Appendix A: Technical Appendix

a. GHG Mitigation Strategies

In order to maximize reduction of CO_2e, our project leverages a combination of technological and behavioral strategies to reduce emissions from the grid and transportation system. Our approach aligns with and is informed by the findings of the IPCC's Fifth Assessment Report. The IPCC Climate Change 2014 Synthesis Report ("Synthesis Report") states that "In the transport sector, technical and behavioural mitigation measures for all modes, plus new infrastructure and urban redevelopment investments, could reduce final energy demand significantly below baseline levels."[1] The Synthesis Report highlights "car sharing" and "fuel-switching to low-carbon fuels" as specific mitigation strategies.[2]

This approach is further developed in IPCC's Climate Change 2014 Mitigation of Climate Change Report ("Mitigation Report"). Carsharing is specifically cited in the Mitigation Report as a strategy for achieving transportation decarbonization: "Demand-responsive, flexible transit, and car sharing services can have lower GHG emissions per passenger kilometre with higher quality service than regional public transport."[3] In a section on transport technologies and practices, the Mitigation Report specifically notes "community car sharing" with electric vehicles powered by renewable energy as a strategy to support fuel carbon intensity reduction through fuel switching, while noting that the barriers to implementation of this strategy include high battery costs for electric vehicles, "lack of infrastructure," and "range anxiety."[4] Finally, the Mitigation Report underscores the significance of mode shift (shifting of vehicle miles traveled, or VMT, from light-duty vehicles to transit, non-motorized (biking and walking), and batched or foregone trips) as a high-impact strategy: "Avoided journeys and modal shifts due to behavioural change, uptake of improved vehicle and engine performance technologies, low-carbon fuels, investments in related infrastructure, and changes in the built environment, together offer high mitigation potential."

In keeping with the approach outlined in the IPCC Fifth Assessment Report, our project will implement three specific mitigation strategies with proven effectiveness at reducing carbon emissions.

Mitigation Strategy 1: **Increase access to electric carshare fueled by renewable energy.** Our project will add 450 new electric carshare vehicles, significantly expanding access to electric carshare for area residents. Carshare is an ideal strategy for mitigating the barrier of the high cost of electric vehicles. Carsharing is akin to fractional ownership, whereby a group of users gain shared access to an asset without any one user having to front the cost, and as such is an ideal strategy for overcoming the barrier of high battery/vehicle costs.

Mitigation Strategy 2: **Increase access to public charging infrastructure powered by renewable energy.** Our project will add 95 highly-visible public charging stations with 190 dedicated Level 2 carshare charging ports, and an additional 190 Level 2 public charging ports, for a total of 380 ports. All charging hubs will be powered by 100% renewable energy and placed in the public right-of-way or in highly visible locations on public property such as parks, libraries and community centers. These charging stations mitigate the lack of charging infrastructure and reduce range anxiety (through high visibility to consumers), two of the main barriers to adoption of electric vehicles. We will procure Renewable Energy

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[1] Climate Change 2014 Synthesis Report, https://archive.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf, p. 100.
[2] Ibid, p. 101.
[3] https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf, p. 619.
[4] Ibid, p. 634.

Credits (RECs) from Xcel Energy, the local electric utility, to ensure that all electricity is from 100% renewable sources.

Mitigation Strategy 3: **Co-locate electric carshare hubs with rapid transit (BRT/LRT).** Our project will co-locate carshare hubs at or adjacent to current and planned high-frequency transit (HFT) lines, including Bus Rapid Transit (BRT) and Light Rail Transit (LRT). In a section on "Modal Shift Opportunities for Passengers," the IPCC Mitigation Report notes that "Small but significant modal shifts from LDVs to bus rapid transit (BRT) have been observed where BRT systems have been implemented."[5] These shared electric vehicles at HFT stations will serve as "transit extenders," increasing efficiency and speed, multiplying the number of destinations reachable by transit, and enhancing the mode-shift potential of rapid transit.

