/counties to available state, federal, and utility funding	Provide grants to install DC fast chargers in strategic areas (through Regional Solicitation and other funding sources)
Identify opportunities to support charging infrastructure in affordable housing communities	Work with a third-party convener to develop model ordinance for EV ready parking standards and new commercial or MUD parking lots	Help cities develop programs/incentives that promote charging in and around multi-unit dwellings
Identify how Regional Solicitation can further support EV readiness projects		
Increase visibility of Livable Communities Act grants to fund EV charger installation and encourage applicants to install make-ready infrastructure		

Table ES-2. Strategies to increase electric vehicle availability

Lead	Partner
Conduct comprehensive fleet and infrastructure electrification study for MTS Contracted Services	Connect cities/counties to available state, federal, and utility funding
Align Metro Transit electric bus routes with the Zero Emission Bus Transition Plan	
Identify how to further provide financial support for EV car sharing programs	
Assess internal fleet for electrification opportunities	
Invest in projects identified in Metro Transit Zero Emission Bus Transition Plan	
Collect and share data on EV access by race, income, gender, age, disability status, and geography	

Table ES-3. Strategies on marketing, education, and outreach

Lead	Partner	Fund
Update Metropolitan Council's Electric Vehicle webpage with basic EV information and links to resources	Continue coordinating actions with other actors in electrification space (state agencies, nonprofits, local agencies, etc.)	Fund local government ride and drives
	Participate in and promote MnDOT's EV-Ready certification program for local governments and help create a full program	
	Convene local government partners on EV and equity opportunities	
	Develop and disseminate representative marketing materials for targeted communities	
	Work with affordable housing providers and other orgs to educate residents	

Table ES-4. Strategies where further study is required

E-bikes	Equity	EV implementation	EV safety	EV charging
Evaluate potential for e-bikes and e-scooters to reduce VMT	Evaluate impacts and opportunities of EVs now and in the future	Evaluate metrics for EV implementation and GHG reduction in Regional Solicitation	Assess gaps in local government response to EV crashes and fires	Evaluate role for counties in deploying charging infrastructure beyond their facilities
Evaluate potential for e-cargo bikes to reduce delivery vehicle trips				

Looking Ahead

GPI and Bellwether Consulting conducted the Electric Vehicles Planning Study for the Metropolitan Council to commence the EV planning process for the seven-county region. The *Electric Vehicle Planning Study: Electric Vehicle Landscape Summary* addresses the first goal of the planning study by summarizing the current landscape related to EVs. The *Electric Vehicle Planning Study: Analyses & Recommendations* evaluates and prioritizes strategies for the Metropolitan Council to accelerate EV adoption to reduce greenhouse gas emissions. The aim is to engage and inform staff and policy makers at the Metropolitan Council and partner agencies.

The Metropolitan Council and other relevant stakeholders can use the study recommendations to develop a strategic plan for EVs. The plan can describe potential Metropolitan Council and partner agency actions to advance EVs and EV charging. The plan can also help prepare the region for EV funding from the federal government as part of the Infrastructure Investment and Jobs Act and related funds.

As the Metropolitan Council implements the recommendations for increased EV uptake, it should ensure an equitable spread of EV adoption benefits. Local governments and partners should engage diverse stakeholders in policy design and implementation. The council should implement the recommendations to lower barriers to EV use for underserved communities and address EV stereotypes. Maximizing the benefits of EVs in the region requires implementers to understand the benefits and burdens of EV expansion and apply lessons learned from other EV acceleration efforts.

Introduction

The Metropolitan Council hired GPI and Bellwether Consulting in January 2021 to conduct an Electric Vehicles Planning Study with the following goals in mind:

- Summarize the current landscape related to electric vehicles (EVs)
- Evaluate and prioritize strategies for the Metropolitan Council as the regions Metropolitan Planning Organization to undertake that can accelerate the adoption of EVs as a means toward reducing greenhouse gas emissions
- Engage and inform staff and policymakers at the Metropolitan Council and partner agencies

This *Analyses & Recommendations* report addresses the second goal of the Electric Vehicles Planning Study, following the *Electric Vehicle Landscape Summary* published in December 2021. This report first provides an assessment of passenger and fleet electric vehicle needs in the Metropolitan Council region based on analyses undertaken throughout the study. Then, the report provides recommendations that the Metropolitan Council can implement to increase electric vehicle adoption in the region to reduce greenhouse gas emissions. Recommendations are based on the results from the analyses and thorough stakeholder vetting.

The Metropolitan Council generally serves the seven-county region of the Twin Cities. As the federally designated Metropolitan Planning Organization (MPO) for the region, it also serves the contiguous urban parts of Wright and Sherburne counties. In preparing the recommendations for this report, the project team considered both the council's statutory roles and regional leadership roles for which the council is well-positioned and equipped to serve:

- **Metropolitan planning organization**: As the federally designated MPO for the Twin Cities metro area, the council oversees regional transportation planning and allocates federal funding for transportation projects channeled through the MPO process.[2]
- **Transit provider**: The council operates Metro Transit, Metro Mobility, and Transit Link and invests in infrastructure that assists these networks.[3]
- **Technical assistance**: Through its Community Development Division, the council oversees the decennial regional and local comprehensive planning process and provides technical assistance (e.g., data analysis and provision, model climate action and resilience best practices, connection to information and financial resources) to local communities.[4]
- **Convener of regional conversations**: The council brings communities across the Twin Cities metro area together to develop policies and tackle key issues affecting the region.[5]

Electric Vehicle Needs in the Twin Cities Metro Area

ASSESSING THE CURRENT ELECTRIC VEHICLE LANDSCAPE

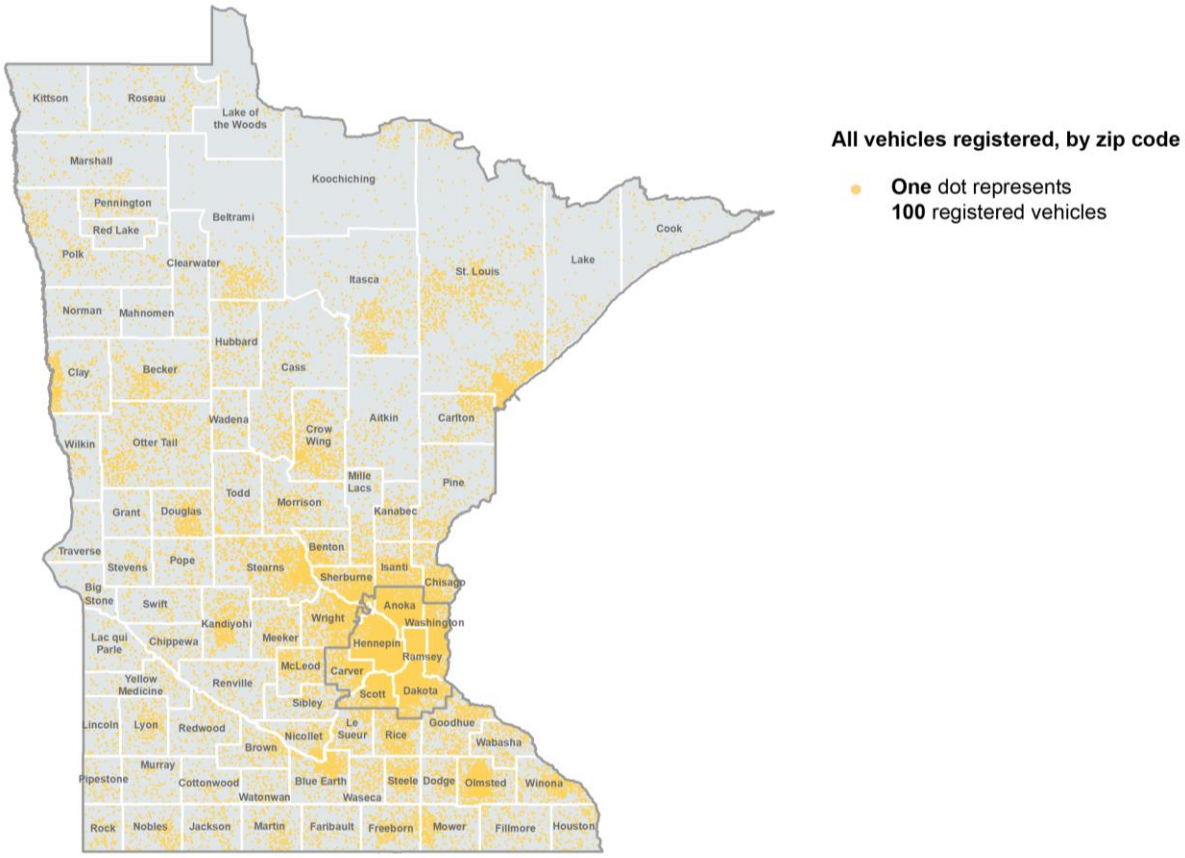
EV adoption and infrastructure are beginning to flourish within the Twin Cities metro region. However, the local market for EVs remains in an early development phase, and EVs make up less than 1 percent of the region's current light-duty vehicle (LDV) registrations. To reach statewide decarbonization targets laid out in the 2019 *Pathways to Decarbonizing Transportation in Minnesota* report, EV adoption must become ubiquitous throughout the state by 2050, with levels of adoption ramping up exponentially over the coming years.

Scaling EV adoption to necessary levels will require proactive planning and focused implementation. Significant effort must be concentrated on developing EV adoption within the Twin Cities metro since over 50 percent of the state's LDV registrations are in that region. This means a comprehensive effort to bring EVs within reach of all metro residents and to build a network of convenient and reliable charging options for all metro EV drivers.

Understanding the Current Distribution of Electric Vehicles

As shown in figure 1, while there are pockets of dense vehicle registration throughout the state, Minnesota's LDV registration is largely centered in the Twin Cities metro region. The region is home to roughly 2.7 million of the states' 5.2 million total LDVs. Light-duty vehicles refer to passenger cars and light-duty trucks with a gross vehicle weight rating of under 10,000 pounds.

Figure 1. Metro region in context: Statewide light-duty vehicle registration

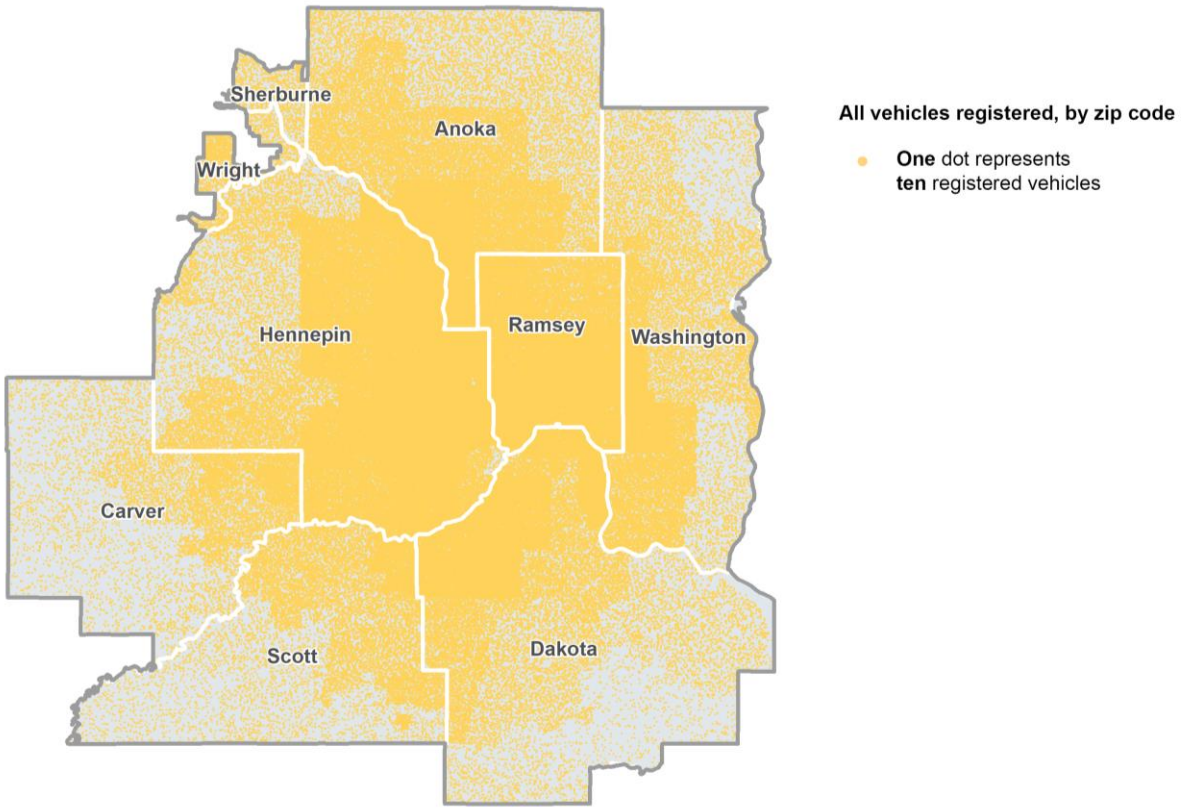


Note: Vehicles are distributed throughout the zip code they are registered in and are not shown at their exact address.

Source: Figure authored by Great Plains Institute, 2021. Based on data from Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

Within the metro region, LDV registration is most dense toward the region's urban population center and more dispersed toward the region's largely rural edges (see figure 2).

Figure 2. Electric vehicles in context: Metro area light-duty vehicle registration

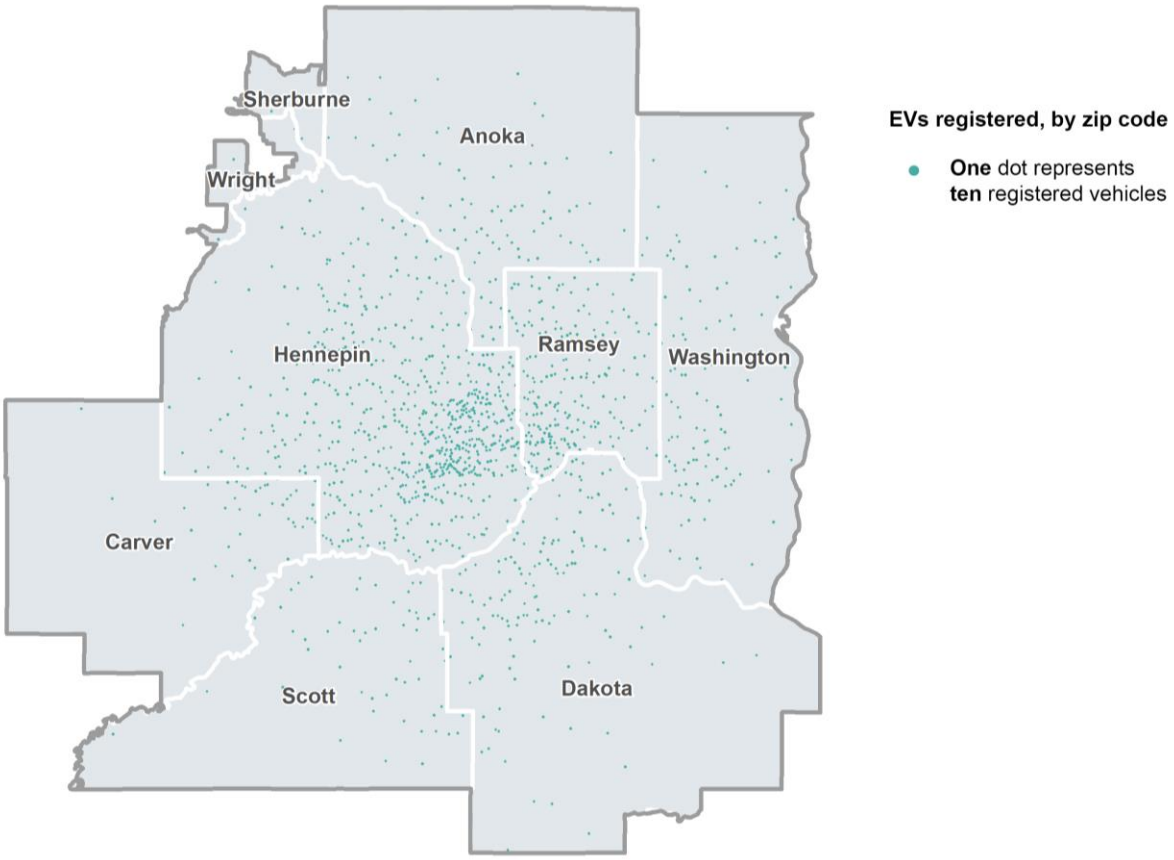


Note: Vehicles are distributed throughout the zip code they are registered in and are not shown at their exact address.

Source: Figure authored by Great Plains Institute, 2021. Based on data from Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

As shown in figure 3, EV registration generally follows a similar spatial pattern, with the region's roughly 13,300 EVs largely clustered around the region's urban core.

Figure 3. Electric vehicle registration in the metro region

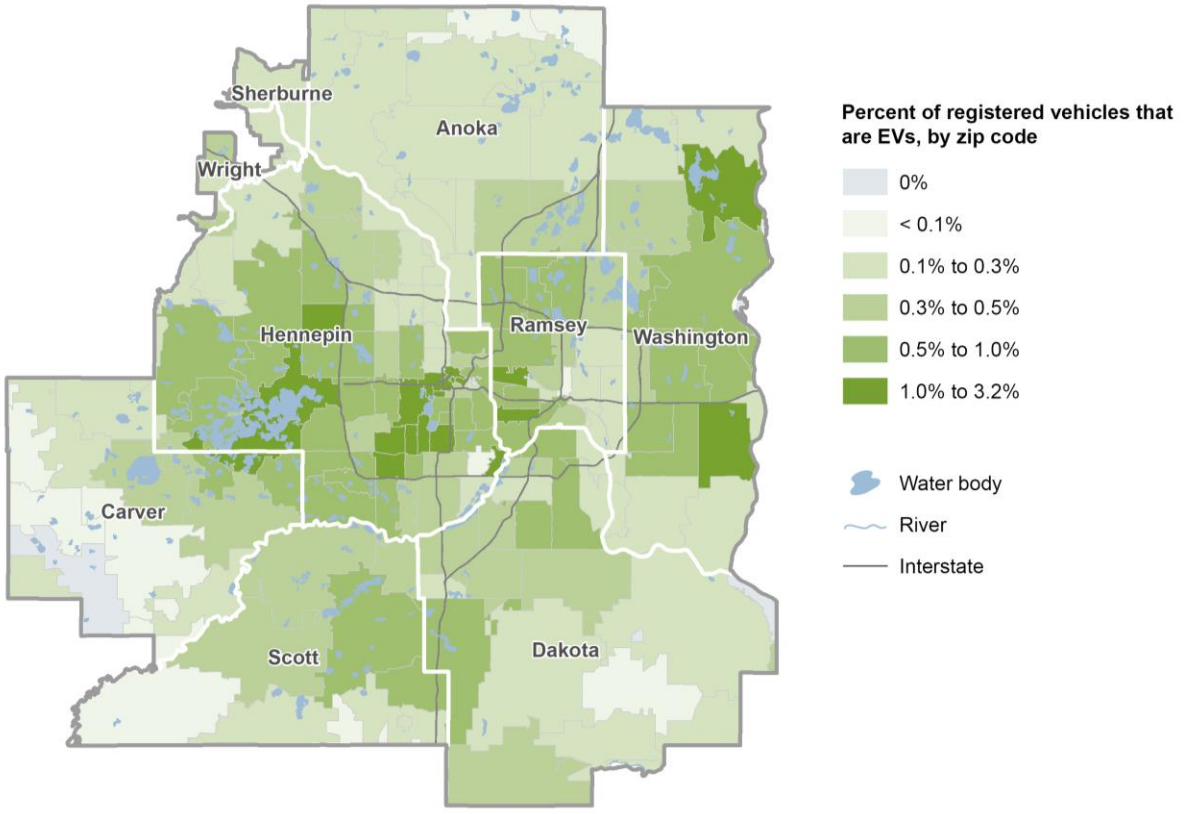


Note: Vehicles are distributed throughout the zip code they are registered in and are not shown at their exact address.

Source: Figure authored by Great Plains Institute, 2021. Based on data from Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

There are high rates of EV adoption in areas including downtown Minneapolis, along the Minneapolis chain of lakes and surrounding areas, in southwestern Saint Paul, and in eastern Washington county (see figure 4). However, even in those high adoption areas, EVs make up a maximum of roughly 3 percent of total light-duty vehicle registrations.