b. Reference Case

Our accompanying GHG Emission Reduction Calculations Spreadsheet ("GHG Spreadsheet") includes a reference case scenario (GHG Spreadsheet "Reference Case" tab). This scenario was constructed using assumptions from FHWA, the Minnesota Department of Transportation, and the 2023 Minnesota Clean Transportation Standard Workgroup report. The scenario incorporates the following assumptions:

1. Baseline VMT of 2,140,943,350 annually in Minneapolis and 1,740,992,018 in Saint Paul, for a total of 3,881,935,368.[6]
2. Annual VMT increases of 0.6% per FHWA projections.[7]
3. Baseline carbon intensity of 0.88 pounds per VMT per EPA data,[8] declining to 95% of baseline by 2030, 85% by 2040, and 70% by 2050 in alignment with the "business as usual" (BAU) case in the Minnesota Clean Transportation Standard Workgroup report[9] ("GHG Spreadsheet "Carbon Intensity of Fuels" tab). The BAU case contains the following assumptions:
    a. No Clean Transportation Standard program in the state of Minnesota
    b. E15 blends continue to increase at their current rates
    c. E85 blends continue at their current volumes.
    d. Carbon intensity of ethanol would start at 2022 levels over the course of the analysis with a modest 1.2% decrease in the direct emissions year-over-year (i.e., there was no assumed uptake of climate smart agriculture practices to lower the carbon intensity of ethanol consumed in Minnesota nor was there consideration of carbon capture and storage deployment)
    e. The biodiesel blending mandate remains in place and most of the feedstock used to produce the biodiesel that is consumed in Minnesota is from soybean oil
    f. There is no renewable diesel consumed in Minnesota
    g. There is no SAF consumed in Minnesota
    h. Zero emission vehicles in the light-duty sector are adopted consistent with Minnesota Clean Cars Rule and then modest growth thereafter

[5] Ibid. p. 620.
[6] Cf. https://www.dot.state.mn.us/roadway/data/reports/vmt/22_ccr.pdf pp. 56, 116.
[7] https://www.fhwa.dot.gov/Policyinformation/tables/vmt/2023_vmt_forecast_sum.pdf.
[8] 0.88 pounds = 400 grams per mile driven; cf. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017FP5.pdf.
[9] https://www.dot.state.mn.us/sustainability/clean-transportation-fuel-standard-working-group.html. It is unknown from the report whether the BAU case includes non-CPRG incentives suchas IRA, BIL, or CHIPS.

i. Zero emission vehicles in the heavy-duty sector are adopted at a rate consistent with projections used in the Moderate Case
j. The average grid electricity was assumed to decrease over time consistent with Minnesota renewable portfolio standard; however, no additional options for reducing the carbon intensity of electricity or hydrogen using other technologies were considered.

Using this model, we estimate that our project will reduce GHG emissions from transportation in Minneapolis and Saint Paul by 2.1% by 2030, and 6.8% by 2050.

c. GHG Reduction Measures

We will implement two measures from the State of Minnesota's Priority Climate Action Plan (PCAP). We describe our methodology, baseline assumptions, and sources below; our full calculations are contained in the accompanying GHG Spreadsheet.