Figure 4. Percent electric vehicle by zip code

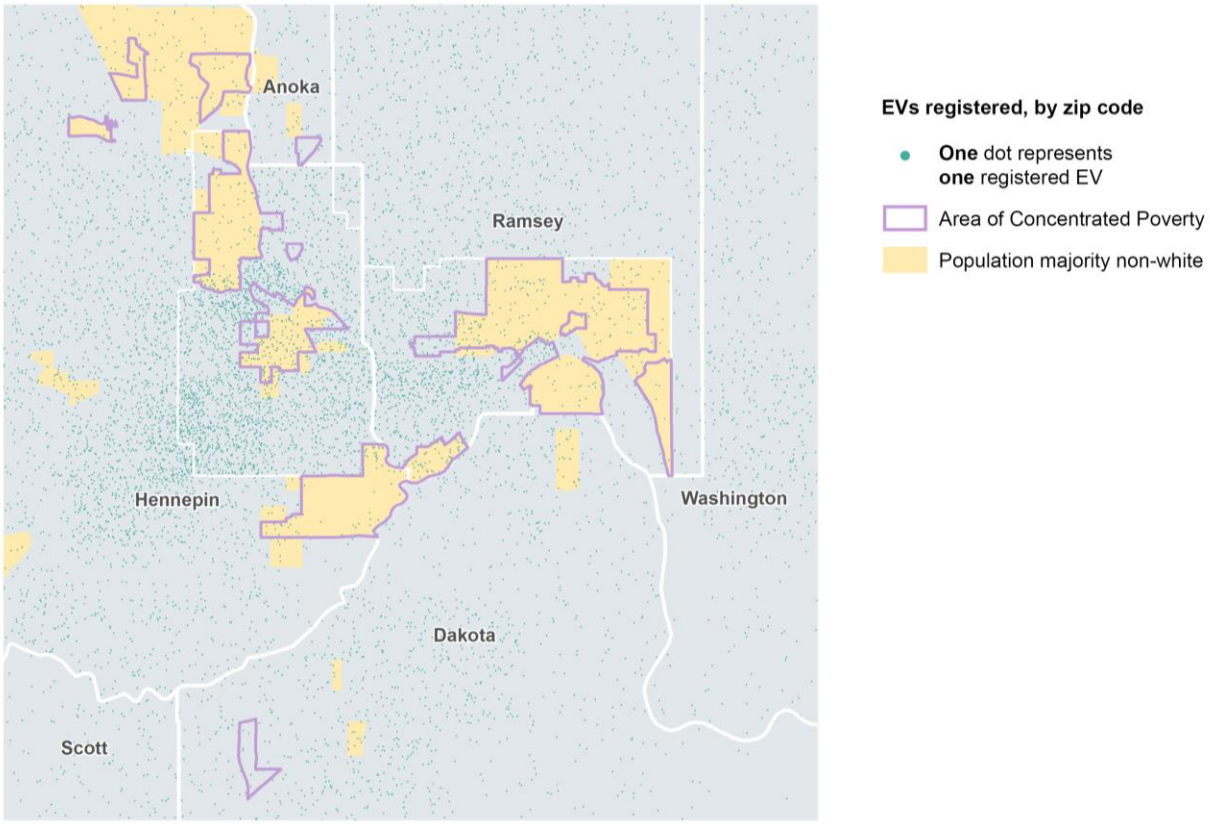


Source: Figure authored by Great Plains Institute, 2021. Based on data from Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

Figure 5 shows that even within the urban core, where a large share of the region's EVs are concentrated, EV registrations are unevenly distributed. Census tracts where 40 percent or more of the residents live with incomes below 185 percent of the federal poverty threshold, also known as Areas of Concentrated Poverty, as well as areas where over 50 percent of the population is not white, tend to have a low concentration of EV registrations.

It is also important to emphasize that the dots representing EV registrations in figure 5 are placed randomly within each zip code. This protects the privacy of any individual EV driver but reduces the precision of the data presented. While address-level EV registration data cannot be publicly shared to protect privacy concerns, data mapped at the address level reveals an even more dramatic divide than is shown in figure 5.[6]

Figure 5. Electric vehicle registration in context: Demographics



Note: Vehicles are distributed throughout the zip code they are registered in and are not shown at their exact address.

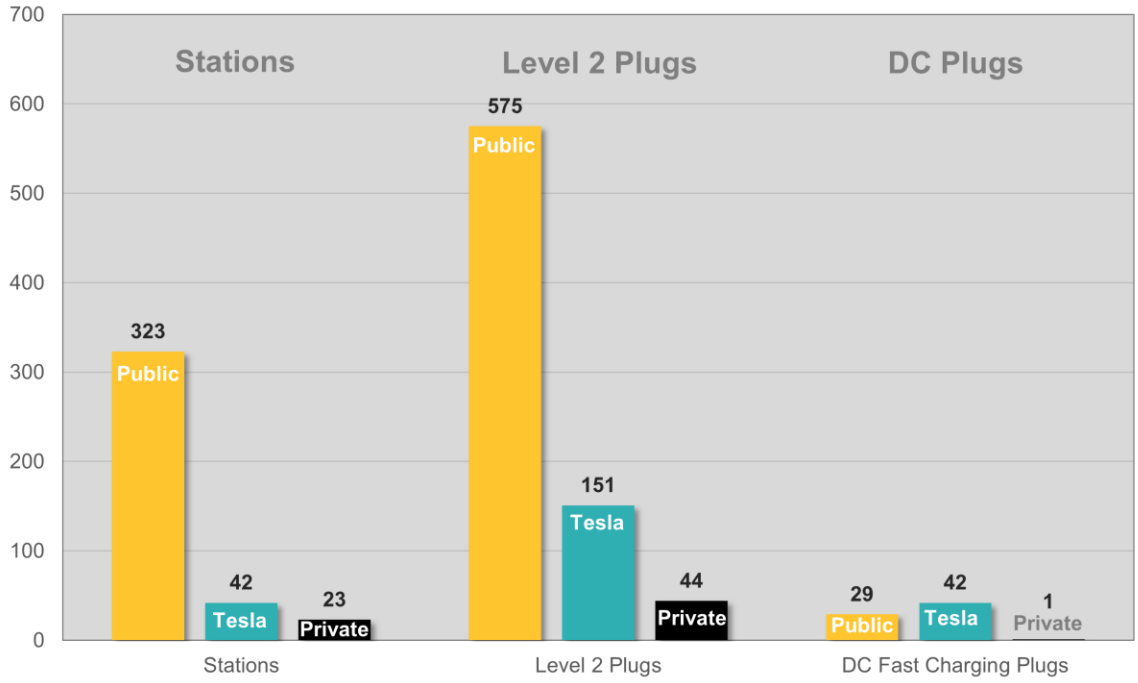
Source: Figure authored by Great Plains Institute, 2021. Based on data from Metropolitan Council, *Equity Considerations for Place-Based Advocacy*; Minnesota Department of Public Safety and Minnesota Pollution Control Agency .

Assessing the Current Electric Vehicle Charging Network

Non-home chargers fall into three access categories: some are restricted to private access, some are open to the public, and others are open to the public for Tesla drivers only. Charging stations also vary in the number of charging plugs available and the power level provided by each plug.

As of November 2021, there were 323 public charging stations within the metro region. The vast majority of charging stations in the region are public stations with Level 2 chargers. The small percentage of DC fast chargers include a small number of Tesla and public plugs (see figure 6).

Figure 6. Electric vehicle chargers by access type and charging level



Source: Figure authored by Great Plains Institute, 2021. Based on data from "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center.

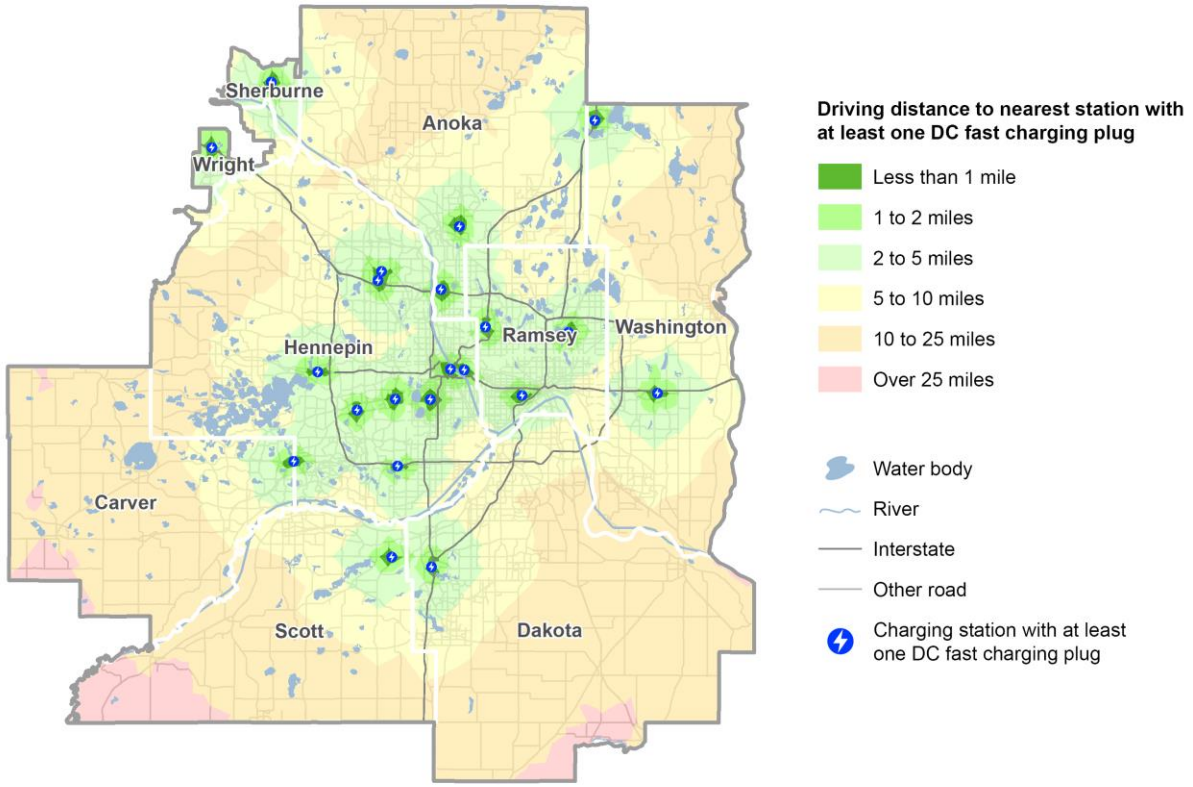
A series of driving distance analyses were conducted to assess the extent of coverage provided by the region's network of public non-Tesla EV chargers. The analysis identified how far a person would have to drive along the region's existing road network to reach the nearest public EV charging station of a particular power level and number of plugs.

Figure 7 shows how far a person would need to drive to reach the nearest charging station that has a minimum of one DC fast charging plug. Areas shaded in the darkest green are within a one-mile drive of a fast charging plug. Areas shaded in lighter green, yellow, and orange require increasingly longer drives to reach a fast charging plug.

The analysis reveals that most (77 percent) of the metro area is more than a 5-mile drive from the nearest DC fast charging plug. Only 1 percent of the metro is within a one-mile drove of a DC fast charging plug and 4.5 percent is within a 2-mile drive.

Stations with a DC fast charging plug are primarily located along interstates, providing fast charging capacity on high-traffic corridors. This analysis shows that several stretches of interstate within the metro lack nearby fast charging infrastructure.

Figure 7. Charging infrastructure network coverage: Stations with at least one DC fast charging plug



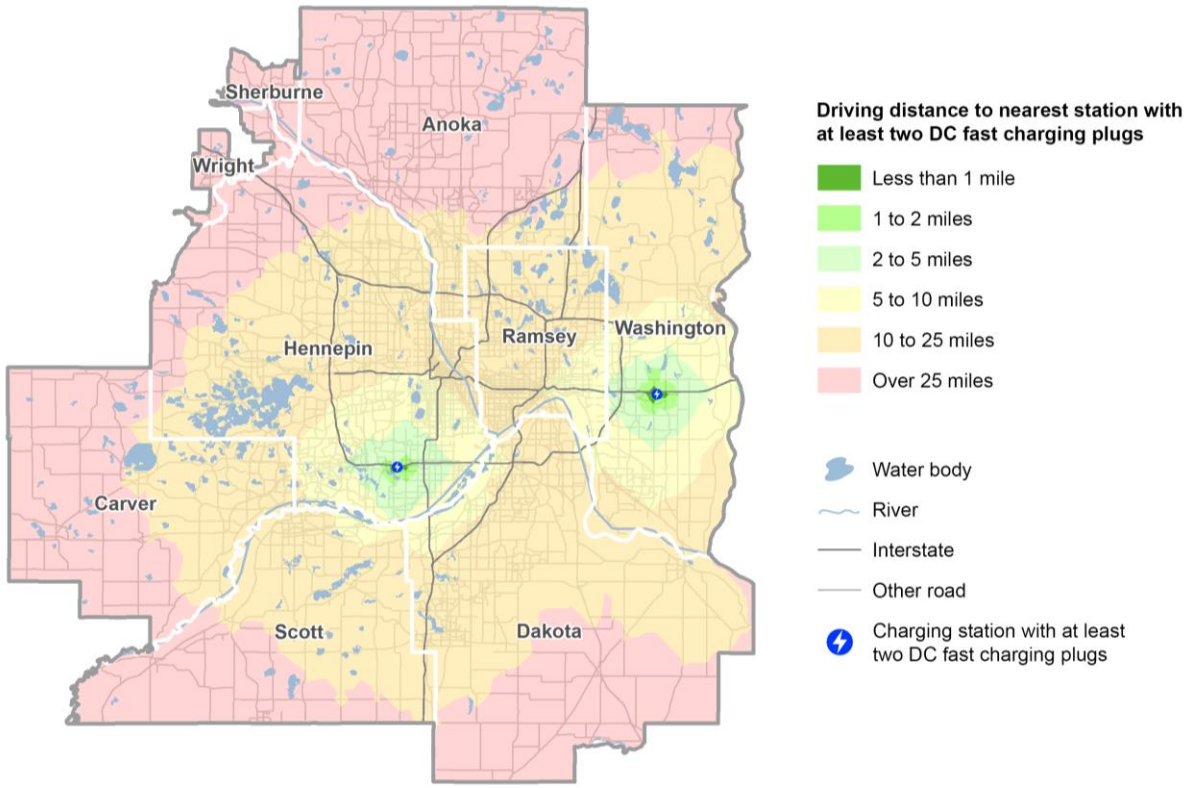
Source: Modeled by the Great Plains Institute based on Federal Highway Administration, *2018 HPMS Public Release of Geospatial Data in Shapefile Format*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center.

As EV adoption increases, not only will geographic gaps in the fast charging network need to be patched, but the number of plugs at each station must also increase. Having multiple plugs at a given station will be key to providing sufficient capacity across the charging network by minimizing wait times and increasing reliability at each station.

As shown in figure 8, only two public, non-Tesla stations in the metro have at least two DC fast charging plugs, with an 8-plug station in Woodbury and a two-plug station in Eden Prairie. With this smaller network footprint, only 0.1 percent of the metro area is within a one-mile drive of a charging station with multiple DC fast charging plugs, 0.5 percent of the metro area is within a two-mile drive, and 3 percent of the metro area is within a five-mile drive.

The limited number of stations with multiple DC fast charging plugs indicates a major area for capacity building. In addition to building out geographic coverage of the fast charging network, fortifying existing stations with additional charging plugs will be key to ensuring that EV drivers have access to convenient and reliable charging options.

Figure 8. Charging infrastructure network coverage: Stations with at least two DC fast charging plugs



Source: Modeled by the Great Plains Institute based on Federal Highway Administration, *2018 HPMS Public Release of Geospatial Data in Shapefile Format*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center.

As shown in figure 9, charging stations with Level 2 charging plugs are much more numerous than stations with fast chargers. There are 308 charging stations with at least one Level 2 charging plug.

While chargers are still generally clustered around the region's center, Level 2 coverage is broader than for the DC fast charging network:

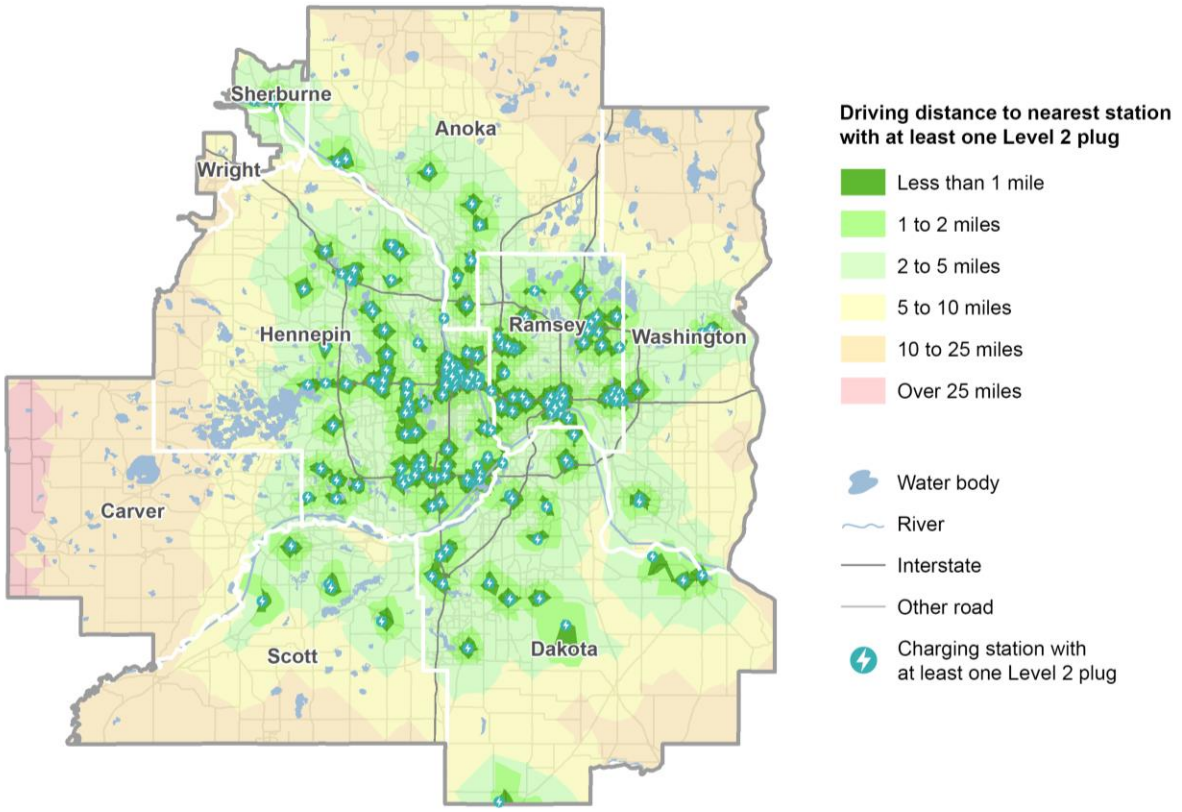
- 6 percent of the metro area is within a one-mile drive of a charging station with at least one Level 2 plug
- 19 percent of the metro area is within a two-mile drive of a Level 2 plug
- 45 percent of the metro area is within a five-mile drive of a Level 2 plug

Given that Level 2 chargers provide a much slower charge than DC fast chargers, Level 2s are typically located at locations where drivers might spend more time.

While the Level 2 network covers a broader area of the metro than the DC fast charging network, over half of the metro is still more than a five-mile drive from the nearest Level 2 charger, with the region's rural edges lacking widespread charging infrastructure. Additionally, a

higher number of plugs at each station could support higher levels of EV adoption and promote future EV growth.

Figure 9. Charging infrastructure network coverage: Stations with at least one Level 2 plug

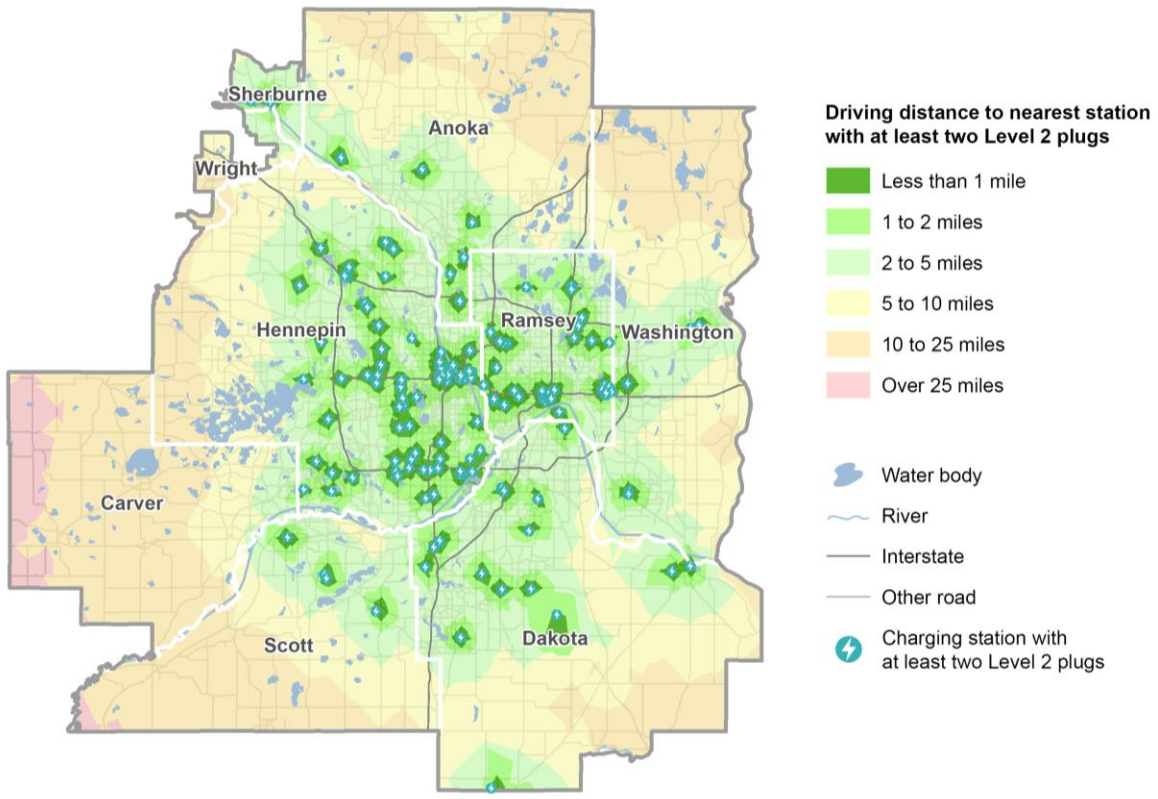


Source: Modeled by the Great Plains Institute based on Federal Highway Administration, *2018 HPMS Public Release of Geospatial Data in Shapefile Format*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center.