1. **Measure 1.1.2 – Improve equitable access to electric vehicle charging infrastructure**
   Implementing this measure will reduce GHG through the following mechanisms:
   A. Fuel switching to 100% renewable energy: Increased access to conveniently located public charging ports powered by 100% renewable energy will lead to replacement of kilowatt hours (kWh) generated using Xcel Energy's Upper Midwest Energy Mix (69% carbon-free, including 41% renewables) to charge personally-owned electric vehicles with kWh generated by 100% renewable sources.
   B. Accelerated adoption of personally-owned electric vehicles: Highly visible public charging infrastructure will lead to decreased range anxiety and accelerated adoption of personally-owned electric vehicles by purchasers.
2. **Measure 1.2.3 Facilitate equitable access to electric vehicle car-share programs**
   Implementing this measure will reduce GHG through the following mechanisms:
   A. Direct replacement of VMT: Increased access to electric carshare will lead to replacement of trips and VMT in internal-combustion engine (ICE) vehicles with trips and VMT in electric carshare vehicles powered by renewable energy.
   B. Mode shift/behavior change: Increased access to electric carshare will lead to car-shedding/deferred purchasing of personally-owned autos and increased use of less carbon-intensive modes, including transit, non-motorized (biking and walking), and batched/foregone trips.
   C. Accelerated adoption of personally-owned electric vehicles: Increased visibility of and familiarity with electric vehicles will lead to increased consumer preference for and accelerated adoption of personally-owned electric vehicles by purchasers.

1. Measure 1.1.2 – Improve equitable access to electric vehicle charging infrastructure

A. Fuel switching to 100% renewable energy

As a direct result of increased access to conveniently-located public charging ports powered by 100% renewable energy, drivers will charge their vehicles with kWh generated by 100% renewable sources, replacing kWh generated using Xcel Energy's Upper Midwest Energy Mix (currently 69% carbon-free, including 41% renewables). We estimate replacement of 2,159,829 kWh reducing 446 metric tons (mT) CO_2e by 2030, and 82,125,269 kWh reducing 1,452 mT CO_2e, by 2050 (GHG Spreadsheet "GHG Reductions," "Public Charging Ports" tabs).

We base our estimates of public charging uptake and utilization on an economic analysis of EVSE charging developed for the City of Saint Paul by the Electrification Coalition. This analysis incorporated national and local charge session data to model anticipated uptake of new charging infrastructure. Based on this analysis, we assume the following (GHG Spreadsheet "Assumptions" tab):

1. Estimated charge sessions per Level 2 charge port in Year 1: 0.25 (one charge per port every fourth day) based on local and national data.
2. Estimated average dwell time: 2 hours
3. Estimated usage growth: 15% year-over-year based on an NYSERDA study,[10] maxing out at a functional ceiling of six charge sessions (=12 hours) per day.
4. Average energy per charging session: 23 kWh (calculated based on assumption of two-hour dwell time).

We corroborated this projection by comparing it to data from the current EV Spot public charging network. In year two of the project, the public charging stations averaged 0.3 charge sessions per port per day, which is on projection (baseline assumption of 0.25 sessions per port per day x 15% increase per year = 0.29 sessions per port per day).

We calculated GHG emissions per kWh using a baseline assumption of 0.604 pounds GHG per kWh per Xcel Energy's most recent carbon intensity report.[11] Carbon intensity declines to zero by 2040 per Minnesota's new law requiring carbon-free electricity by 2040[12] (GHG Spreadsheet "Carbon Intensity of Fuels" tab).

We calculated the GHG reduction from charging with 100% renewable energy as the full emissions from electricity generation using Xcel Energy's Upper Midwest Mix on a per-kWh basis.

B. Accelerated Adoption of Electric Vehicles (Access to Public Charging)

As a direct result of placing highly visible and accessible public charging infrastructure located in the public right-of-way and off-street in public locations such as parks, libraries, and community centers, our project will lead to decreased range anxiety and facilitate accelerated adoption of electric vehicles (i.e., increased initial purchasing of electric vehicles over and above purchases that would have happened in the absence of project activities). We estimate that this will lead to adoption of 715 personally-owned electric vehicles by 2030, achieving CO_2e reduction of 6,577 mT, and 4,515 personally-owned electric vehicles by 2050, achieving CO_2e reduction of 201,364 mT (GHG Spreadsheet "Adoptions," "GHG Reductions" tabs). We arrived at this estimate as follows:

1. We estimate that each Level 2 public charging port placed in service will result in approximately one induced adoption of a personally-owned electric vehicle per year (GHG Spreadsheet "Assumptions" tab). We base this estimate on the findings of researchers Shuping Wu and Zan Yang, who in a 2020 study found that every charge port placed into service results in increased electric vehicle purchasing at a rate equivalent to about one new electric vehicle purchase

[10] https://www.nyserda.ny.gov/All-Programs/ChargeNY/Support-Electric/Data-on-Electric-Vehicles-and-Charging-Stations.
[11] https://www.xcelenergy.com/staticfiles/xe-responsive/Environment/Carbon/Carbon-Emission-Intensities-Info-Sheet.pdf
[12] https://mn.gov/commerce/news/?id=17-563384.

annually per charge port.[13] Additional research further supports the assertion that increased public charging infrastructure induces additional electric vehicle purchasing:

a. "The Market for Electric Vehicles: Indirect Network Effects and Policy Design," by Shanjun Li, Lang Tong, Jianwei Xing, Yiyi Zhou, found that constructing public charging had over twice the impact dollar for dollar as purchase incentives on electric vehicles.[14]
b. "The role of demand-side incentives and charging infrastructure on plug-in electric vehicle adoption: analysis of US States" by Easwaran Narassimhan and Caley Johnson, found that "The presence of public charging infrastructure has a strong influence on vehicle purchases decisions."[15]

2. To measure annual emissions reductions for each EV adoption, we used the following calculations:
    a. We assumed baseline carbon intensity of a kilowatt hour (kWh) generated using Xcel Energy's Upper Midwest Mix[16] (69% carbon-free, including 41% renewables) to be 0.604 pound of CO_2e per Xcel's most recently published report on carbon intensity[17] (cf. the "Carbon Fuels Intensity" tab). We used this assumption for year one, projecting straight-line decline of carbon intensity through 2040 in view of Minnesota's 100% carbon-free electricity law, which mandates carbon-free electricity generation in the state by 2040.[18]
    b. We estimated the average electric vehicle fuel economy to be 3.25 miles per kWh[19] (GHG Spreadsheet "Assumptions" tab).
    c. We assumed that each adopted electric vehicle would be driven 11,467 miles annually based on FHWA averages[20] (GHG Spreadsheet "Assumptions" tab).
    d. We calculated baseline carbon intensity of an average passenger vehicle as 0.88 pounds per passenger mile per EPA data.[21] We used this assumption for year one, declining to 95% of baseline by 2030, 85% by 2040, and 70% by 2050 in alignment with the "business as usual" case in the Minnesota Clean Transportation Standard Workgroup report[22] ("GHG Spreadsheet "Carbon Intensity of Fuels" tab).

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[13] "Availability of Public Electric Vehicle Charging Pile and Development of Electric Vehicle: Evidence from China" (https://www.mdpi.com/2071-1050/12/16/6369). Using a regression analysis to control for other purchasing factors, the authors found that "one standard deviation change in the number of public charging piles [ports] would cause about a 1.5% standard deviation change in the sales of electric vehicles in the next month." Dr. Saif Benjaafar, former head of the Department of Industrial and Systems Engineering at the University of Minnesota, analyzed the underlying equations and concluded that this would translate to a 0.5 vehicle per month increase in sales for every 6.75 charging ports constructed, a ratio of annual vehicle sales to charging ports of 0.9:1.

[14] https://www.journals.uchicago.edu/doi/full/10.1086/689702.

[15] https://iopscience.iop.org/article/10.1088/1748-9326/aad0f8 p. 9.

[16] https://mn.my.xcelenergy.com/s/energy-portfolio/power-generation.

[17] https://www.xcelenergy.com/staticfiles/xe-responsive/Environment/Carbon/Carbon-Emission-Intensities-Info-Sheet.pdf.

[18] https://mn.gov/commerce/news/?id=17-563384.