There are 237 charging stations that have more than one Level 2 charger. With a network footprint similar to that in figure 10, metro residents are within the following driving distance of at least two Level 2 plugs:

- 5 percent of the metro area is within a one-mile drive
- 17 percent of the metro area is within a two-mile drive
- 44 percent of the metro area within a five-mile drive

Figure 10. Charging infrastructure network coverage: Stations with at least two Level 2 plugs

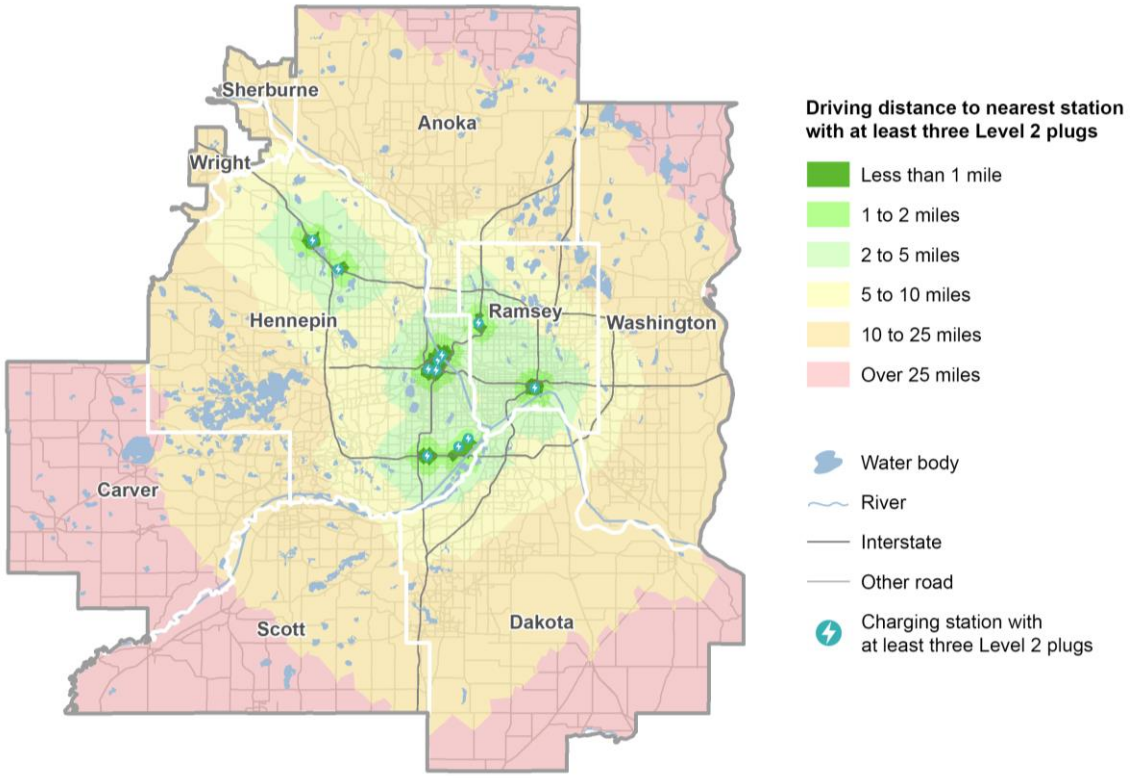


Source: Modeled by the Great Plains Institute based on Federal Highway Administration, *2018 HPMS Public Release of Geospatial Data in Shapefile Format*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center.

As shown in figure 11, only 12 of the region's charging stations have a minimum of three Level 2 plugs. These charging stations are clustered within the region's urban center and along a stretch of I-94 within Hennepin County. This analysis reveals that 0.5 percent of the metro area is within a one-mile drive of a charging station with at least three Level 2 plugs and 2 percent of the metro area is within a two-mile drive. Ninety percent of the metro area is more than a five-mile drive from a charging station with at least three Level 2 charging plugs.

These results again indicate a capacity gap, highlighting that relatively few stations have enough Level 2 charging plugs for three or more vehicles to charge simultaneously.

Figure 11. Charging infrastructure network coverage: Stations with at least three Level 2 plugs

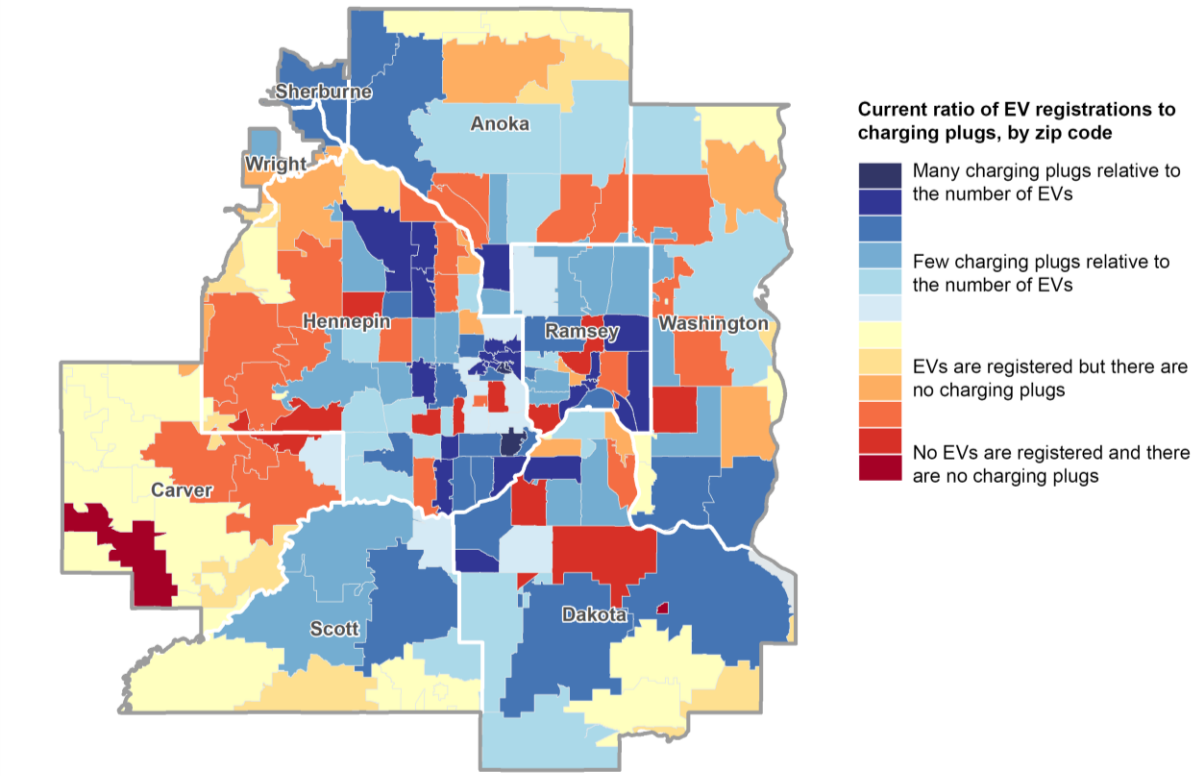


Source: Modeled by the Great Plains Institute based on Federal Highway Administration, *2018 HPMS Public Release of Geospatial Data in Shapefile Format*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center.

Examining the ratio of EVs to charging plugs in each zip code provides additional insight into capacity gaps in the existing charging network. While many people rely on public chargers at their workplace or other areas outside of their home zip code, figure 12 provides an initial sense of where local charging capacity may be strained currently or in the near future. Areas shaded in blue generally have a low number of EVs relative to the number of chargers. In other words, chargers in blue areas have a more manageable number of EVs to support. In yellow and orange areas, the number of EVs per charging plug is much higher, indicating more strain on each plug.

The metro region has an overall ratio of 22 EVs to one plug. In the darkest blue zip codes, that ratio is lower, with 10 or fewer EVs per plug, while some yellow zip codes have over 100 EVs per plug. Additional charging capacity may be needed in the near term in yellow areas to attain a lower EV to plug ratio that can support EV growth in those areas. Meanwhile, zip codes in orange lack a single EV charging plug.

Figure 12. Charging network capacity for future growth



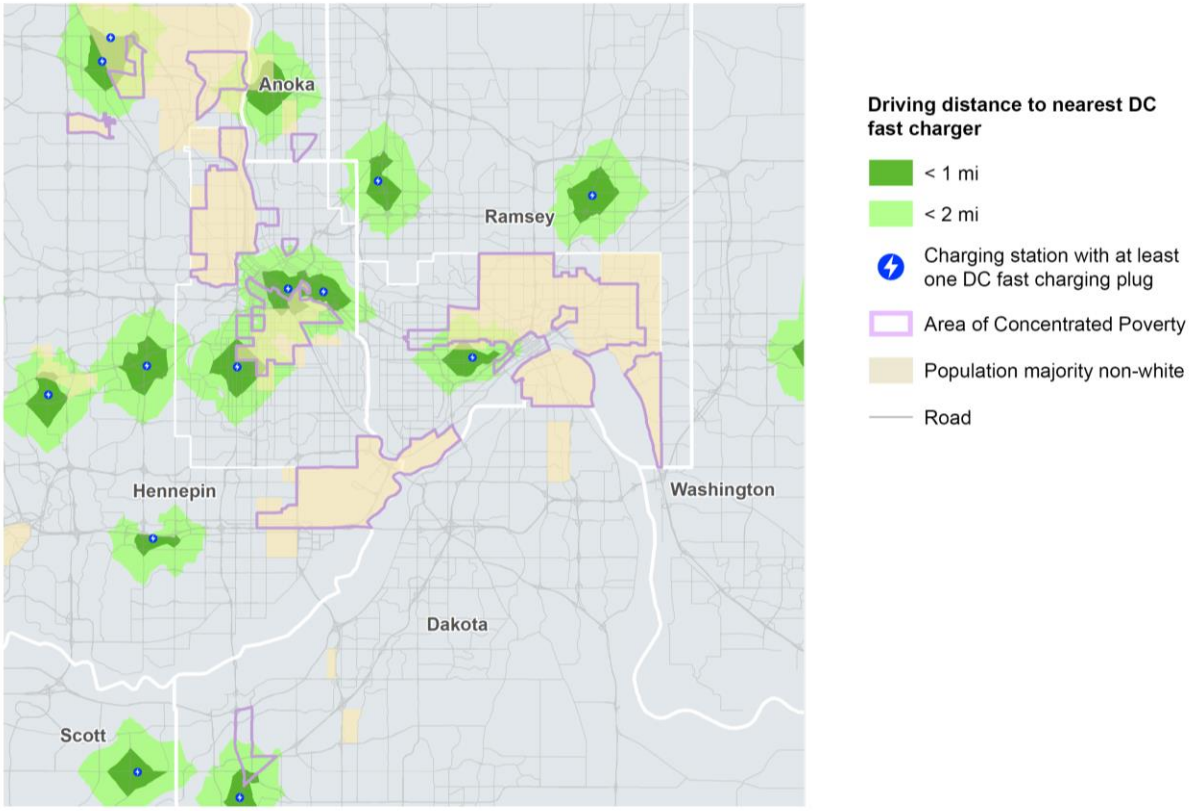
Note: Calculations include both Level 2 and DC fast charging plugs and do not distinguish between the two.

Source: Modeled by the Great Plains Institute based on Federal Highway Administration, *2018 HPMS Public Release of Geospatial Data in Shapefile Format*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center.

Zooming in on the metro region's urban center reveals additional insights into existing gaps in the distribution of EV charging infrastructure. Figure 13 shows that while many of the region's DC fast chargers are located in Minneapolis, Saint Paul, and surrounding communities, there is little to no charging coverage in Areas of Concentrated Poverty and areas that are majority non-white.

Consideration of existing disparities and historic burdens must be integrated into EV infrastructure investment and planning to assist communities that may need additional support to access the benefits of electrification. To make this integration successful, care must be taken to build out the EV network through substantive community partnerships, integration with policies to prevent gentrification and displacement, and initiatives to advance local economic empowerment. Investment and planning efforts should also advance other zero-carbon modes of transportation, such as electrifying public transit (see Mapping Equity Considerations for Electric Vehicle Deployment and Infrastructure Build-Out for more details).[7]

Figure 13. Electric vehicle charging infrastructure in context: Demographics



Source: Modeled by the Great Plains Institute based on Federal Highway Administration, *2018 HPMS Public Release of Geospatial Data in Shapefile Format*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Metropolitan Council, *Equity Considerations for Place-Based Advocacy and Decisions in the Twin Cities Region*.

PLANNING FOR FUTURE GROWTH

Several factors must be considered to understand where and to what extent charging infrastructure will need to expand within the metro region:

- identifying the locations of existing charging capacity gaps
- forecasting the extent of EV growth that will be necessary to meet midcentury emissions reduction goals
- considering the role of public charging in various geographic contexts and at various levels of EV adoption
- incorporating demographic considerations to ensure that infrastructure investments actively advance equity within the region

Scaling Up Electric Vehicle Adoption

The speed and extent of EV growth within the metro will depend largely on supportive policy implementation and market intervention. Three statewide EV sales growth scenarios varying by level of market intervention were modeled as part of the Minnesota Department of

Transportation's statewide 2021 Electric Vehicle Assessment. Those scenarios are described in tables 1 and 2, scaled to the metro region.

The modeled scenarios range from a low growth scenario, in which minimal market intervention results in a 10 percent annual EV sales growth rate, up to a high growth scenario, in which extensive market intervention results in a 40 percent annual EV sales growth rate. A scenario in which levels of EV growth are sufficient to align with the state's goal to eliminate all surface transportation greenhouse gas (GHG) emissions by 2050 (referred to as the 100x50 GHG reduction goal) was also scaled to the metro region.

The three modeled scenarios and 100x50 goal are summarized in tables 1 and 2.

Table 1. Electric vehicle sales growth scenarios: 2030 benchmarks

EV Sales Growth Scenario	Description	Annual Growth in EV Sales	EVs Sold in 2030 Alone	EVs as % of Vehicle Sales in 2030	EVs on the road by 2030	EVs as % of all Metro LDVs in 2030	Estimated Cumulative GHG Emission Reduction by 2030 (million metric tons)
Low Growth	Mild Market Intervention	10%	6,087	3.60%	57,200	2.10%	1,171,897
Medium Growth	Moderate Market Intervention	25%	21,856	12.80%	116,200	4.30%	1,802,996
High Growth	Extensive Market Intervention	40%	67,881	39.70%	253,100	9.30%	3,053,314
MN 100x50 Goal	Highest Levels of Market Intervention and Support. Aligns With *Pathways* 100x50 Goal.	60%	170,996	100%	632,700	23.20%	6,431,305

Note: The MN 100x50 goal aligns with the modeled EV sales required for adoption levels identified in the *Pathways to Decarbonizing Transportation in Minnesota* report, published in 2019.

Source: Modeled EV sales at various degrees of adoption, forecast by the Great Plains Institute. Scenario EV sales forecasts are based on both historic sales trends and the "Annual Energy Outlook 2020," US Energy Information Administration, which forecasts electricity consumption in the transportation sector.

Table 2. Electric vehicle sales growth scenarios: 2050 benchmarks

EV Sales Growth Scenario	EVs Sold in 2050 Alone	EVs as % of Vehicle Sales in 2050	EVs on the Road by 2050	EVs as % of all Metro LDVs in 2050	Year that Scenario Achieves 100% EVs on the Road	Estimated Cumulative GHG Emission Reduction by 2050 (million metric tons)
Low Growth	46,406	23.95%	483,532	16%	After 2050	17,579,228
Medium Growth	193,780	100.00%	3,012,944	100%	2050	102,878,480
High Growth	193,780	100.00%	3,904,977	100%	2045	161,429,457
MN 100x50 Goal	193,780	100%	4,395,244	100%	2042	201,037,685

Note: The MN 100x50 goal aligns with the modeled EV sales required for adoption levels identified in the *Pathways to Decarbonizing Transportation in Minnesota* report, published in 2019.

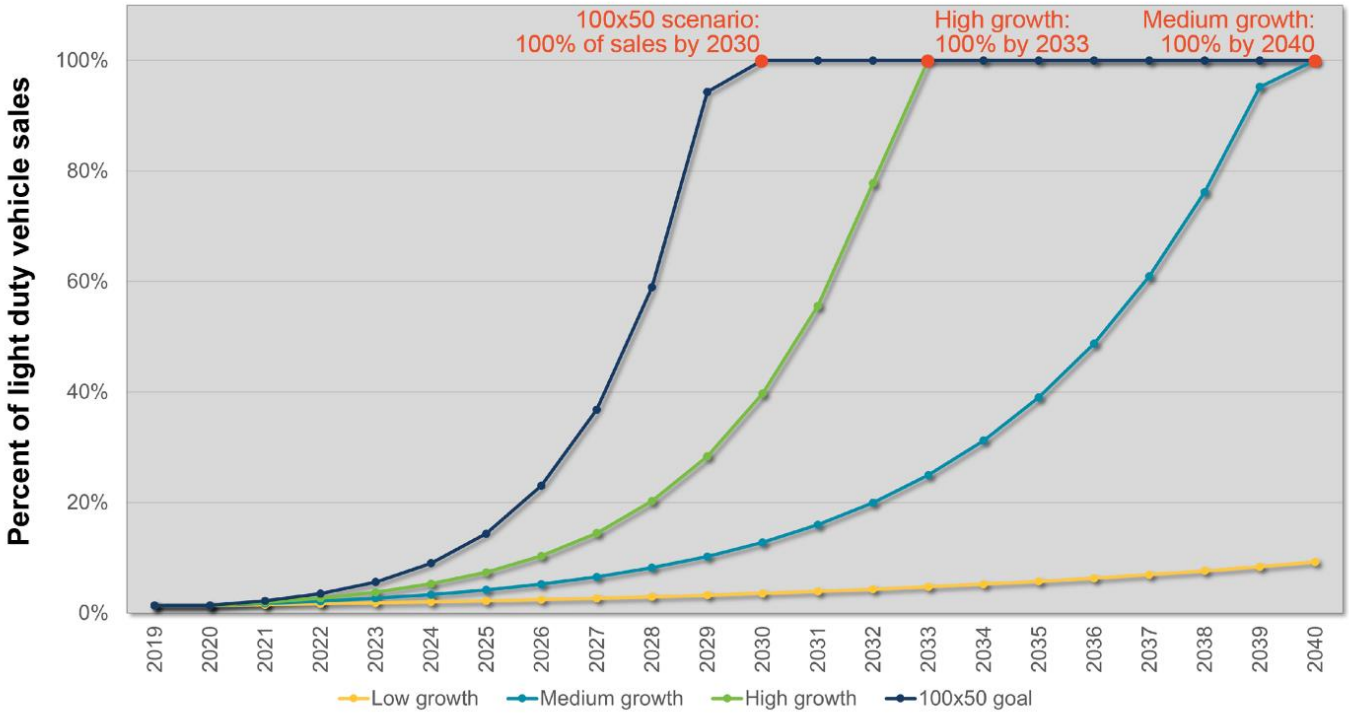
Source: Modeled EV sales at various degrees of adoption, forecast by the Great Plains Institute. Scenario EV sales forecasts are based on both historic sales trends and the "Annual Energy Outlook 2020," US Energy Information Administration, which forecasts electricity consumption in the transportation sector.

Tables 1 and 2 also report estimated cumulative GHG reductions in 2030 and 2050 for each scenario. Estimates for GHG emission reductions use baseline vehicle growth projections consistent with the 2019 *Pathways to Decarbonizing Transportation in Minnesota* report. The EV adoption rates are determined by each of the low, medium, high, and 100x50 growth scenarios. GHG reductions from EVs are based on displacing Minnesota average gasoline carbon intensity.

In these estimates, EVs charge on an average Minnesota electric grid which accounts for the current portfolio fuel mix of all generating electric power facilities within the state. The estimates assume that this grid mix will fully decarbonize by 2050 through measures including increasing deployment of renewable and zero-carbon electric generation sources.

Figure 14 shows EVs as a portion of LDV sales each year by scenario. In the 100x50 scenario, EVs comprise all vehicle sales by 2030. In the high growth scenario, EVs make up all sales by 2033. In the medium growth scenario, EVs make up all sales by 2040. Meanwhile, in the low growth scenario, EVs only grow to around a quarter of sales by midcentury.