[19] "On average, modern electric cars have an efficiency of 3 to 3.5 miles (4.8 to 5.6 kilometers) per kWh" (cf. https://justwe-gpi.com/ev-charging/electric-car-mileage/). The Nissan Leaf has a fuel economy of 3.3 miles per kwh (https://www.fueleconomy.gov/feg/noframes/46016.shtml), and the Chevy Bolt has a fuel economy of 3.6 miles per kwh (https://www.fueleconomy.gov/feg/noframes/45751.shtml).

[20] https://www.fhwa.dot.gov/policyinformation/statistics/2018/pdf/vm1.pdf

[21] 0.88 pounds = 400 grams per mile driven; cf. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017FP5.pdf.

[22] https://www.dot.state.mn.us/sustainability/clean-transportation-fuel-standard-working-group.html.

e. We calculated the annual GHG reduction per electric vehicle adoption as the emissions of a gas-powered vehicle driven 11,467 miles minus the emissions from electricity generation to power an electric vehicle driven the same number of miles (GHG Spreadsheet "Carbon Intensity of Fuels" tab).

2. Measure 1.2.3 Facilitate equitable access to electric vehicle car-share programs

A. Direct Replacement of Vehicle Miles Traveled

As a direct result of implementing the carshare service, trips taken in electric vehicles powered by renewable energy will replace trips that would otherwise have been taken in gas-powered vehicles. By 2030, we estimate that our project will replace 27,604,260 VMT in gas-powered vehicles with trips in electric vehicles fueled by 100% renewable energy, reducing 10,648 mT GHG, and by 2050 our project will replace 180,726,660 VMT and reduce 61,455 mT GHG (GHG Spreadsheet "Annual Mileage," "GHG Reductions" tabs). We arrived at this estimate as follows:

1. Miles per trip (cf. the "Annual Mileage" tab):
    a. One-way: we estimate that each trip in a one-way (free-floating) electric vehicle will average 10.2 miles, based on internal data provided by project partner HOURCAR. In the first two years of the Evie Carshare program, users took 184,351 trips spanning 1,882,767 miles, for an average of 10.2 miles per trip.
    b. Round trip: we estimate that each trip in a round-trip (two-way or "return to base") electric vehicle will average 44 miles, based on internal data provided by project partner HOURCAR. Over a three-year period from 2021-2023, users took 64,683 trips spanning 2,845,370 miles, for an average of 44 miles per trip.
2. Annual trips per vehicle: our calculation is based on a model developed and used by project partner HOURCAR to forecast usage based on historical data. The model includes variables such as the "vintage" year of each vehicle (i.e., what year the vehicle was put into service) and the percentage of the total fleet that is available for use at any given time given that a certain number of vehicles will always be unavailable due to maintenance, low charge, or other factors. We use differing assumptions for one-way and round-trip vehicles to account for the unique characteristics of each type of service.
    a. To estimate annual one-way trips (GHG Spreadsheet "One-Way Trips" tab), we used the following calculation:
        i. Take the average number of vehicles in the one-way fleet in a given year (calculated as the average of the number of vehicles at the beginning of the year and at the end of the year)
        ii. Multiply this by the estimated percentage of vehicles in service (i.e., the percentage of the total fleet that is available for use at any given time given that a certain number of vehicles will be unavailable due to maintenance, low charge, or other factors). For the one-way fleet, we estimate 70% average fleet availability (HOURCAR's average availability for the Evie fleet in 2023 was 67.3%).
        iii. Calculate the average number of trips per month for each vehicle by "vintage" (i.e., what year the vehicle was put into service), with the assumption that vehicles put into service in a given year increase in usage over time as the market matures. We estimate three trips per available vehicle per day in the first year,

four trips in the second year, and so on up to six trips per available vehicle per day in years four and following. This calculation is corroborated by HOURCAR's experience with the Evie fleet; in the second year of the service, the fleet (which consists of a mix of first- and second-year vintage vehicles) averaged 3.6 trips per available vehicle per day.