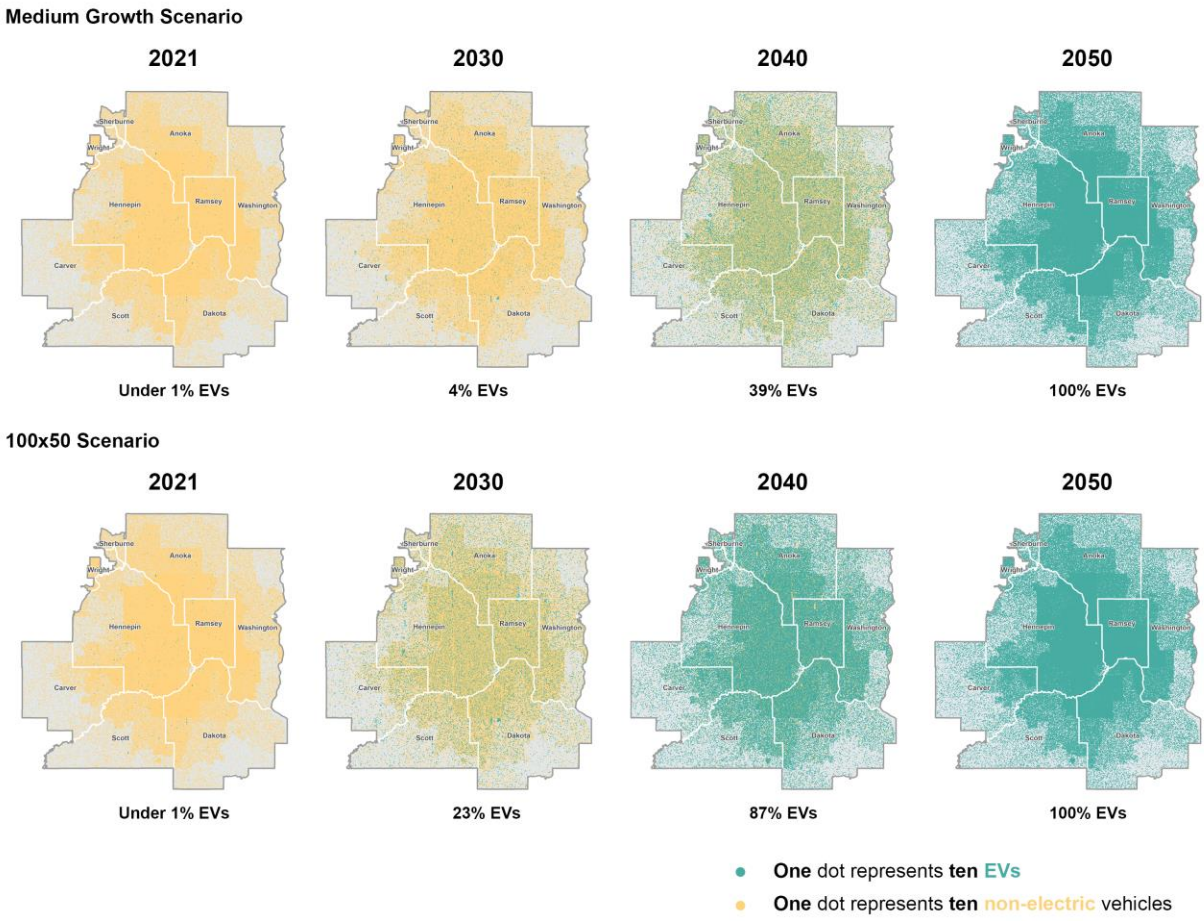
Figure 14. Electric vehicle adoption scenarios: Electric vehicles as a portion of total light-duty vehicle sales



Source: Calculations by the Great Plains Institute, 2021.

Figure 15 shows how EV growth in the medium growth scenario compares to growth in the 100x50 scenario. As seen in the transition from yellow dots (non-EVs) to teal dots (EVs), EVs make up a larger share of total vehicles much sooner in the 100x50 scenario than in the medium growth scenario.

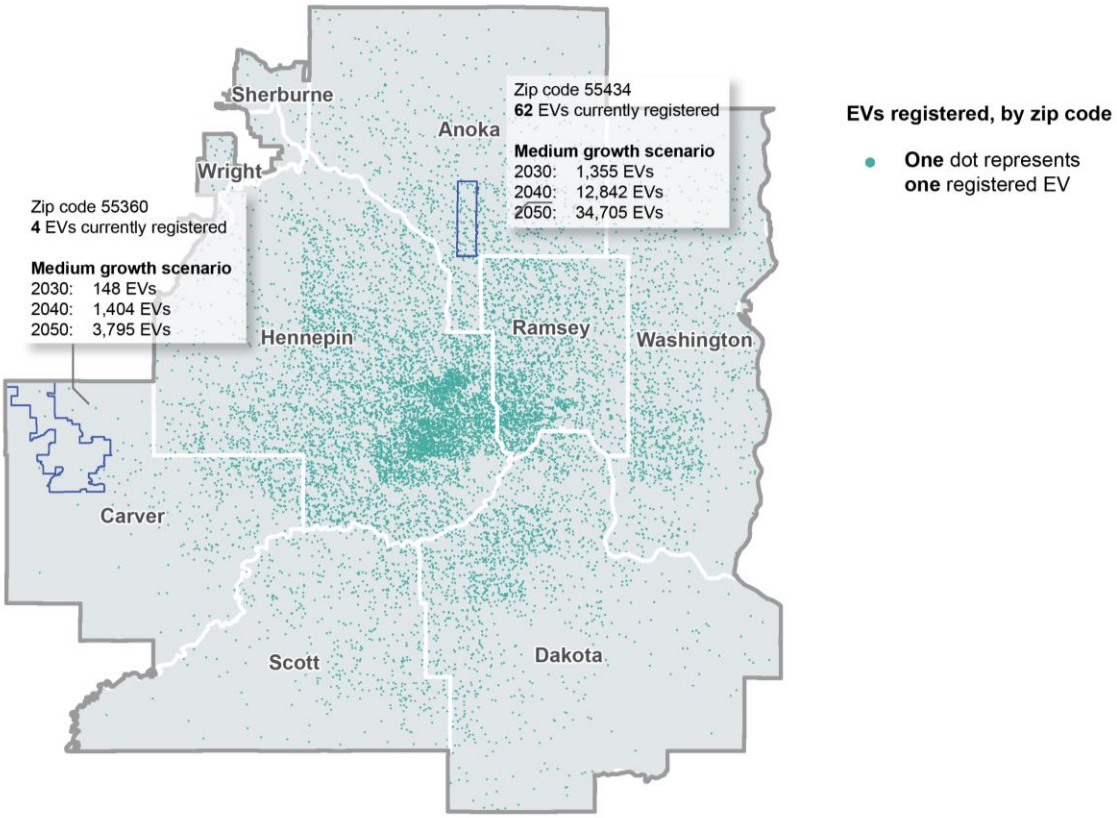
Figure 15. Medium growth vs. 100x50 scenario



Source: Calculations by the Great Plains Institute, 2021.

To meet state emissions reductions goals, areas across the metro will need to rapidly scale up EV adoption within the next 10 years. For example, a zip code in Carver County that currently has four EVs would need to scale up to 148 EVs by 2030, over 1,000 EVs in 2040, and roughly 4,000 EVs in 2050 under the medium growth scenario (see figure 16).

Figure 16. Meeting state goals requires major metrowide electric vehicle adoption

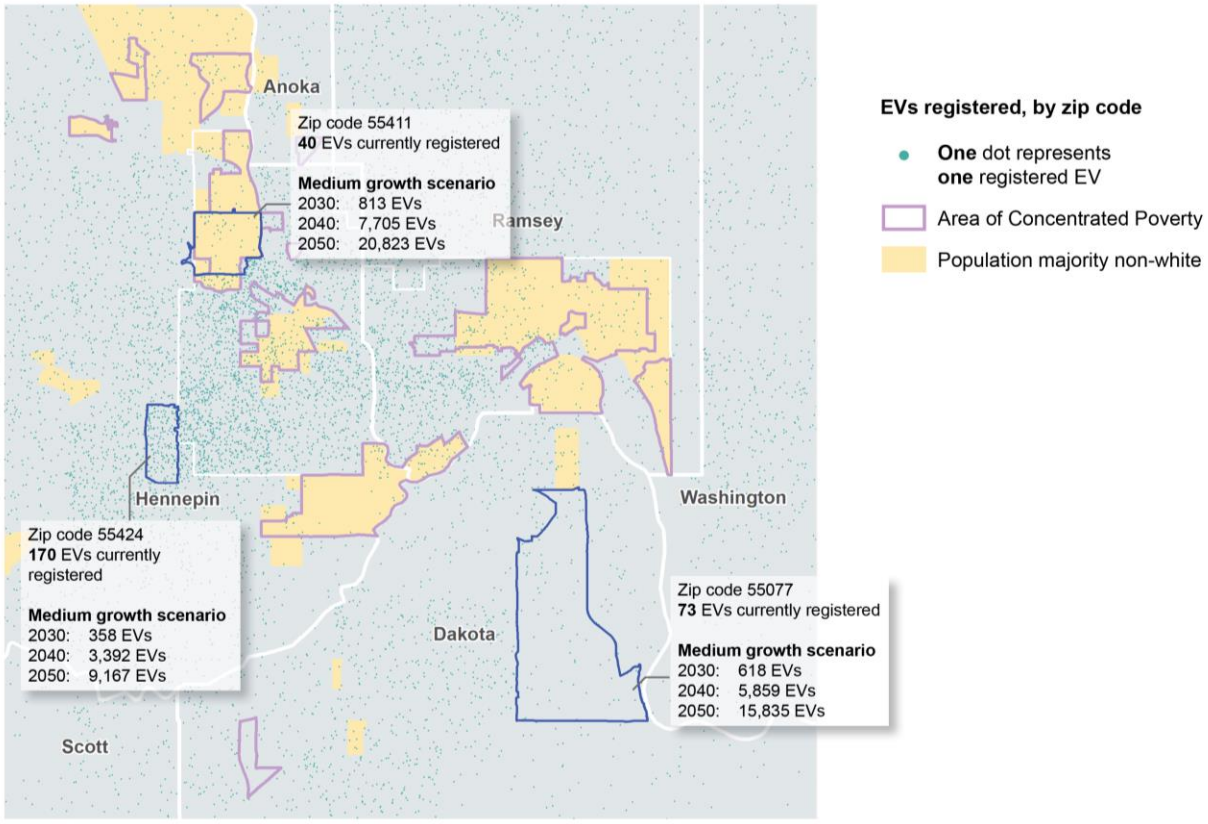


Note: Vehicles are distributed throughout the zip code they are registered in and are not shown at their exact address.

Source: Calculations by the Great Plains Institute, 2021.

Areas with low rates of EV adoption will require the greatest levels of growth to achieve the rates of EV adoption needed to meet midcentury goals. As shown in figure 17, this will include a major scale-up in Areas of Concentrated Poverty where EV adoption rates are lower than in surrounding areas.

Figure 17. Major increases needed in areas with low rates of adoption



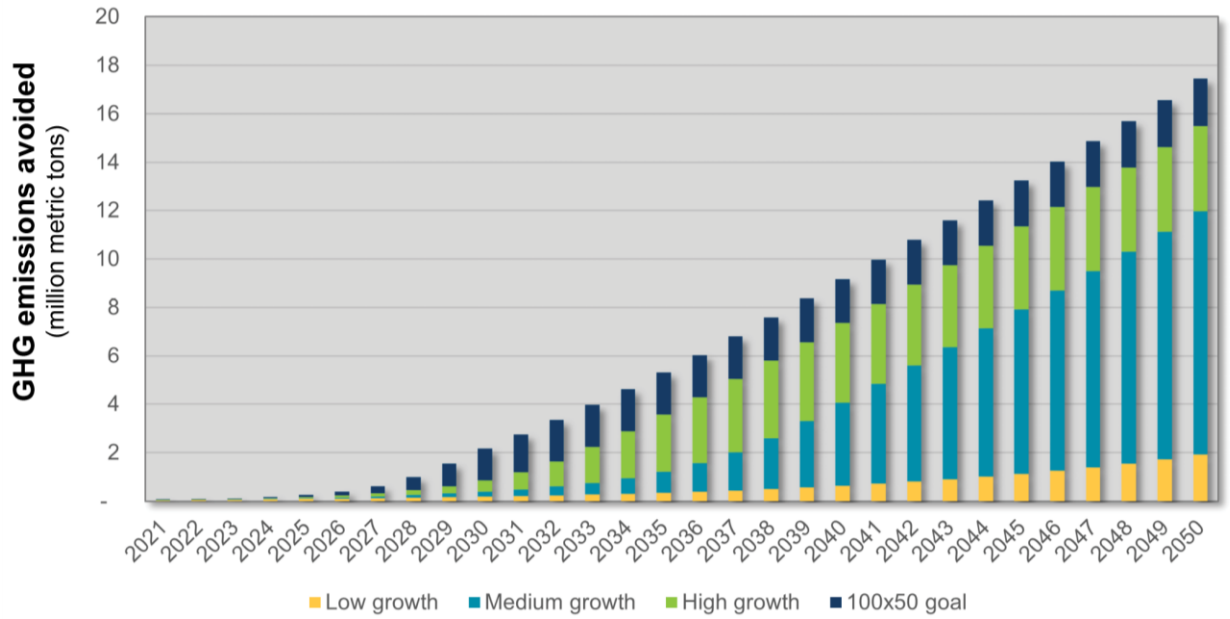
Note: Vehicles are distributed throughout the zip code they are registered in and are not shown at their exact address.

Source: Calculations by the Great Plains Institute, 2021; Metropolitan Council, *Equity Considerations for Place-Based Advocacy and Decisions in the Twin Cities Region*.

The forecasted EV adoption scenarios result in varying levels of emissions reductions, with more aggressive EV sales growth scenarios resulting in greater annual emissions reductions.

As shown in figure 18, EVs reduce surface transportation GHG emissions by 865,000 metric tons per year in 2030 in the high growth scenario versus 195,000 metric tons per year in the low growth scenario. This gulf widens over time, with EVs contributing 11 times the amount of GHG reductions in 2040 in the high growth scenario as compared to the low growth scenario, and eight times the amount of GHG reductions in 2050 as compared to the low growth scenario.

Figure 18. Annual GHG savings attributable to electric vehicles, by scenario



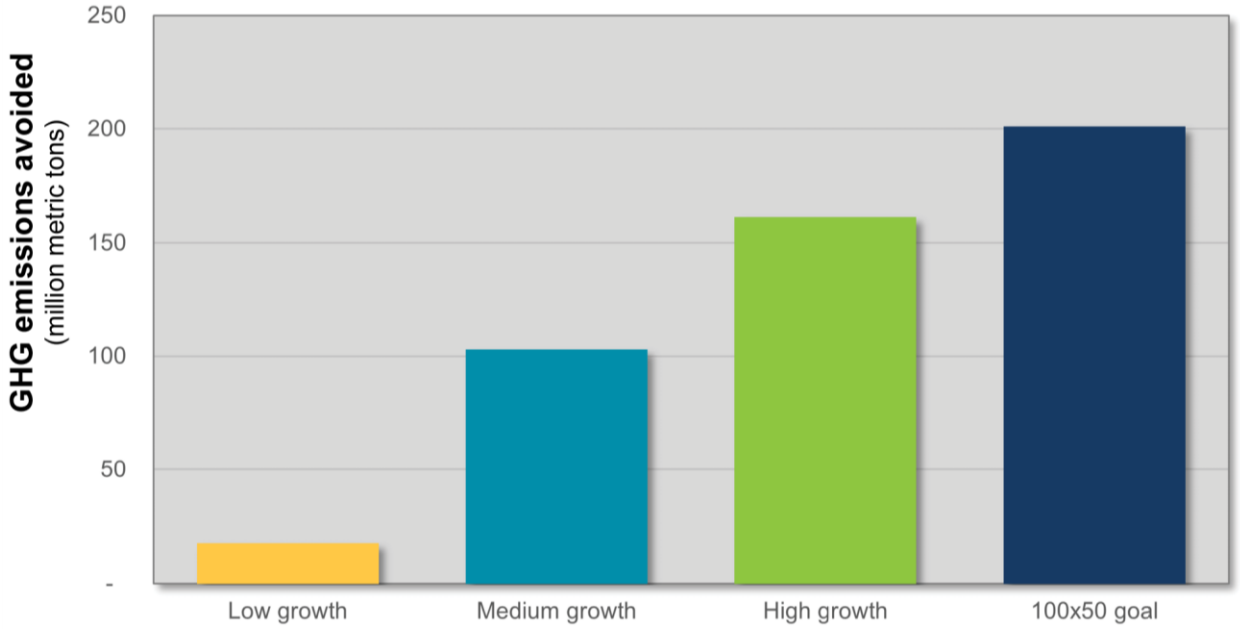
Note: The MN 100x50 goal aligns with the modeled EV sales required for adoption levels identified in the *Pathways to Decarbonizing Transportation in Minnesota* report, published in 2019. Estimates for GHG emission reductions assume that all EVs charge on an average Minnesota grid which accounts for the portfolio fuel mix of all generating electric power facilities within the state and assumes that this grid mix will fully decarbonize by 2050 through measures including increasing deployment of renewable and zero-carbon electric generation sources.

Source: Modeled GHG emission reduction at various degrees of EV adoption, calculated by the Great Plains Institute. Scenario EV sales forecasts are based on both historic sales trends and the "Annual Energy Outlook 2020," US Energy Information Administration," which forecasts electricity consumption in the transportation sector.

The longer EV adoption takes to ramp up, the lower the cumulative GHG reductions will be over time. While the medium, high, and 100x50 scenarios all achieve a 100 percent EV sales rate by 2050, figure 19 shows that the varied growth rates result in major differences in cumulative GHG savings. For example, the 100x50 scenario yields roughly twice as much GHG savings as the medium scenario by 2050.

However, while a wide range of GHG reduction impacts result from the modeled EV adoption scenarios, all increases in EV adoption help reduce GHG emissions, minimizing the degree to which the region must rely on other decarbonization strategies to meet its goals.

Figure 19. Cumulative GHG savings attributable to electric vehicles by 2050, by scenario



Note: The MN 100x50 goal aligns with the modeled EV sales required for adoption levels identified in the *Pathways to Decarbonizing Transportation in Minnesota* report, published in 2019. Estimates for GHG emission reductions assume that all EVs charge on an average Minnesota grid which accounts for the portfolio fuel mix of all generating electric power facilities within the state and assumes that this grid mix will fully decarbonize by 2050 through measures including increasing deployment of renewable and zero-carbon electric generation sources.

Source: Modeled GHG emission reduction at various degrees of EV adoption, calculated by the Great Plains Institute. Scenario EV sales forecasts are based on both historic sales trends and the "Annual Energy Outlook 2020," US Energy Information Administration, which forecasts electricity consumption in the transportation sector.

Scaling Up Electric Vehicle Charging Infrastructure

A major scale-up in EV charging infrastructure will be needed to support the levels of EV growth required to eliminate emissions from the transportation sector by midcentury. Ensuring widespread charger availability can increase consumer confidence in EVs and facilitate EV adoption. However, many factors influence how many chargers will be needed to support a given number of EVs.

There is no universal ideal ratio of EVs to public charging plugs or Level 2 to DC fast charging plugs.[8] Research from the International Council on Clean Transportation, Electric Power Research Institute, and National Renewable Energy Laboratory indicates that suggested ratios of EVs to plugs may range from as few as seven EVs per plug to as many as 40 EVs per plug.[9] Research also indicates that the ideal ratio of EVs to chargers may change over time as EVs become a larger percentage of the vehicle population.[10]

Access to home and workplace charging are major determining factors in how much and what type of public charging is needed. Generally, fewer public plugs are needed in areas with widespread access to home and workplace charging, where public charging plays more of a supplemental role.[11] Meanwhile, in areas where access to private home charging is more

limited, public charging takes on a role more like that of home or workplace chargers elsewhere.[12] Thus, areas with fewer single-family homes and less access to home charging will require more chargers per EV than areas with more home charging access to support similar levels of EV adoption.[13]

In the US, 80 percent of EV charging is done at home.[14] However, early EV adopters are more likely to live in single-family homes with access to and control over private EV charging.[15] As more residents of dense urban areas without access to home charging become EV drivers, the importance of public charging infrastructure will grow, indicating that the ratio of EVs to chargers that supports today's EV drivers may be insufficient to meet the needs of future EV drivers.

Meanwhile, research from the International Council on Clean Transportation estimates that as EV adoption becomes widespread, the ratio of EVs to non-home chargers will actually increase. This is because closer proximity between EVs and charging stations lead to each charging station experiencing greater use (hours of use per day) and a greater number of EVs served by each charger. However, these network effects are not expected to materialize until levels of EV adoption are several orders of magnitude larger than they are today.

The share of EVs that are plug-in EVs will impact the ideal ratio of Level 2 to DC fast charging plugs, as most plug-in EVs are unable to charge at DC fast charging stations.[16] Recent trends in the Twin Cities metro area suggest that battery EVs are becoming an increasingly large share of the region's EVs (see the 2021 *Electric Vehicle Landscape Summary*). The rising share of battery EVs indicates that DC fast charging plugs may be used more in the coming years.

Additionally, research from the National Renewable Energy Laboratory notes that as EV ranges increase, drivers may rely less on public charging to supplement home and workplace charging as more trips can be completed without supplemental charging stops.[17] This consideration may influence what level of public charging will be most useful in a given area to serve EV drivers, especially those without access to home charging.

With these considerations in mind, the ideal ratio of EVs to chargers may likely vary between areas of the metro with higher housing density, which may rely more on public chargers to fulfill the role of home or workplace chargers, and areas of the metro with lower housing density, where access to home charging may necessitate fewer public chargers. It is also likely that the ideal ratio of EVs to chargers may evolve.

What is clear is that significant near-term increases in EV charging infrastructure are critical to encourage EV adoption and support a rapidly growing population of EV drivers in the metro region.

Table 3 outlines the number of charging plugs that would need to be present in the charging network by 2030 and 2050 to maintain a viable ratio of EVs to plugs under each projected growth scenario.

For example, to maintain the region's current ratio of 22 EVs per plug under the low growth scenario, a total of 2,008 charging plugs would be required in the metro region by 2030. This would mean an addition of 1,429 charging plugs to the network's existing 604 plugs. Keeping in

mind that these are additional plugs needed, not additional stations needed, if each new charging station had 8 to 12 plugs, this would mean an addition of between 170 and 250 stations by 2030.

Table 3. Electric vehicle chargers needed at target dates by scenario

2030 Total EV charging plugs needed

Ratio of EVs to Charging Plugs	Low Growth	Medium Growth	High Growth	100x50
40 EVs to 1 plug	1,429	2,905	6,327	15,817
Current ratio	2,612	5,309	11,565	28,911
20 EVs to 1 plug	2,858	5,809	12,654	31,635
10 EVs to 1 plug	5,715	11,619	25,308	63,269

2050 Total EV charging plugs needed

Ratio of EVs to Current Plugs	Low Growth	Medium Growth	High Growth	100x50
40 EVs to 1 plug	12,088	75,324	97,624	109,881
Current ratio	22,095	137,677	178,439	200,842
20 EVs to 1 plug	24,177	150,647	195,249	219,762
10 EVs to 1 plug	48,353	301,294	390,498	439,524

Note: These calculations include both Level 2 and DC fast charging plugs and do not distinguish between the two.

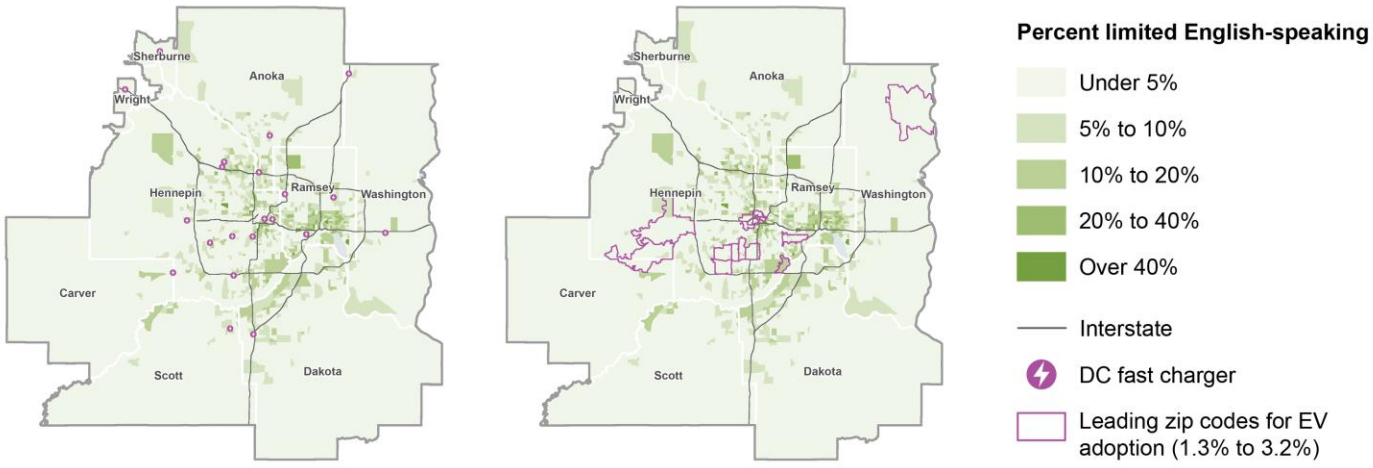
Sources: Minnesota Department of Public Safety and Minnesota Pollution Control Agency; "Annual Energy Outlook 2020," US Department of Energy, Alternative Fuels Data Center.

Mapping Equity Considerations for Electric Vehicle Deployment and Infrastructure Build-Out

EV registrations and supportive infrastructure are not evenly distributed across the metro area. A wide variety of factors can affect access to the benefits of EVs and electrification. Identification of existing disparities can be used to target future support to ensure that benefits of electrification are accessed evenly throughout the metro region.

Language can be another barrier to accessing many resources, including EVs. Figure 20 shows that early EV adopter zip codes tend to have a very small share of residents with limited English-speaking proficiency. Three-quarters of leading EV adopter zip codes having a lower percent of limited English-speaking residents than the metro wide median.

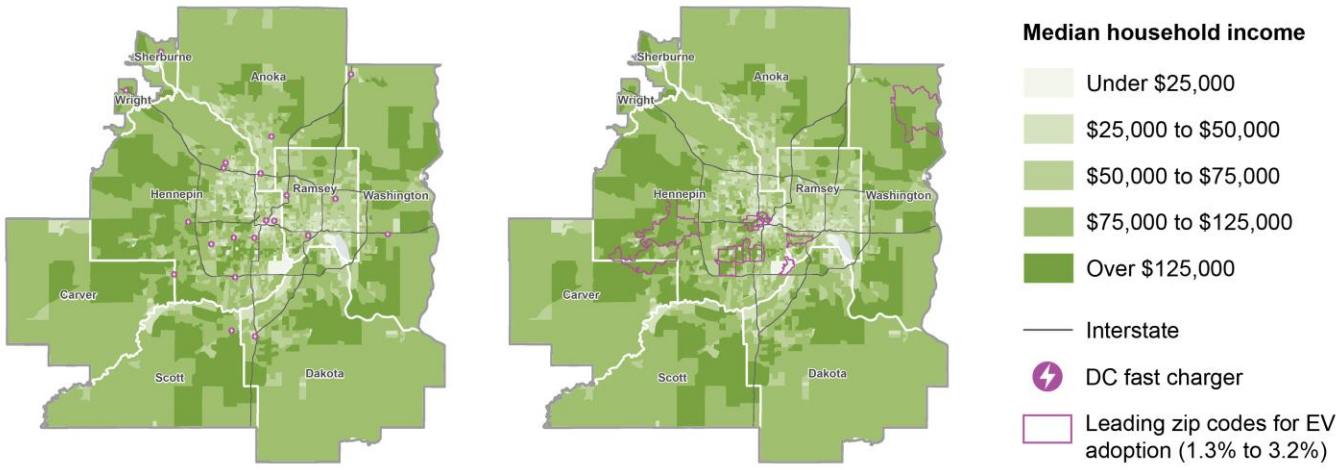
Figure 20. Percent limited English-speaking, with charging locations and leading electric vehicle adopters



Source: Figure authored by Great Plains Institute, 2021. Based on data from US Census American Community Survey for 2019 5-year estimates (table C16002); "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

Figure 21 shows how the leading zip codes for EV adoption also tend to be comprised of high-income households, with 70 percent of the region's leading EV zip codes having a higher median household income than the metro wide median.

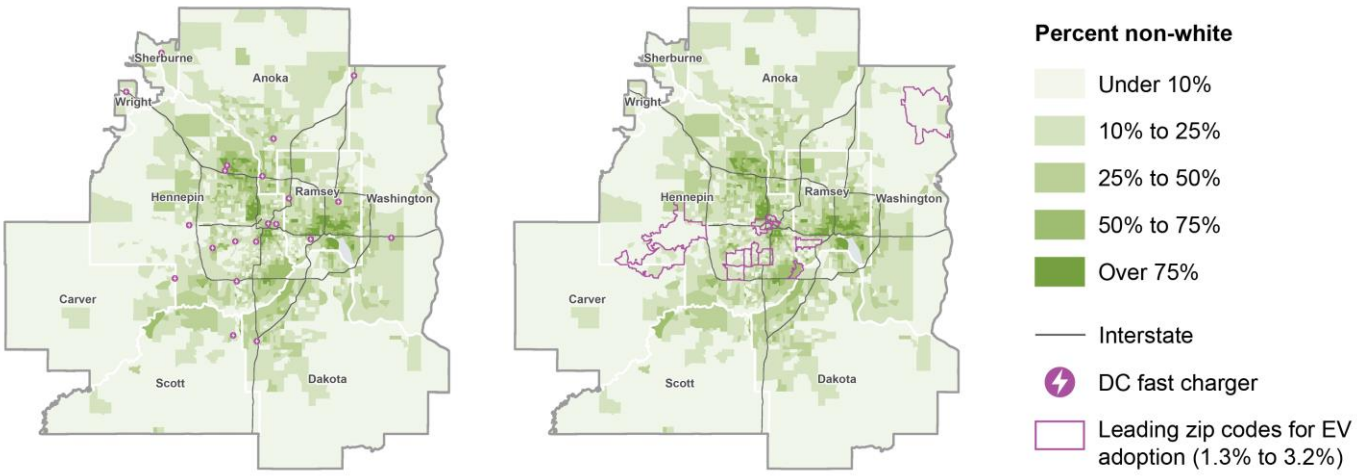
Figure 21. Median household income, with charging locations and leading electric vehicle adopter



Source: Figure authored by Great Plains Institute, 2021. Based on data from US Census American Community Survey for 2019 5-year estimates (table B19013), Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

Figure 22 shows leading EV zip codes tend to have a high percentage of white residents, with a majority of the leading EV zip codes having a higher share of white residents than the metro as a whole. Meanwhile, zip codes with the highest share of non-white residents tend to have a lower rate of EV adoption than the metro region as a whole.

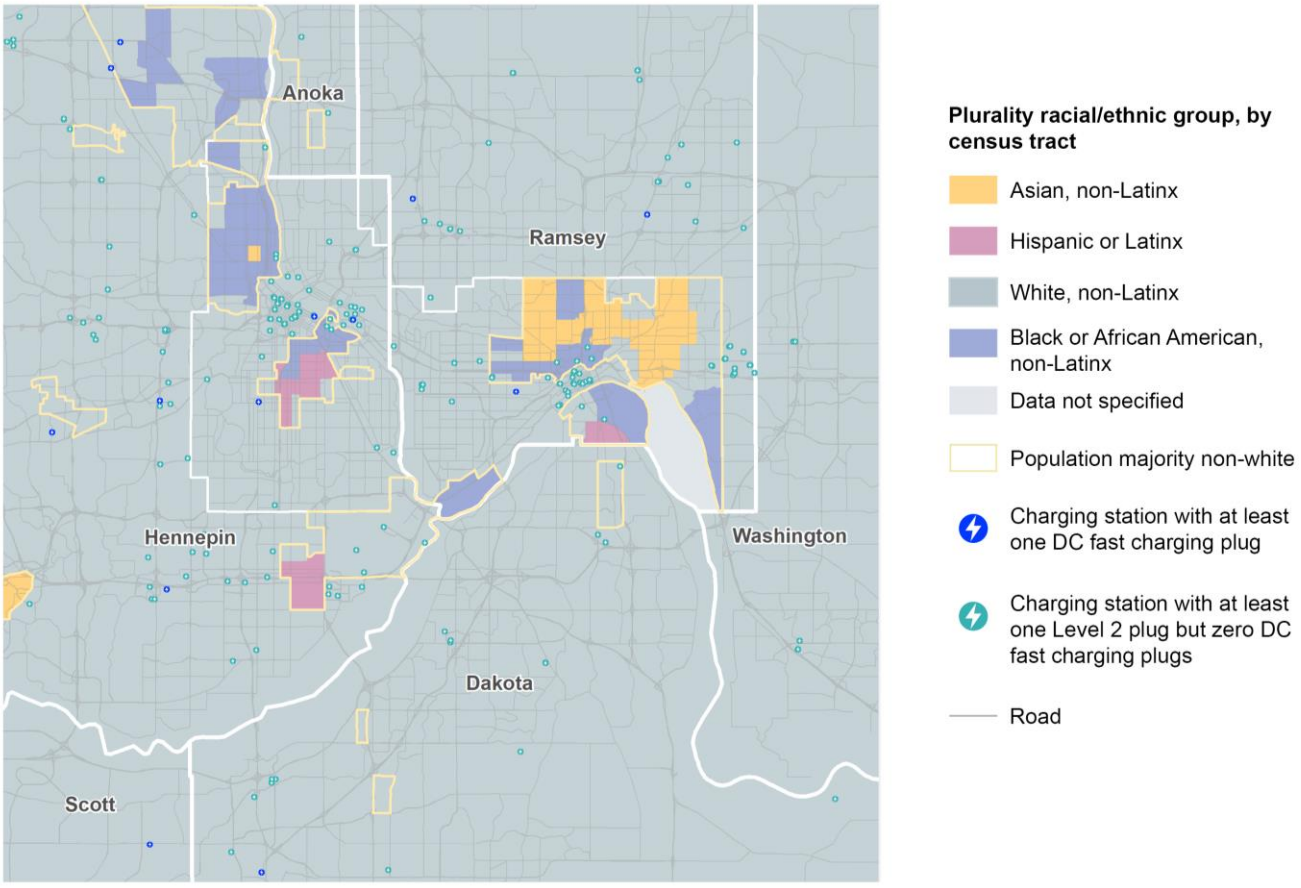
Figure 22. Percent non-white, with charging locations and leading electric vehicle adopters



Source: Figure authored by Great Plains Institute, 2021. Based on data from US Census American Community Survey (table B03002), "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

Examining demographic data in further detail begins to reveal additional important insight into the specific stories of access to EVs that may vary by racial and ethnic community, among other factors, as shown in figure 23.

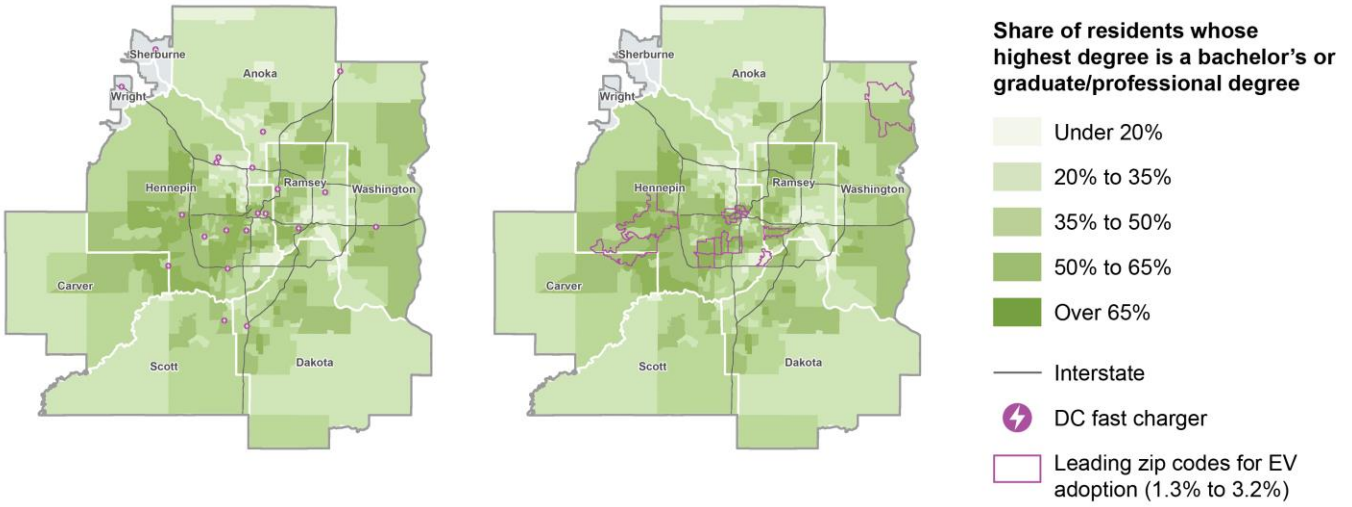
Figure 23. Distribution of electric vehicle charging infrastructure: race and ethnicity



Source: Figure authored by Great Plains Institute, 2021. Based on data from Metropolitan Council, *Equity Considerations for Place-Based Advocacy*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

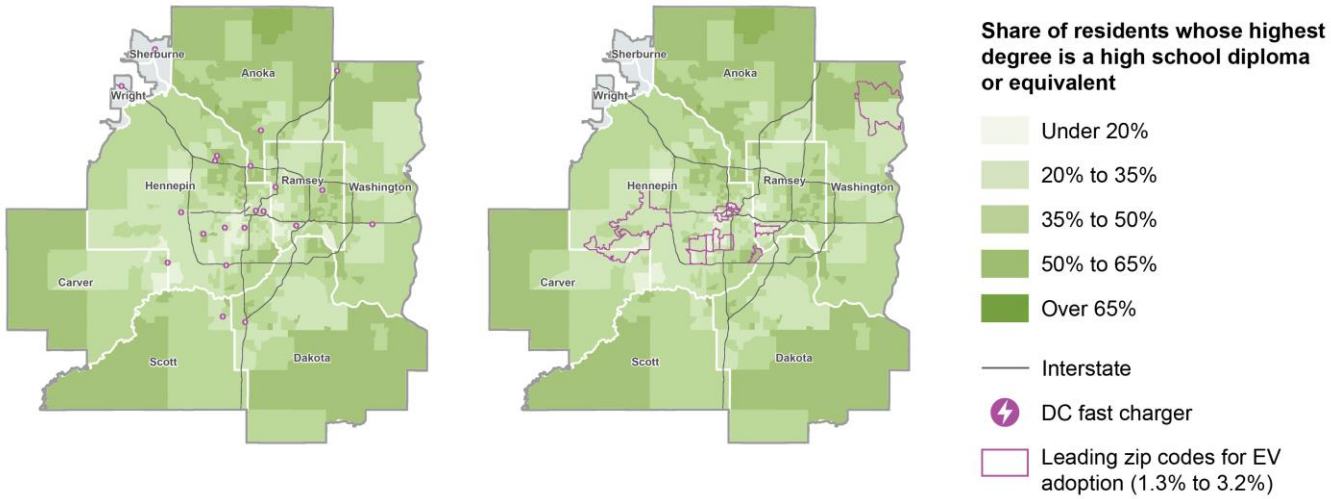
Figure 24 shows that leading EV zip codes tend to be highly educated. Conversely, populations with only a high school diploma or with no high school diploma tend not to be among the leading zip codes for EV adoption, as shown by Figures 25 and 26.

Figure 24. Education: Advanced degree, with charging locations and leading electric vehicle adopters



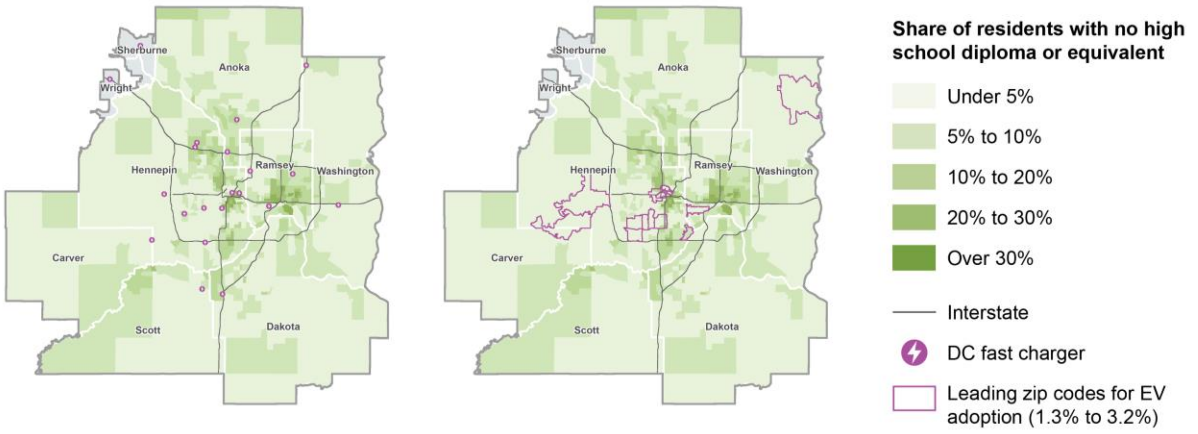
Source: Figure authored by Great Plains Institute, 2021. Based on data from Metropolitan Council, *Equity Considerations for Place-Based Advocacy*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

Figure 25. Education: High school diploma only, with charging locations and leading electric vehicle adopters



Source: Figure authored by Great Plains Institute, 2021. Based on data from Metropolitan Council, *Equity Considerations for Place-Based Advocacy*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

Figure 26. Education: No high school diploma, with charging locations and leading electric vehicle adopters

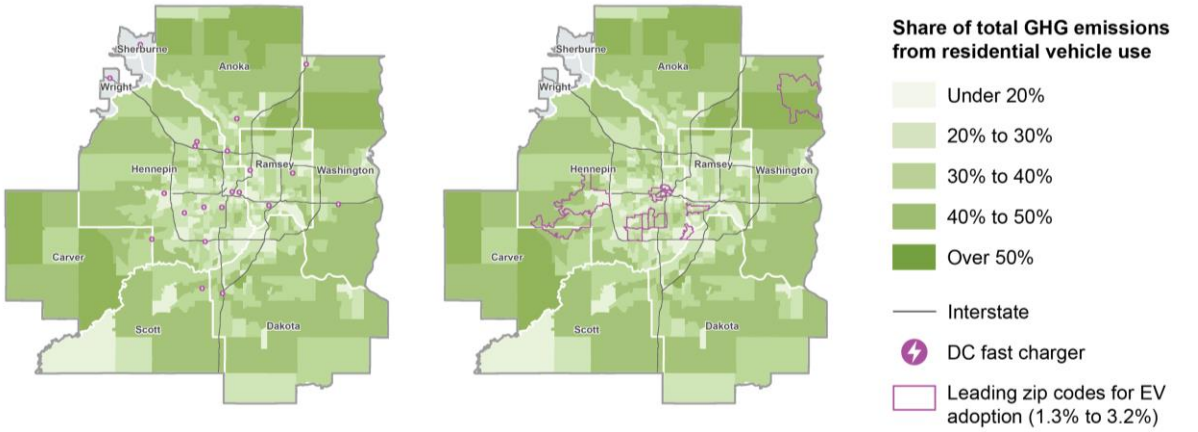


Source: Figure authored by Great Plains Institute, 2021. Based on data from Metropolitan Council, *Equity Considerations for Place-Based Advocacy*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

Emissions profiles and air pollution impacts vary across the metro. Figure 27 shows that the outer ring of the metro tends to have a higher share of GHG emissions coming from residential vehicle use than areas toward the region's urban center, indicating that investing in EV adoption and infrastructure in those exurban and rural areas would have an outsized impact on those areas' GHG emissions.

Meanwhile, air pollution (figure 28) and associated health risks (figure 29) are concentrated toward the region's urban center. This dynamic underscores the importance of balancing investment throughout the metro region and supporting EV growth across the entire metro.