   b. To estimate annual trips in round-trip/two-way vehicles, (GHG Spreadsheet "Two-Way Trips" tab), we used the following calculation:
      i. Take the average number of vehicles in the round-trip fleet in a given year.
      ii. Multiply this by the estimated percentage of vehicles in service. For the round-trip fleet, we estimate 85% average fleet availability. This is higher than the estimate for the one-way fleet given the particularities of round-trip vs. one-way carsharing (each round-trip vehicle has its own dedicated charging port). HOURCAR's average availability for its two-way fleet in 2023 was 85.3%.
      iii. Calculate the average number of trips per month for each vehicle by "vintage." We estimate one trip per available vehicle per day in the first year and 1.5 trips in years two and following. HOURCAR's round-trip fleet (which has been operational for many years) averages 1.6 trips per vehicle per day.

3. Annual mileage: total estimated miles driven per year (GHG Spreadsheet "Annual Mileage" tab) is calculated as the product of the total number of trips per year for the one-way and two-way services, multiplied by the average miles per trip for each service.
4. To estimate the GHG impact of replacing miles traveled in ICE vehicles with miles traveled in EVs powered by renewable energy, we used the following calculations.
   a. We calculated baseline carbon intensity of an average passenger vehicle as 0.88 pounds per passenger mile per EPA data.[23] We used this assumption for year one, declining to 95% of baseline by 2030, 85% by 2040, and 70% by 2050 in alignment with the "business as usual" case in the Minnesota Clean Transportation Standard Workgroup report[24] ("GHG Spreadsheet "Carbon Intensity of Fuels" tab).
   b. We calculated the total GHG reduction of replacing miles in gas-powered vehicles with miles in electric vehicles powered by renewable energy as the full estimated GHG emissions of the gas-poowered vehicles (GHG Spreadsheet "Direct Replacement of VMT" tab).

B. Behavior Change Leading to Mode Shift

Increased access to electric carshare and placement of electric carshare vehicles alongside high-frequency transit lines will enable an estimated 22,500 households by 2030 and annually thereafter to reduce their reliance on personally-owned vehicles and shift approximately 35% of their VMT to transit, non-motorized travel (biking and walking), and batched and/or foregone trips (GHG Spreadsheet "Member Growth" tab). This will achieve CO_2e reduction of 63,707 mT between 2025 and 2030, and 436,307 mT between 2025 and 2050 (GHG Spreadsheet "GHG Reduction" tab).

Carsharing has demonstrated ability to achieve substantial GHG reduction through "mode shift." As a result of access to carsharing, households either dispose of currently-owned vehicles or defer purchase of vehicles that they otherwise would have acquired in the absence of carsharing. These behaviors are

[23] 0.88 pounds = 400 grams per mile driven; cf. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017FP5.pdf.
[24] https://www.dot.state.mn.us/sustainability/clean-transportation-fuel-standard-working-group.html.

collectively referred to as "car-shedding." Carshare users who shed vehicles shift significant amounts of VMT to other modes of travel, primarily public transit, but also non-motorized travel (biking/walking) and batched or foregone trips., reducing emissions on a per-passenger-mile basis.

There is robust evidence for the efficacy of carsharing to induce mode shift. As FHWA notes in its "Congestion Mitigation and Air Quality Improvement (CMAQ) Program 2020 Cost-Effectiveness Tables Update," carsharing "enables households to carry out travel activities while reducing the number of cars owned by households, both of which may result in decreases in VMT through eliminating some discretionary trips and mode shift to public transit."[25] The quantitative benefits of carsharing have been extensively analyzed by Susan Shaheen and her collaborators at UC Berkeley's Transportation Studies Research Center. Studies by Shahen et al have demonstrated that carshare users shed vehicles and/or defer vehicle purchases and take more trips using transit, biking, and walking. Findings from five studies by Shaheen and her collaborators are summarized in the Transportation Research Center's "Mobility and The Sharing Economy: Impacts Synopsis."[26] Among their findings are that:

1. 50% of carshare users either shed a vehicle or deferred an auto purchase. Project partner HOURCAR's internal data suggests a higher figure: in a 2024 survey of carshare members with 648 respondents, 77% indicated that they either shed a vehicle (29%) or deferred an auto purchase (48%).
2. As a result of car-shedding, every carshare vehicle put into service suppresses 9-13 private vehicle purchases.
3. Carshare users reduce household VMT by 27%-43% (mean 35%).