Figure 27. Share of GHGs from residential vehicle use

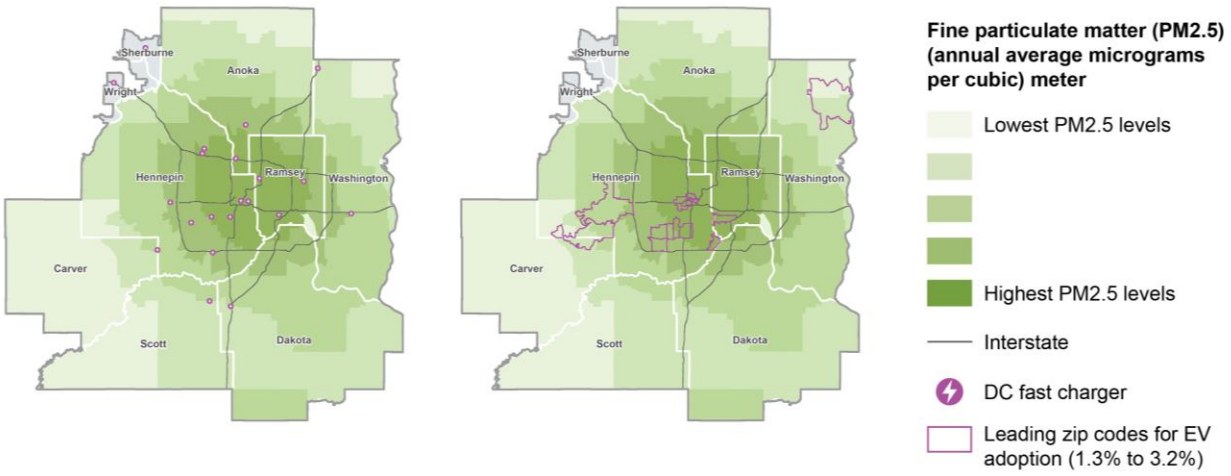


Source: Figure authored by Great Plains Institute, 2021. Based on data from Metropolitan Council, *Equity Considerations for Place-Based Advocacy*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

While both fine particulate matter pollution and EV infrastructure are generally clustered around the urban center, there are significant chargers. And given the limited number of plugs at most existing stations, a major scale-up of EV infrastructure and adoption will be required to make a dent in those pollution levels.

Additionally, most of the leading EV zip codes do not overlap with the areas with the greatest fine particulate matter (PM2.5) burden.

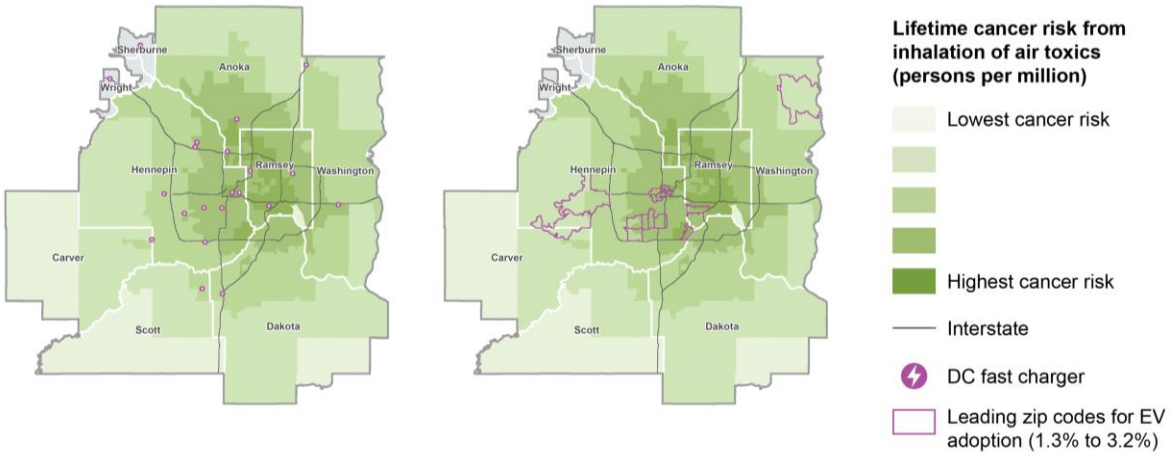
Figure 28. Fine particulate matter



Source: Figure authored by Great Plains Institute, 2021. Based on data from Metropolitan Council, *Equity Considerations for Place-Based Advocacy*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

The most severe concentration of lifetime cancer risk from air toxics centers on Ramsey County along a stretch of I-35E and 694.

Figure 29. Cancer risk from air toxics



Source: Figure authored by Great Plains Institute, 2021. Based on data from Metropolitan Council, *Equity Considerations for Place-Based Advocacy*; "Electric Vehicle Charging Station Locations," US Department of Energy, Alternative Fuels Data Center; Minnesota Department of Public Safety and Minnesota Pollution Control Agency.

ANALYSIS CONCLUSION

EV infrastructure and adoption will need to scale up rapidly to meet midcentury climate goals. Extensive policy support is likely necessary to catalyze this growth. In addition to having geographic gaps between charging stations, the metro has relatively few chargers with multiple plugs. Building out new stations and expanding charging capacity at existing stations will be important to maintain EV infrastructure at levels that support and encourage increased levels of EV adoption.

Additionally, this analysis finds existing disparities in access to EVs and EV infrastructure that correlate with several demographic factors. Action must be taken to prioritize equity in infrastructure build-out and EV adoption support to ensure even access to the benefits of electrification across the metro.

Different parts of the metro may also require unique approaches to electrification and require a varied density and makeup of chargers (see use cases for more). As the EV landscape expands over the coming years, periodic monitoring will be critical to ensure that the region continues to adapt to meet evolving needs.

Residential Use Case Analysis

GPI has developed a residential use case analysis for the seven-county region as part of the Electric Vehicles Planning Study. The residential use case analysis aimed to understand the vehicle needs of the region's residents. We studied the preferred vehicle types, average daily miles traveled, and budgets for five different use cases:

1. Residents who live in urban apartments.
2. Residents who live in suburban apartments.
3. Residents who live in urban houses.[18]
4. Residents who live in suburban houses.
5. Residents who live in rural houses.

The GPI team subdivided these use cases by income level and household size to accurately represent the needs of region's diverse population.

The team then used the Pew Research Center's data to define the income thresholds for the Minneapolis-St. Paul-Bloomington Metro Area.[19] The classifications are presented in Table 4.

Table 4. Median income thresholds for the Minneapolis-St. Paul-Bloomington Metro Area

	1-person household	2–4-person household
Low-income	$0-$28,800	$0-$49,800
Medium-income	$29,900-$86,400	$49,800-$149,500
High-income	$86,500 and above	$149,500 and above

Source: Jesse Bennett, Richard Fry, and Rakesh Kochhar, "Are You in the American Middle Class? Find out with Our Income Calculator."

The GPI team combined the data on income thresholds for the Minneapolis-St. Paul-Bloomington Metro Area with conventional financial advice about recommended budgets for vehicle purchases.[20] This combination helped determine a reasonable budget for vehicle purchases for each use case we studied. The information on income levels and corresponding monthly payments, and the total vehicle value is presented in Table 5.

Table 5. Vehicle purchase budget for each use case in the Minneapolis-St. Paul-Bloomington Metro Area

Income tier	Monthly payment (10% of median income)	Total value of vehicle
Low-income (1-person)	$0-$240	Up to $15,580
Moderate- to high-income (1-person)	$240-$720	$15,580-$46,740
Low-income (2-4 people)	$0-$415	Up to $27,000
Moderate- to high-income (2-4 people)	$415-$1,245	$27,000-$80,800

Source: Monthly car payment and total value of vehicle, calculated by the Great Plains Institute. The analysis is based on the parameters laid out by Philip Reed, "How Much Car Can You Afford? Understanding the Numbers."

Furthermore, the GPI team conducted market research for EVs in the seven-county area. It noted the qualified EVs that fulfill the vehicle needs for each use case.

The residential use case analysis recommends the EV charging infrastructure required to replace the internal combustion vehicles with EVs in each use case. The analysis based those recommendations on the vehicle needs data for each use case and the battery range for qualified EVs. It should be noted that the analysis uses the advertised range for EVs. The range may with weather conditions, state of battery, and other factors.

Our market research revealed that 20 of the 21 new EV models sold in the region have more than 200 miles of range on a full battery. That range fulfills the daily driving requirements for all use cases studied.[21] However, limited access to charging infrastructure is still a primary concern for potential EV drivers in the region, leading to "range anxiety" for EV drivers.

The residential use case analysis also includes the barriers that residents of the seven-county region face in accessing the EV charging infrastructure. Alongside the barriers is a list of potential solutions that will allow the residents covered by the five use cases to have better access to EV charging infrastructure and encourage them to adopt EVs.

Travel Behavior Inventory

GPI gathered valuable insights about travel patterns for residential vehicles in the Twin Cities region from the Travel Behavior Inventory (TBI). The TBI has been carried out by the Metropolitan Council in the greater Twin Cities region every 10 years since 1949.[22] It currently covers 19 counties, including western Wisconsin.

GPI relied on the Wave 1 schedule of TBI data that was collected from October 1, 2018, through September 30, 2019. The survey covered 7,837 households, including residents from different age groups, socioeconomic backgrounds, genders, races, ethnicities, employment statuses, and disability statuses from the seven-county region.[23]

The TBI survey collects detailed information on different facets of travel behavior like the number of trips taken by residents, the mode of transportation used, trip routes, the purpose of trips, and trip distances and duration.

GPI relied on the TBI to obtain data for the average miles traveled per day by the Twin Cities metro region residents. The GPI team then broke the data down by income level, household size, and location.

The TBI results revealed that the region's residents travel 41 miles per day on average. The average does not include the days when the vehicles were parked all day. The data also suggests that the average miles traveled per day increased with income, household size, and distance from the urban center.

GPI developed a residential use case analysis based on the TBI data and publicly available data about popular vehicle makes and models of EVs available on the market and charging infrastructure in the Twin Cities metro region.[24] As displayed in tables 6, 7, 8, and 9, the analysis shows the suitable EV models, both new and used, available for the different use cases.

Table 6. Low-income use cases

	Urban Apartment		Suburban Apartment		Urban House		Suburban House		Rural House	
Household size	1	2-4	1	2-4	1	2-4	1	2-4	1	2-4
Budget	$15,800	$27,000	$15,800	$27,000	$15,800	$27,000	$15,800	$27,000	$15,800	$27,000
Average Daily Distance Traveled	9 miles	29 miles	21 miles	26 miles	12 miles	27 miles	36 miles	40 miles	12 miles	30 miles
Current Vehicles	Pickup, sedan, or compact	Pickup, sedan, or compact	Pickup, sedan, or compact	Pickup, sedan, or compact	Pickup, sedan, or compact	Pickup, sedan, or compact	Pickup or sedan	Pickup or sedan	Pickup, sedan, or compact	Pickup, sedan, or compact

Table 7. Suitable electric vehicle options for low-income households

Household Size	Electric Vehicle Options
1-person Household	**Used:** Fiat 500e, Mitsubishi i-MieV, Nissan Leaf, Ford Focus EV, Volkswagen (VW) e-Golf, Chevrolet Spark EV
2-4-person Household	**New:** Nissan Leaf, Mini Cooper SE **Used:** Hyundai Kona Electric, Mitsubishi i-MieV, Ford Focus EV, VW e-Golf, Chevrolet Spark EV, Chevrolet Bolt, BMW I3, Kia Soul EV, Mercedes B-Class ED

Sources: Jukka Kukkonen, "EV Info List;" "2019 Travel Behavior Inventory Household Survey Results," Metropolitan Council.

Table 8. Moderate- to high-income use cases

	Urban Apartment		Suburban Apartment		Urban House		Suburban House		Rural House	
Household Size	1	2-4	1	2-4	1	2-4	1	2-4	1	2-4
Budget	$15,580-$46,740	$27,000-$80,800	$15,580-$46,740	$27,000-$80,800	$15,580-$46,740	$27,000-$80,800	$15,580-$46,740	$27,000-$80,800	$15,580-$46,740	$27,000-$80,800
Average Daily Distance Traveled	20 miles	43 miles	89 miles	71 miles	22 miles	52 miles	26 miles	77 miles	29 miles	76 miles
Current Vehicles	Pickup, crossover, SUV, or sedan	Pickup, crossover, SUV, or sedan	Pickup, crossover, or SUV	Pickup, crossover, or SUV	Pickup, crossover, or SUV	Pickup, crossover, or SUV	Pickup or sedan	Pickup or sedan	Pickup, sedan, or minivan	Pickup, sedan, or minivan

Table 9. Suitable electric vehicle options for moderate- to high-income households

Household Size	Electric Vehicle Options
1-person Household	**New:** Chevrolet Bolt, Chevrolet Bolt EUV, VW ID.4, Ford Mustang Mach-e, Ford F-150 Lightning, Polestar 2, Nissan Leaf. **Used:** Tesla Model S, Tesla Model X, Tesla Model 3, Tesla Model Y, Porsche Taycan, Jaguar i-Pace, Volvo XC-40, Audi e-Tron.
2-4-person Household	**New:** Tesla Model 3, Tesla Model Y, Chevrolet Bolt, Chevrolet Bolt EUV, VW ID.4, Jaguar i-Pace, Ford Mustang Mach-e, Ford F-150 Lightning, Rivian R1T, Nissan Leaf, Volvo XC-40, Audi-e-Tron. Used EV options include: Tesla Model S, Tesla Model X, Porsche Taycan, Audi e-Tron GT

Household Size	Electric Vehicle Options
	Used: Hyundai Kona Electric, Mitsubishi i-MieV, Ford Focus EV, VW e-Golf, Chevrolet Spark EV, Chevrolet Bolt, BMW I3, Kia Soul EV, Mercedes B-Class ED

Sources: Jukka Kukkonen, "EV Info List;" "2019 Travel Behavior Inventory Household Survey Results," Metropolitan Council.

The GPI team noted that while EVs have become significantly accessible, even for low-income drivers in the seven-county region, the lack of access to charging is a bigger deterrent for residents across the five residential use cases studied. The following is a list of barriers residents face as they try to access EV charging:

- **Cost of chargers:** The high upfront cost associated with purchasing and installing chargers deters many potential EV buyers, especially low-income buyers.
- **Multi-unit dwelling residents:** Some multi-unit dwellings may not allow chargers; others may not offer reserved parking for residents. This makes it difficult for EV owners to charge their vehicles cheaply overnight.
- **Capacity issue at old homes**: Older detached garages may not have the capacity for Level 2 chargers. In such cases, residents may have to make expensive renovations to make their garages capable for Level 2 chargers.
- **Lack of public Level 2 charging:** There are limited public chargers outside the urban centers in the seven-county region. EV drivers, even those with access to home charging, prefer to have public charging options as backup.
- **Lack of DC fast chargers:** DC fast chargers are the closest alternative to the gas-station model of refueling. Some drivers may need DC fast chargers along longer routes to recharge their batteries on longer trips. This is especially true for rural drivers who often travel long distances and may not have access to Level 2 charging at home.
- **Lack of grid capacity:** Local rural grids may not support DC fast charging or multiple Level 2 chargers in one neighborhood. These lines may require expensive and time-consuming upgrades.

The GPI team recommends the following solutions to make EV charging more accessible to the residents of the seven-county region and help them electrify their vehicles:

- **Financial assistance:** Rebates and other incentives for purchasing and installing Level 2 chargers and installation can make EV ownership more affordable, especially for low-income residents.
- **Multi-unit dwelling access:** Multi-unit dwellers can access EV charging infrastructure if bylaws are updated to require multi-unit dwellings to provide chargers to EV drivers or allow them to install chargers.
- **Workplace charging:** Workplace charging is a suitable alternative for residents who do not have overnight charging at home (e.g., multi-unit dwellers). Subsidized or free charging for low-income drivers can make EV ownership attractive to them.
- **Behind-the-meter costs:** Some residents may require significant upgrades to their power lines before they can install Level 2 chargers. Utility or government support for the behind-the-meter upgrades may encourage these residents to opt for Level 2 chargers.
- **Public charging:** Accessible public chargers in rural areas and suburban areas will help lower the “range anxiety” of residents in these areas who are considering buying EVs. Multi-unit dwellers may also rely on curbside street parking or DC fast charging at central locations as their primary charging method.

- **Grid upgrades:** Rural areas with outdated grids can focus on upgrading the parts of the grid where they expect DC fast charging corridors to pass through. This will help residents make longer trips. Furthermore, some neighborhoods may also require grid upgrades to allow multiple houses to install and operate Level 2 chargers simultaneously.

Charging Recommendations

The GPI team also drafted charging recommendations for each use case. The team concluded that to meet the travel requirements of the average resident in each use case an all of the above approach to installing charging infrastructure must be taken. EV drivers across the different use cases will need daytime, nighttime, and public charging. Each use case requires Level 1 and Level 2 charging at workplaces and homes. These chargers should also be supplemented by DC fast chargers in accessible public areas.

Equity Insights for Residential Use Cases

As the Metropolitan Council works on solutions to some of the barriers identified by the residential use case analysis, it should consider the following best practices, identified by Bellwether Consulting during the equity analysis of the study, to keep equity centered in the process:

- Support strategic EV charging deployment in low-to-moderate income, rural, and Black, Indigenous, and people of color (BIPOC) communities and workplaces.
- Support EV charging in multi-unit dwellings through grants, ordinances, and other programs.
- Promote ability accessible EV charging station design.
- Promote personal safety-informed EV charging design.
- Provide grants administered by cities for businesses or residents to install EV chargers, focusing on underserved census tracts.
- Be intentional and engage communities before installing public EV chargers in low-income neighborhoods, remaining mindful of potentially harmful ramifications.
- Promote cohort and workforce EV rideshares.
- Work with affordable housing providers and other organizations to educate people about the benefits and opportunities of EVs.
- Work with community leaders to demonstrate new EV models and EV car sharing opportunities.

Commercial Use Case Analysis

GPI developed a commercial use case analysis for the seven-county region alongside the residential use case as part of the EV Planning Assessment. The commercial use case analysis process was similar to the residential use case exercise.

The GPI team sought to understand the vehicle needs for commercial fleets in the seven-county region. We studied the preferred vehicle types, average daily miles traveled, and other aspects of these vehicle's duty cycles for seven different commercial use cases.

The commercial use case analysis includes information on current vehicle usage, barriers to electrification, solutions to help electrification, suitable EV options, and charging needs for commercial fleets. We have included the following fleets in the analysis:

- Urban delivery company
- Local government fleet
- Private company fleet
- Distribution delivery
- Transportation network company fleet
- Rental car fleet
- Repair and service fleet

Fleet Analysis

The GPI team relied on the fleet analysis exercise to collect the commercial use case analysis data. GPI and Bellwether Consulting conducted the fleet analysis exercise for the *EV Planning Study*.

The fleet analysis was a two-part exercise. We surveyed fleet managers from various organizations in the seven-county region in the first part. The survey included questions about the type of vehicles the fleets operate, and the minimum, maximum, and average miles traveled per day. We asked other questions that focused on filling our knowledge gaps about how fleet managers decide to purchase vehicles and the barriers they face to electrifying their fleets.

We then followed up with some of the fleet managers with detailed interviews. The interviews helped us gather valuable qualitative information about barriers to fleet electrification. We were also able to pin down some potential solutions that can help fleet managers in their journey to fleet electrification.

Finally, we gathered the information from the fleet analysis and carried out additional secondary research to fill gaps in the data on each use case and charging needs. We scanned the market for commercial EVs in the United States and selected the relevant EVs for each use case.

THE URBAN DELIVERY COMPANY USE CASE

- This use case includes Class 3-5 vehicles, like box trucks and delivery vans.
- The vehicles make deliveries within city limits and return to their home base every night.
- These vehicles travel up to 150 miles each day, making multiple stops.
- The payload capacity for these vehicles is 3,100-11,500 lbs.

Barriers to Electrifying Urban Delivery Vehicles

- **Lack of fleet advisory services:** Fleet managers struggle with pinning down expected costs and benefits of electrifying fleets. They do not have access to reliable data on the expected total cost of ownership and lifetime emissions of commercial EVs.
- **Lack of charging service providers:** There is a shortage of reliable third parties that can install and maintain charging infrastructure. Fleet managers find it challenging to forecast the expected energy needs of these vehicles. They also struggle with selecting, purchasing, and installing the correct charging equipment.
- **Lack of public charging infrastructure:** While most electric delivery vehicles will not require public charging if they start their shift on a full battery, some vehicles with longer duty cycles may require additional charging at stops or during breaks. The lack of public chargers means fleet managers are unwilling to electrify these vehicles.

Solutions to Electrify Urban Delivery Vehicles

- **Fleet advisory services:** Utilities, local governments, and other experts can play a significant role in advising fleets on their electrification options. Fleet managers are more likely to electrify their vehicles if they have information like the total costs of ownership and lifetime emissions for the EVs. Smaller fleets may require financial assistance to carry out a fleet analysis.
- **Turnkey charging solutions:** Third-party service providers can ease the transition to electrification for fleet managers. These service providers can offer charging as a service by installing and maintaining the chargers.
- **Public charging:** Access to public charging infrastructure near warehouse districts and retail locations where these vehicles stop can reduce “range anxiety” for these fleets.

Charging Needs for Urban Delivery Company Fleets

- Opportunity charging at stops and during lunch breaks can help significantly extend the range for these vehicles and cover most duty cycles.
- Most urban delivery company fleets will perform their duty cycle with overnight Level 2 charging at their depots.

Fleet managers can consider accessing DC fast chargers at some stops (or central locations along routes) for vehicles that need to extend their range and perform longer duty cycles.

Table 10. Examples of suitable electric vehicles for urban delivery companies

Make and Model	Ford E-Transit	Workhorse C1000
Cargo Capacity	3,880 lbs.	6,000 lbs.
Range	126 miles	150 miles

THE LOCAL GOVERNMENT FLEET USE CASE

- Local governments use a wide variety of vehicles as part of their fleets.
- Some vehicles have fixed routes, while others have more flexible routes.
- This analysis includes Class 4-7 commercial vehicles used in street cleaning, garbage disposal, and firefighting.
- These vehicles travel less than 100 miles per day on average.

Barriers to Electrifying Local Government Fleet Vehicles

- **Lack of fleet advisory services:** Fleet managers struggle with pinning down expected costs and benefits of electrifying fleets. They do not have access to reliable data on the expected total cost of ownership and lifetime emissions of commercial EVs.
- **Lack of charging service providers:** Not many reliable third parties can install and maintain charging infrastructure. Fleet managers find it challenging to forecast the expected energy needs of these vehicles. They also struggle with selecting, purchasing, and installing the correct charging equipment.
- **Lack of model availability:** There are limited EVs for special operations like fire trucks and street cleaners on the market.
- **High upfront costs:** The specialty models available as EVs are more expensive than internal combustion engine models. Local government fleet managers often have limited budgets and may not be able to afford these electric models.
- **Vehicle lifecycles:** Many of these government fleet vehicles have long lifecycles. This means many fleet managers will only think about electrifying their fleets at the end of their current fleet's life, which can be more than a decade down the line.
- **Labor costs:** Local government fleets often have their mechanics and technicians for the upkeep of the vehicles. A switch to EVs would require retraining the staff to work on EVs or making significant personnel changes. Both options can be costly and unpopular with employees.

Solutions to Electrify Local Government Fleet Vehicles

- **Fleet advisory services:** Utilities, local governments, and other experts can play a significant role in advising fleets on their electrification options. Fleet managers are more likely to electrify their vehicles if they have information like the total costs of ownership and lifetime emissions for the EVs. Smaller fleets may require financial assistance to carry out a fleet analysis.
- **Turnkey charging solutions:** Third-party service providers can ease the transition to electrification for fleet managers. These service providers can offer charging as a service by installing and maintaining the chargers.
- **Training programs:** Training programs for mechanics and technicians can ensure that the transition to EVs is smooth in local government fleets.

Charging Needs for Local Government Fleets

Most government fleet vehicles will perform their duty cycle with overnight Level 2 charging at their depots.

Table 11. Examples of suitable electric vehicles for local government fleets

Make and Model	BYD 6R	Peterbilt 520 EV
Cargo Capacity	12,520 lbs.	33,000 lbs.
Range	124 miles	80-100 miles

THE PRIVATE COMPANY FLEET USE CASE

- This use case includes Class 1, 2a, or 2b passenger vehicles.
- The vehicles are used by the employees to conduct their jobs and for their personal use.
- The vehicles do not have fixed routes.
- The vehicles can travel up to 100-200 miles each day.
- The average distance traveled per day for this class of vehicles is 41 miles.

Barriers to Electrifying Private Company Fleet Vehicles

- **Lack of fleet advisory services:** Fleet managers struggle with pinning down expected costs and benefits of electrifying fleets. They do not have access to reliable data on the expected total cost of ownership and lifetime emissions of commercial EVs.
- **Lack of charging service providers:** There is a shortage of reliable third parties that can install and maintain charging infrastructure. Fleet managers find it challenging to

forecast the expected energy needs of these vehicles. They also struggle with selecting, purchasing, and installing the correct charging equipment.

- **Lack of public charging:** While Level 2 charging can cater to the average daily miles traveled by these fleets, they might need public DC fast charging to complete occasional long-distance trips. The lack of DC fast charging infrastructure means otherwise capable EVs cannot fulfill the long-distance use case.
- **Installing charging infrastructure:** Most vehicles are parked at employee residences overnight. This means the company must install chargers at their employees' residences and pay for the vehicles' charging. That can be complicated and costly as it may require the installation of separate meters or smart chargers.
- **Employee resistance:** Some employees may resist electrification because they do not perceive these vehicles as capable as their internal combustion engine counterparts.

Solutions to Electrify Private Company Fleet Vehicles

- **Fleet advisory services:** Utilities, local governments, and other experts can play a significant role in advising fleets on their electrification options. Fleet managers are more likely to electrify their vehicles if they have information like the total costs of ownership and lifetime emissions for the EVs. Smaller fleets may require financial assistance to carry out a fleet analysis.
- **Turnkey charging solutions:** Third-party service providers can ease the transition to electrification for fleet managers. These service providers can offer charging as a service by installing and maintaining the chargers.
- **Public charging:** Public DC fast charging infrastructure along highways can help dispel range anxiety and allow employees to use the vehicles for longer business and personal trips.
- **Smart chargers:** Smart chargers can record the electricity used by company EVs and make it easy to reimburse employees for charging done at their residences.
- **Education and outreach:** Programs like ride and drives can increase awareness about the capabilities and benefits of EVs. This can reduce employee resistance to the electrification of private company fleets.

Charging Needs for Private Company Fleets

- Most private company fleet vehicles will perform their duty cycle with overnight Level 2 charging.
- For vehicles that need to extend their range and perform longer duty cycles or vehicles assigned to employees with no access to charging at home, companies can install Level 2 chargers at workplaces.
- Private company fleet vehicles may need DC fast charging along routes when they occasionally make longer trips.

Table 12. Examples of suitable electric vehicles for private company fleets

Make and Model	Tesla Model 3	VW ID.4.
Cargo Capacity	5 passengers, 809 lbs.	5 passengers, 1,347 lbs.
Range	273 miles	249 miles

THE DISTRIBUTION DELIVERY FLEET USE CASE

- This use case includes Class 7-8 regional-haul tractors.
- The tractors use fixed routes.
- The tractors travel 100 miles per day on average to transport goods from warehouses and distribution centers to urban centers.

Barriers to Electrifying Distribution Delivery Fleet Vehicles

- **Lack of fleet advisory services:** Fleet managers struggle with pinning down expected costs and benefits of electrifying fleets. They do not have access to reliable data on the expected total cost of ownership and lifetime emissions of commercial EVs.
- **Lack of charging service providers:** Not many reliable third parties can install and maintain charging infrastructure. Fleet managers find it challenging to forecast the expected energy needs of these vehicles. They also struggle with selecting, purchasing, and installing the correct charging equipment.
- **Grid capacity:** Fleet managers fear that if they electrify their fleets, the local grid may not support their charging needs. They may have to wait for upgrades to the grid before they can charge multiple trucks simultaneously.
- **Demand charges:** Another issue with charging multiple trucks at once, even if it is overnight, is that it causes a high peak demand. Fleets that cause high peak demands often must pay high demand charges to utilities on top of their regular electricity charges. This can significantly increase the fuel costs for electric distribution delivery fleets.
- **High upfront costs:** Electric tractor trailers are still significantly more expensive than their internal combustion engine counterparts. This, along with the need to install related charging infrastructure, makes the upfront cost of electrifying distribution fleets prohibitively high for some fleets.

Solutions to Electrify Distribution Delivery Fleet Vehicles

- **Fleet advisory services:** Utilities, local governments, and other experts can play a significant role in advising fleets on their electrification options. Fleet managers are more likely to electrify their vehicles if they have information like the total costs of ownership

and lifetime emissions for the EVs. Smaller fleets may require financial assistance to carry out a fleet analysis.

- **Turnkey charging solutions:** Third-party service providers can ease the transition to electrification for fleet managers. These service providers can offer charging as a service by installing and maintaining the chargers.
- **Utility Transportation Electrification Plans:** Utilities can coordinate with policymakers and fleet managers to forecast expected demand from EVs and make the required grid upgrades ahead of time.
- **Utility programs:** Utility programs that temporarily waive or reduce demand charges can help distribution delivery fleets electrify and establish themselves.
- **Financial incentives:** Rebates, grants, and other financial incentives for purchasing commercial EVs and related charging infrastructure help fleet managers make the business case for electrification and ease the transition to EVs.

Charging Needs for Distribution Delivery Fleets

- Most distribution and delivery fleet vehicles will be able to perform their duty cycle with overnight Level 2 charging.
- The vehicles travel 100 miles on average, and most electric regional-haul and straight trucks have more than 120 miles of range. Daytime opportunity charging can be an option for vehicles that need to extend their range and perform longer duty cycles.
- These trucks make multiple stops during their workday. Distribution delivery fleets can access DC fast chargers at these stops so the trucks can charge.

Table 13. Examples of suitable electric vehicles for distribution delivery fleets

	Example #1	Example #2
Make and Model	BYD 8TT	Lion Electric Co. Lion 8T
Cargo Capacity	20,000 lbs.	30,000 lbs.
Range	124 miles	210 miles

THE TRANSPORTATION NETWORK COMPANY USE CASE

- Companies like Uber and Lyft utilize Class 1-2 light-duty passenger vehicles ranging from compact cars to SUVs and minivans.
- The vehicles drive between 50-200 miles each day, depending on when and where they drive.
- They often do not have fixed routes or fixed timings.

Barriers to Transportation Network Company Fleet Vehicles

- **High upfront costs:** The higher upfront price of EVs and the need to install related charging infrastructure make investing in EVs too expensive for some transportation network company drivers.
- **Public charging:** Drivers who drive more than 200 miles per day may need additional public charging during their shift to complete the longer shifts. The lack of public charging in the seven-county region dissuades these drivers from shifting to EVs.

Solutions to Electrify Transportation Network Company Fleet Vehicles

- **Financial incentives:** Rebates, grants, and other financial incentives for purchasing electric vehicles and related charging infrastructure help make the transition to EVs easier for transportation network company drivers.
- **Flexible renting options:** Transportation network companies often offer their drivers to rent vehicles through flexible rental programs. These companies can include EVs in their flexible rental programs for their drives. This allows drivers to electrify without having to buy EVs.
- **Subsidized access to public charging:** Transportation network companies can partner with charging service providers and give their drivers subsidies or free access to charging networks.
- **DC fast charging network:** Accessible and reliable DC fast charging in the seven-county region helps drivers who drive longer distances to charge their vehicles during breaks and complete their shifts without any “range anxiety.”

Charging Needs for Transportation Network Company Fleets

- Most Class 1 passenger EVs offered on the market offer more than 200 miles of range. That allows for most transportation network company drivers to complete an 8-hour shift with a full charge.
- Overnight Level 2 charging at homes (or wherever the drivers park their vehicles) will allow the drivers to have a full battery every morning.
- Public Level 2 and DC Fast Charging may be needed if the drivers put in longer shifts.

Table 14. Examples of suitable electric vehicles for transportation network company fleets

Make and Model	Tesla Model X	Nissan Leaf +
Cargo Capacity	7 passengers, 1,366 lbs.	5 passengers, 1,016 lbs.
Range	348 miles	226 miles

THE RENTAL CAR USE CASE

- Rental car fleets consist of Class 1-2 light-duty passenger vehicles ranging from compact cars to SUVs and minivans.
- They serve two use cases:
    - Local driving: Visitors who use rental vehicles to drive in the seven-county region. This use case is like the residential use case. These drivers travel 41 miles per day on average.
    - Road trips: Seven-county region residents who use rental vehicles to make long trips. These vehicles can travel up to 600 miles per day.

Barriers to Rental Car Fleet Vehicles

- **High upfront costs:** The higher upfront price of EVs and the need to install related charging infrastructure at their depots make investing in EVs too expensive for rental fleets.
  Public charging: The success of electric rental fleets depends on the availability of charging infrastructure. This is especially true for users who want to make longer road trips with rental vehicles. Rental car companies are hesitant to invest in EVs until there is a dense network of public chargers for their potential customers.

Solutions to Electrify Rental Car Fleet Vehicles

- **Bulk buys:** Rental car companies leverage their buying power to avail discounts on EVs when they buy in bulk. These companies receive similar discounts when they buy internal combustion engine vehicles in bulk.
- **Partnerships with charging service providers:** Rental car companies can partner with charging service providers to provide free or subsidized charging to their customers. This will help grow the market for rental EVs.
- **Dealership rental model:** While rental cars ramp up their EV fleets, dealerships that have EVs on their lot can also offer them for rent. This serves the dual advantages of

increasing exposure for dealership vehicles and allowing rental customers to access EV options.

Charging Needs for Rental Car Fleets

- Most Class 1 passenger EVs on the market have more than 200 miles of range on a full charge. That allows rental fleets to satisfy the needs of local visit drivers using overnight Level 2 charging at hotels (or wherever the drivers park their vehicles).
- The rental fleet company will also have to invest in Level 2 charging at their depot to ensure that all customers start their trips with full battery charge.
- Rental car drivers who want to make road trips with their vehicles will have to rely on public DC fast chargers along the major corridors across Minnesota.

Table 15. Examples of suitable electric vehicles for rental car fleets

Make and Model	VW ID.4	Tesla Model 3
Cargo Capacity	5 passengers, 1,347 lbs.	5 passengers, 809 lbs.
Range	249 miles	273 miles

THE REPAIR AND SERVICE FLEET USE CASE

- Class 1-5 commercial vehicles are used by a variety of service providers (e.g., plumbers, internet providers, and utilities).
- These businesses can modify the chassis cabs to serve as bucket trucks, dump trucks, crane trucks, and service trucks.
- These vehicles are mostly used within town.

Barriers to Electrifying Repair and Service Fleet Vehicles

- **Lack of fleet advisory services:** Fleet managers struggle with pinning down expected costs and benefits of electrifying fleets. They do not have access to reliable data on the expected total cost of ownership and lifetime emissions of the commercial EVs.
- **Lack of charging service providers:** There are not many reliable third parties that can install and maintain charging infrastructure. Fleet managers find it difficult to forecast the expected energy needs of these vehicles. They also struggle with selecting, purchasing, and installing the correct charging equipment.
- **Lack of vehicle availability:** While the light- and heavy-duty EV market has been growing rapidly, the market for medium-duty EVs has not received much attention. As a

result, there are few commercial electric pickups and vans available for repair and service fleets.

Solutions to Electrify Repair and Service Fleet Vehicles

- **Fleet advisory services:** Utilities, local governments, and other experts can significantly advise fleets on their electrification options. Fleet managers are more likely to electrify their vehicles if they have information like the total costs of ownership and lifetime emissions for the EVs. Smaller fleets may require financial assistance to carry out a fleet analysis.
- **Turnkey charging solutions:** Third-party service providers can ease the transition to electrification for fleet managers. These service providers can offer charging by installing and maintaining the chargers.
- **Financial incentives:** Rebates, grants, and other financial incentives make electric models of commercial medium-duty vehicles price competitive. This helps fleet managers make a business case for electrification.

Charging Needs for Repair and Service Fleets

- Most repair and service fleet vehicles will perform their duty cycle with overnight Level 2 charging.
- The vehicles travel under 100 miles on average and rarely leave their town or city. Daytime opportunity charging can be an option for vehicles that need to extend their range and perform longer duty cycles.
- These vehicles may require on-site power (e.g., bucket trucks need the energy to fulfill their stationary duty in addition to the energy needed to commute to and from sites). Electric models may also provide power to sites (e.g., for work tools).

Table 16. Examples of suitable electric vehicles for repair and service fleets

	Example #1	Example #2
Make and Model	Ford F-150 Lightning	Ford E-Transit
Cargo Capacity	5 passengers, 2,000 lbs.	2 passengers, 3,880 lbs.
Range	230 miles	126 miles

Equity Insights for Commercial Use Cases

Bellwether Consulting has conducted an equity literature review and interviews as part of an equity analysis for the *EV Planning Study.* As the Metropolitan Council works on the solutions to some of the barriers identified by the commercial use case analysis, it should consider the following best practices, identified by the equity analysis, to keep equity centered in the process:

- Create more support for EV-related projects through the Regional Solicitation.
- Support strategic EV charging deployment in low-to-moderate income, rural, and BIPOC communities and workplaces.
- Provide grants to cities to administer for businesses or residents to install EV chargers, with a focus on underserved census tracts.
- Be intentional and engage communities prior to installing public EV chargers in low-income neighborhoods, remaining cognizant of potential harmful ramifications.
- Support targeted workforce development for people to build careers in transportation electrification.
- Support rural and BIPOC businesses with EV charging infrastructure development.
- Conduct a study to determine how to incorporate EVs in Metro Mobility's fleet, including the barriers, costs, and vehicle options.
- Explore targeted programs to electrify public fleets and deploy charging infrastructure.
- Work with local governments to share information on pool EV procurement.
- Promote cohort and workforce EV rideshares.

Recommendations to Increase Electric Vehicle Adoption in the Twin Cities Metro Area

Process

The project team drafted strategies that the Metropolitan Council could implement to increase electric vehicle adoption in the Twin Cities metro area based on completed analyses, subject matter expertise, and alignment with strategies identified in the *2021 Minnesota Electric Vehicle Assessment*.[25] Then, the team used a combination of stakeholder meetings and a survey to refine and evaluate the draft strategies, arriving at a list of final recommendations.

Recommendations

The Metropolitan Council can significantly impact EV adoption in the Twin Cities metro area in its roles as a Metropolitan Planning Organization, transit provider, technical assistance provider, and convener.

The recommendations are categorized based on how the council can impact EV adoption: supporting additional charging infrastructure; increasing availability of EVs; marketing, education, and outreach; and pursuing further studies.

Based on their overall effectiveness and urgency, these recommendations have been listed in order of priority. The project team considered each strategy's effectiveness in increasing EV adoption, reducing greenhouse gas (GHG) emissions, and reducing inequities for communities of concern (e.g., people of color, rural communities, low income). A summary of the recommendations is presented in Table 15.

SUPPORT ADDITIONAL CHARGING INFRASTRUCTURE

The *Electric Vehicle Landscape Summary* cited additional charging stations as a best practice for increasing EV adoption. Additionally, our analysis showed that there are still gaps to fill in the charging network in the Twin Cities metro area. The following recommendations reflect how the Metropolitan Council can support additional charging infrastructure.

1. Partner with the Minnesota Department of Transportation or other state agency to connect cities and counties to the available state, federal, and utility funding for public charging stations, including through the federal Infrastructure Investment and Jobs Act.

   When working to implement this strategy, the following suggestion should be considered: develop a guide to help local governments understand various funding streams and apply for those funds.

2. Generate, collect, and provide EV analysis, best practices, and data (e.g., EV charging station count, traffic patterns, etc.) in the next Transportation Policy Plan and the Regional Development Guide (e.g., Thrive MSP 2040) to inform county transportation plans and city comprehensive plans. Additionally, provide county and city level EV data

to local governments for inclusion in the transportation section of city comprehensive plans and county transportation plans.
When working to implement this strategy, the following suggestion should be considered: work with the Minnesota Geospatial Advisory Council on data needs.

3. Provide grants and other support to entities, including cities and counties, through the Regional Solicitation and other funding sources to install DC fast chargers in strategic areas (e.g., schools, community colleges, regional parks, other public buildings, convenience stores, and workplaces).

   When working to implement this strategy, the following suggestions should be considered:

   a. Encourage grantees to be intentional and engage communities—especially low-income communities—and workplaces before installing chargers, remaining aware of opportunities to distribute the benefits and burdens of EV technology fairly.
   b. Encourage applicants to work with their utility to plan for charging infrastructure needs.
   c. Recommend that applicants co-locate multiple DC fast chargers and plugs at one location.
   d. Consider the needs of medium- and heavy-duty vehicles in addition to light-duty vehicles when possible (e.g., larger parking spaces, higher voltage).
   e. The grants should encourage the installation of 350 kW DC fast chargers to future-proof investments. However, the language should be flexible and allow for lower-powered chargers where DC fast chargers are unnecessary.
   f. While Regional Solicitation funds primarily go to public entities, the possibility of supporting public-private partnerships should also be considered when developing future funding opportunities.
   g. Guidance documents for grantees should be developed. The guidance documents should help grantees understand various funding streams and how to apply for those funds.

4. Provide technical assistance and funding to cities in developing programs or incentives that promote EV charging in and around multi-unit dwellings.

   When working to implement this strategy, the following suggestions should be considered:

   a. Align with Minnesota Housing's "Multifamily Consolidated RFP" to be explicit in aligning EV charging with affordable housing development.
   b. Technical assistance could involve establishing partnerships (e.g., with utilities, landlords), providing resources, etc.
   c. Design charging stations to be accessible to the public, whenever possible.

5. Convene cities, or partner with a third-party convener (e.g., League of Minnesota Cities), to develop a model ordinance for EV readiness in parking standards and new

commercial or multifamily building parking lots. Then, encourage cities to adopt the model ordinance by providing technical assistance.

6. Identify opportunities to create innovative programs that can support additional charging infrastructure in affordable housing communities. For example, consider developing an EV charging station voucher program. Like the council's Solar-for-Vouchers Program, the council would provide technical assistance to multifamily property owners to install EV charging stations.

   When working to implement this strategy, the following suggestion should be considered: use this strategy to maximize equity outcomes by partnering with carshare programs like HOURCAR.

7. Evaluate opportunities in the Regional Solicitation to further support EV charging and other EV projects and seek opportunities to communicate these. Help applicants understand how EV readiness projects are scored.

   When working to implement this strategy, the following suggestions should be considered:
   a. Charging infrastructure should be included within other larger funding proposals under the Regional Solicitation.
   b. The Regional Solicitation funds should be used to fill the gaps from the Infrastructure Investment and Jobs Act.

8. Highlight funding public and private EV chargers as eligible activities within the Livable Communities Act grant programs. Also, encourage applicants to consider installing make-ready infrastructure at a minimum.

   When working to implement this strategy, the following suggestions should be considered:
   a. Make-ready infrastructure is defined as all necessary electrical infrastructure needed to operate a charging station (i.e., all conduit and wire).
   b. Consider language developed by Minnesota Housing's *Minnesota Overlay and Guide to the 2020 Enterprise Green Communities Criteria™* to aid in refining implementation language for the Livable Communities Act.[26]
   c. Provide resources within the Livable Communities Act grant resource library that compares EV charger installation costs during and after a development project.

INCREASE AVAILABILITY OF ELECTRIC VEHICLES (LIGHT-, MEDIUM-, AND HEAVY-DUTY)

The *Electric Vehicle Landscape Summary* also stressed the importance of making EVs more readily available. The following recommendations reflect how the Metropolitan Council can increase EVs in the Twin Cities metro area.

9. Partner with the Minnesota Department of Transportation, Minnesota Department of Administration, or other state agencies to connect fleets to available state, federal, and utility funding for EVs.

When working to implement this strategy, the following suggestion should be considered: the Metropolitan Council should also weigh in on program implementation.

10. Conduct a comprehensive fleet and infrastructure electrification study for Metropolitan Transportation Services (e.g., Metro Mobility, Transit Link, Contracted Fixed Route) to understand the opportunities and liabilities to transition to electric buses and other more efficient vehicles.

    When working to implement this strategy, the following suggestions should be considered:
    a. Outcomes may include seeking funding for a pilot project to electrify a small number of Metro Mobility vehicles and purchase electric buses and charging stations as it makes sense to do so.
    b. The data created from the study and pilot programs should be shared with other public and private fleets with similar vehicles.

11. Make future Metro Transit electric bus segments consistent with the Metro Transit *Zero-Emission Bus Transition Plan* guiding principles of technical viability, equity and environmental justice, and financial impact.

12. Evaluate opportunities to provide more financial support to expand EV car sharing programs and communicate these to appropriate audiences.

    When working to implement this strategy, the following suggestions should be considered:
    a. In this evaluation, identify how to ensure the maintenance and longevity of the programs.
    b. The Metropolitan Council should make sure that this strategy is implemented in tandem with EV charging infrastructure deployment programs.
    c. Car sharing programs should be inclusive to all segments of the population.
    d. Car sharing programs should implemented in a way that reduces the total vehicle miles traveled in the region.

13. Assess internal agency fleet vehicles for opportunities to further electrify and otherwise improve efficiency.

14. Seek funding for and invest in projects identified in the Metro Transit *Zero-Emission Bus Transition Plan*.

15. Collect and share data on EV access by race, income, gender, age, disability status, and geography.

    When working to implement this strategy, the following suggestion should be considered: This strategy should be implemented after some of the other strategies are implemented, and regional transportation electrification projects are completed. The data generated from those programs will allow decision makers to target gap areas for transportation electrification. It may also help increase funding for EVs in the future.

MARKETING, EDUCATION, AND OUTREACH

EV adoption needs to scale beyond the early adopters to meet GHG reduction and other climate goals. To do so, more consumers need to be familiar with EVs and feel empowered to make the switch. The Metropolitan Council can implement the following recommendations to increase consumer and fleet familiarity with EVs.

16. Continue coordinating actions with state agencies, nonprofits, local agencies, utilities, and other actors working in the electrification space.

    When working to implement this strategy, the following suggestion should be considered: This strategy will be most effective if the Metropolitan Council and partners work with a shared workplan. This can ensure that the agencies work in tandem and there is no duplication of effort. The Metropolitan Council or another organization can develop the shared work plan.

17. Participate in and promote the Minnesota Department of Transportation's pilot EV-ready certification program for local governments and help create a full program (similar to council support for GreenStep Cities, SolSmart, and other technical assistance initiatives).

18. Fund ride and drives for cities to educate community members about EVs.

19. Convene local government partners to identify and collaborate on EV and equity opportunities.

20. Develop and disseminate marketing materials that promote EVs and represent targeted communities, including people of color and women.

    When working to implement this strategy, the following suggestions should be considered:
    a. The Metropolitan Council should partner with other organizations, especially those already working on EV education, to implement this strategy.
    b. Local electric utilities and city governments should be encouraged to execute the marketing programs as they see fit.

21. Work with affordable housing providers and other organizations to educate residents about the benefits and opportunities of EVs (e.g., lower total cost of ownership, zero tailpipe emissions).

22. Update the Metropolitan Council Electric Vehicle webpage to provide basic information and links to existing EV education and implementation resources (e.g., Drive Electric Minnesota, Shift2Electric, etc.).

    When working to implement this strategy, the following suggestion should be considered:
    a. Include information that provides guidance to local governments on best practices and etiquette for charging station utilization (e.g., unplugging a vehicle

that has finished charging, require moving vehicles after charging is complete, sending reminders through apps, etc.).

b. The webpage should be treated as a resource that links to other EV expert websites rather than one that acts as a standalone website.

PURSUE FURTHER STUDIES

Several recommendations associated with scaling EV adoption warrant further exploration in the form of additional funded studies or periods of evaluation. The following recommendations reflect areas that require additional research.

23. Evaluate the role that counties have in scaling EV adoption beyond installing charging stations at their facilities.
24. Evaluate the potential for e-bikes and e-scooter programs to reduce vehicle miles traveled. Additionally, develop guidance for cities that identifies how these vehicles work in addition to any liabilities. Then, encourage cities to develop e-bike and e-scooter programs if it makes sense to do so.
25. Continue to evaluate the equity impacts and opportunities of EVs, now and anticipated in the future.

    When working to implement this strategy, the following suggestion should be considered: in this evaluation, review lessons learned from the EV Spot Network community outreach and study the long-term impacts of installing charging stations in low-income and people of color communities.
26. Evaluate metrics for EV implementation strategies and GHG reduction in the Regional Solicitation and then create an agreed-upon metric.
27. Evaluate the potential for e-cargo bikes to reduce delivery vehicle trips. Then, consider the next steps that support a higher deployment of e-cargo bikes.

    When working to implement this strategy, the following suggestion should be considered: while the Metropolitan Council should support research on this topic, the private sector (e-bike manufacturers and sellers) should take the lead on deployment.
28. Evaluate the local government emergency response to EV crashes and fires and consider action items to reduce any gaps that are found.

Table 17. Summary of recommendations to increase electric vehicle adoption in the Twin Cities metro area

Strategy	Lead	Partner	Fund	Urgency Ranking	Effectiveness Ranking	Total Score
Connect cities and counties to available state, federal, and utility funding.		**X**		4.1	3.6	3.9
Generate, collect, and provide EV analysis, best practices, and data in the Transportation Policy Plan and Regional Development Guide.	**X**			3.9	3.1	3.5
Provide grants to install DC fast chargers in strategic areas (through Regional Solicitation and other funding sources).			**X**	3.6	3.3	3.5
Help cities develop programs and incentives that promote charging in and around multi-unit dwellings.			**X**	3.5	3.1	3.3
Work with a third-party convener to develop model ordinance for EV-ready parking standards and new commercial or muti-unit dwelling parking lots.		**X**		3.6	2.9	3.3
Identify opportunities to support charging infrastructure in affordable housing communities.	**X**			2.8	3.2	3.0
Identify how Regional Solicitation can further support EV readiness projects.	**X**			3	2.8	2.9
Increase visibility of Livable Communities Act grants to fund EV charger installation and encourage applicants to install make-ready infrastructure.	**X**			2	2.5	2.3

Strategy	Lead	Partner	Fund	Urgency Ranking	Effectiveness Ranking	Total Score
Connect cities and counties to available state, federal, and utility funding.		**X**		4.5	3.7	4.1
Conduct comprehensive fleet and infrastructure electrification study for Metropolitan Transportation Services Contracted Services.	**X**			4.2	3.4	3.8
Align Metro Transit electric bus segments with Zero-Emission Bus Transition Plan.	**X**			4	3.4	3.7
Identify how to provide more financial support for EV car sharing programs.	**X**			3.7	3.6	3.7
Assess internal fleet for electrification opportunities.	**X**			3.9	3	3.5
Invest in projects identified in Metro Transit Zero-Emission Bus Transition Plan.	**X**			3.1	2.9	3
Collect and share data on EV access by race, income, gender, age, disability status, and geography.	**X**			3	2.8	2.9
Continue coordinating with other partners (state agencies, nonprofits, local agencies, etc.)		**X**		4.3	3.6	4
Participate in and promote MnDOT's EV-ready certification program for local governments and help create a full program.		**X**		4	3.2	3.6

Strategy	Lead	Partner	Fund	Urgency Ranking	Effectiveness Ranking	Total Score
Fund local government ride and drives.			**X**	3.1	3.3	3.2
Convene local government partners on EV and equity opportunities.		**X**		3.2	2.9	3
Develop and disseminate representative marketing materials for targeted communities.		**X**		3.2	2.8	3
Work with affordable housing providers and other organizations to educate residents.		**X**		3	3	3
Update the Metropolitan Council's Electric Vehicle webpage with basic EV education information and links to resources.	**X**			3.5	2.4	3
Evaluate the role for counties in deploying charging infrastructure beyond their facilities.	**X**			3.2	2.8	3
Evaluate the potential for e-bikes and e-scooters to reduce VMT.	**X**			3	2.6	2.8
Evaluate impacts and opportunities of EVs now and in the future.	**X**			3	2.5	2.8
Evaluate metrics for EV implementation and GHG reduction in Regional Solicitation.	**X**			2.8	2.4	2.6
Evaluate the potential for e-cargo bikes to reduce delivery vehicle trips.	**X**			2.4	2.3	2.4

Strategy	Lead	Partner	Fund	Urgency Ranking	Effectiveness Ranking	Total Score
Assess gaps in local government response to EV crashes and fires.	**X**			2.5	1.9	2.2

Equitable Implementation of the Recommendations

As the Metropolitan Council works to implement the recommendations, it should consider the following best practices, identified by Bellwether Consulting during the equity analysis of the study, to keep equity centered in the process:

- Understand the context for the strategy; research and openly articulate the related historical decisions that have impacted BIPOC and other underrepresented communities.
- Explore the potential for funding set-asides for vulnerable or underrepresented communities in the implementation of the strategy.
- Fund BIPOC-led community organizations to engage their community members in the development and implementation of each strategy.
- Work toward building long-term relationships with community organizations and residents by collaborating on the strategy.
- Find opportunities to connect the strategy to existing programs and priorities that have emerged from community-based organizations, partnerships, or residents.
- Conduct additional engagement and data analysis to understand how to maximize the strategy's impact on equity goals.
- Build public sector staff capacity, awareness, and accountability systems to achieve more equitable outcomes.
- Set equity goals and measures to track the success of the strategy.
- Establish a communication plan to track and report progress towards equity goals and measures transparently.

By following these best practices, the Metropolitan Council will more readily meet greenhouse gas emission reduction goals, reduce existing inequities, and contribute to creating more just and equitable communities.

Conclusion

GPI and Bellwether Consulting prepared the Electric Vehicles Planning Study for the Metropolitan Council to commence the EV planning process for the seven-county region.

The *Electric Vehicle Planning Study: Analyses & Recommendations* evaluates and prioritizes strategies for the Metropolitan Council to undertake to accelerate the adoption of EVs to reduce greenhouse gas emissions.

The project team drafted the strategies based on completed analyses, subject matter expertise, and alignment with the 2021 Minnesota Electric Vehicle Assessment strategies.

The analyses include a fleet analysis, residential and commercial use case analysis, and EV and charging scenario analysis for the region.

The project team completed an analysis to assess current EV adoption and infrastructure trends as well as to forecast future needs for EV growth. This analysis highlighted the following:

- the major scale-up in EV adoption that will be required to achieve alignment with a midcentury greenhouse gas emissions reduction goal
- the key role that policy and market support can play in making this scale-up a reality
- the variation in access to EVs and EV infrastructure among different parts of the metro region
- the importance of tailoring approaches to electrification to meet varying needs of communities across the region

The residential use case analysis gathers data on the vehicle needs and travel patterns for the following use cases as a representative sample for the seven-county region:

- Urban apartment
- Urban house
- Suburban apartment
- Suburban house
- Rural house

The project team divided each of the five residential use cases by income and household size to understand each segment's vehicle needs and travel patterns. The project team determined that while the EV options in the region are limited, today’s EVs meet the minimum vehicle requirements and vehicle budgets for most residents.

The residential use case analysis includes a section that identifies barriers and solutions to the electrification of residential fleets in the region. The lack of access to EV charging is the main barrier to electrification. The residential use case analysis also proposes solutions to help increase access to EV charging.

The commercial use case analysis focuses on seven commercial fleet use cases to understand the vehicle needs and travel patterns for commercial fleets in the seven-county region. The commercial use case analysis includes the following commercial fleets:

- Urban delivery company
- Local government fleet
- Private company fleet
- Distribution delivery
- Transportation network company fleet
- Rental car fleet
- Repair and service fleet

The project team conducted surveys and interviews with fleet managers as part of a fleet analysis exercise. The fleet analysis helped the project team collect vital data on vehicle requirements and travel patterns for these fleets. The surveys and interviews also helped the project team collect information about barriers and solutions to the electrification of these fleets from fleet managers.

The project team determined that there are commercial EVs available for each fleet studied. Most of the equivalent EVs can complete the typical duty cycles for the fleet vehicles. While most commercial EVs are available at a reasonable price compared to their internal combustion engine counterparts, there are some exceptions, like local government fleets. Comparable electric versions of fleet vehicles used by local governments, particularly medium- and heavy-duty vehicles, are not as readily available and are often prohibitively expensive.

The commercial fleet analysis described the lack of access to EV charging, the uncertainty about the total costs of installing charging infrastructure, and the uncertainty about energy costs of running EVs as the main barriers to commercial fleet electrification. The commercial use case analysis also proposes solutions to help alleviate the concerns of fleet managers for each commercial use case.

Finally, the project team conducted a combination of stakeholder meetings and a survey to refine and evaluate the draft strategies. The strategies were ranked in order of priority based on their effectiveness and urgency, assigned the relevant Metropolitan Council role, and placed in one of the following four buckets:

- Strategies to support additional EV charging infrastructure
- Strategies to increase EV availability
- Strategies on marketing, education, and outreach
- Strategies where further study is required

The Metropolitan Council and other relevant stakeholders can use the *Electric Vehicle Planning Study* recommendations to develop a strategic plan for EVs that describes potential Metropolitan Council and partner agency actions that advance EVs and EV charging. The *Electric Vehicle Planning Study* can also help prepare the seven-county region for EV funding

from the federal government as part of the Infrastructure Investment and Jobs Act and related funds.

As the Metropolitan Council implements the recommendations for increased EV uptake, it should ensure that the benefits of EV adoption are spread equitably. Local governments and partners should engage diverse stakeholders in policy design and implementation. The recommendations should be implemented to lower barriers to EV use for underserved communities and address EV stereotypes.

Maximizing the benefits of electric vehicles in the seven-county region requires implementers to understand the benefits and burdens of EV expansion and apply lessons learned from other EV acceleration efforts.

Selected Bibliography

This selected bibliography provides information on the sources used for the figures and tables.

Bennet, Jesse, Richard Fry, and Rakesh Kochhar. “Are You in the American Middle Class? Find out with Our Income Calculator.” Pew Research Center, August 3, 2021. https://www.pewresearch.org/fact-tank/2020/07/23/are-you-in-the-american-middle-class/.

Federal Highway Administration. *2018 HPMS Public Release of Geospatial Data in Shapefile Format*. November 2018. Shapefile. https://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm.

Kukkonen, Jukka. “EV Info List,” Shift2Electric (website), accessed March 9, 2022. https://www.shift2electric.com/evinfolist.

Metropolitan Council. *Equity Considerations for Place-Based Advocacy and Decisions in the Twin Cities Region*. Last updated March 5, 2021. Shapefile. https://gisdata.mn.gov/dataset/us-mn-state-metc-society-equity-considerations.

Metropolitan Council (website). “Travel Behavior Inventory.” Transportation. Accessed March 9, 2022. https://metrocouncil.org/Transportation/Performance/Travel-Behavior-Inventory.aspx.

Minnesota Department of Public Safety and Minnesota Pollution Control Agency. April 2021. Unpublished statewide vehicle registration data shared via secure email communication to Jessi Eidbo, April 2021.

Reed, Philip. “How Much Car Can You Afford? Understanding the Numbers.” *NerdWallet*, accessed March 9, 2022, https://www.nerdwallet.com/article/loans/auto-loans/much-spend-car.

US Census American Community Survey for 2019 5-year estimates (table B03002). https://data.census.gov/cedsci/.

US Census American Community Survey for 2019 5-year estimates (table B19013). https://data.census.gov/cedsci/.

US Census American Community Survey for 2019 5-year estimates (table C16002). https://data.census.gov/cedsci/.

US Department of Energy. “Electric Vehicle Charging Station Locations.” Alternative Fuels Data Center. Accessed November 10, 2021. https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC.

US Energy Information Administration. “Annual Energy Outlook 2020 | Table 2. Energy Consumption by Sector and Source.” https://www.eia.gov/outlooks/aeo/data/browser/#/?id=2-AEO2022&cases=ref2022&sourcekey=0.

Notes

[1] "Travel Behavior Inventory," Metropolitan Council (website), accessed March 9, 2022, https://metrocouncil.org/Transportation/Performance/Travel-Behavior-Inventory.aspx.

[2] "Metropolitan Planning Organization (MPO)," Metropolitan Council (website), accessed January 4, 2022, https://metrocouncil.org/Transportation/Planning-2/Transportation-Planning-Process/Metropolitan-Planning-Organization-(MPO).aspx.

[3] "What We Do," Metropolitan Council (website), accessed January 4, 2022, https://metrocouncil.org/About-Us/What-We-Do.aspx.

[4] "Community Development," Metropolitan Council (website), accessed January 4, 2022, https://metrocouncil.org/About-Us/What-We-Do/Departments/CommunityDevelopment.aspx.

[5] "What We Do," Metropolitan Council (website), accessed January 4, 2022, https://metrocouncil.org/About-Us/What-We-Do.aspx.

[6] Minnesota Department of Public Safety (unpublished statewide electric vehicle registration data shared via secure email communication to Jessi Eidbo, April 2021).

[7] "Part 2: Electrifying Seattle with Equity," Alternative Fuels Data Center, US Department of Energy, May 25, 2021, https://afdc.energy.gov/case/3102.

[8] Dale Hall and Nic Lutsey, *Emerging Best Practices for Electric Vehicle Charging Infrastructure* (The International Council on Clean Transportation, October 2017), https://theicct.org/sites/default/files/publications/EV-charging-best-practices_ICCT-white-paper_04102017_vF.pdf.

[9] Hall and Lutsey, *Emerging Best Practices for Electric Vehicle Charging Infrastructure*; Eric Wood, Clément Rames, Matteo Muratori, Sesha Raghavan, and Marc Melaina, *National Plug-In Electric Vehicle Infrastructure Analysis* (National Renewable Energy Laboratory, September 2017), https://www.nrel.gov/docs/fy21osti/78540.pdf; Simon Árpád Funke, Frances Sprei, Till Gnann, and Patrick Plötz, "How Much Charging Infrastructure Do Electric Vehicles Need? A Review of the Evidence and International Comparison," *Transportation Research Part D: Transport and Environment* 77 (December 2019): 224–42, https://doi.org/10.1016/j.trd.2019.10.024.

[10] Gordon Bauer, Chih-Wei Hsu, Mike Nicholas, and Nic Lutsey, *Charging Up America: Assessing The Growing Need For U.S. Charging Infrastructure Through 2030* (The International Council on Clean Transportation, July 28, 2021), https://theicct.org/sites/default/files/publications/charging-up-america-jul2021.pdf.

[11] Hall and Lutsey, *Emerging Best Practices for Electric Vehicle Charging Infrastructure.*

[12] Hall and Lutsey, *Emerging Best Practices for Electric Vehicle Charging Infrastructure.*

[13] Bauer, Hsu, Nicholas, and Lutsey, *Charging Up America*.

[14] Wood, Rames, Muratori, Raghavan, and Melaina, *National Plug-In Electric Vehicle Infrastructure Analysis.*

[15] Yanbo Ge, Christina Simeone, Andrew Duvall, and Eric Wood, *There's No Place Like Home: Residential Parking, Electrical Access, and Implications for the Future of Electric Vehicle Charging Infrastructure* (National Renewable Energy Laboratory, October 2021), https://www.nrel.gov/docs/fy22osti/81065.pdf.

[16] Wood, Rames, Muratori, Raghavan, and Melaina, *National Plug-In Electric Vehicle Infrastructure Analysis.*

[17] Wood, Rames, Muratori, Raghavan, and Melaina, *National Plug-In Electric Vehicle Infrastructure Analysis.*

[18] Urban houses include townhomes.

[19] Jesse Bennett, Richard Fry, and Rakesh Kochhar, "Are You in the American Middle Class? Find out with Our Income Calculator," Pew Research Center (website), August 3, 2021, https://www.pewresearch.org/fact-tank/2020/07/23/are-you-in-the-american-middle-class/.

[20] Philip Reed, "How Much Car Can You Afford? Understanding the Numbers," *NerdWallet*, accessed March 9, 2022, https://www.nerdwallet.com/article/loans/auto-loans/much-spend-car.

[21] Jukka Kukkonen, "EV Info List," Shift2Electric (website), accessed March 9, 2022, https://www.shift2electric.com/evinfolist.

[22] "2019 Travel Behavior Inventory Household Survey Results," Metropolitan Council.

[23] "2019 Travel Behavior Inventory Household Survey Results," Metropolitan Council.

[24] "2019 Travel Behavior Inventory Household Survey Results," Metropolitan Council.

[25] "Sustainability and Public Health," Electric Vehicles – MnDOT, accessed March 9, 2022. https://www.dot.state.mn.us/sustainability/electric-vehicles.html.

[26] Minnesota Housing, *Minnesota Overlay and Guide to the 2020 Enterprise Green Communities Criteria* (Minnesota Housing, April 2021), 18-19, https://www.mnhousing.gov/get/MHFA_247757.