A recent (2023) study of the BlueLA program in Los Angeles by Shaheen, Elliot Martin, and Ziad Yassine reaffirmed these findings. BlueLA is a carsharing program that shares many similarities with the Evie Carshare program in the Twin Cities, including use of all-electric vehicles and a focus on service to disadvantaged communities. Shaheen, Martin and Yassine found that:

1. Each BlueLA carshare vehicle put into service suppresses 16 private vehicle purchases (p.10).
2. Users of the BlueLA service reduced their household VMT by 34% (p. 11).

To estimate GHG reductions as a result of mode shift and reduced household VMT, we made the following calculations:

1. We estimate that each vehicle put into service will be used by 25 users in the first year, 40 in the second year, and maxing out at 50 in the third year and each subsequent year thereafter (GHG Spreadsheet. "Member Growth" tab). Shaheen and Martin's seminal 2011 study "Greenhouse Gas Emission Impacts of Carsharing in North America" found an average 50 members per vehicle for North American carshare services,[27] and the 2023 BlueLA study referenced above found 51 members per vehicle.[28]

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[25] Cf. https://www.fhwa.dot.gov/ENVIRonment/air_quality/cmaq/reference/cost_effectiveness_tables/fhwahep20039.pdf p. 35)

[26] http://innovativemobility.org/wp-content/uploads/Innovative-Mobility-Industry-Outlook_SM-Spring-2015.pdf

[27] "…an estimated 378,000 carsharing members sharing approximately 7,500 vehicles in North America." 378,000 ÷ 7,500 = 50.4 average members per vehicle. Cf. https://escholarship.org/content/qt6wr90040/qt6wr90040_noSplash_e366483edc74bed2c6d6630c113452ac.pdf?t=psbfuu p.1.

[28] Shaheen et al reported that BlueLA had "3074 registered users" (p. 1) and "60 Chevrolet Bolt EVs" (p. 2). 3074 ÷ 60 = 51.2 average members per vehicle.

2. We estimate that each carshare member will reduce household VMT by 35% (GHG Spreadsheet "Assumptions" tab), the mean of the high-end and low-end estimates (43% and 27% respectively) in Shaheen's "Impacts Synopsis," and the close equivalent of the BlueLA study's VMT reduction estimate (34%).
3. We assume annual VMT per household of 9,000 miles (GHG Spreadsheet "Assumptions" tab), the per capita average VMT in the Twin Cities area as per the 2023 study "Motorization Trends in Minnesota" by the Transportation Policy and Economic Competitiveness program of the University of Minnesota.[29] A 35% reduction is equivalent to an average household reduction of 3,150 VMT. Given that 75% of households surveyed reported that carsharing enabled them to shed or defer purchase of at least one personally-owned auto, and that the average personally-owned auto is driven 11,467 miles annually per FHWA statistics,[30] this is a conservative estimate.[31]
4. We calculated baseline carbon intensity of an average passenger vehicle as 0.88 pounds per passenger mile per EPA data.[32] We used this assumption for year one, declining to 95% of baseline by 2030, 85% by 2040, and 70% by 2050 in alignment with the "business as usual" case in the Minnesota Clean Transportation Standard Workgroup report[33] ("GHG Spreadsheet "Carbon Intensity of Fuels" tab).
5. We estimated baseline marginal emissions from transit as a result of mode shift at 0.4 pounds CO_2E per passenger-mile in 2025 by averaging the reported emissions per passenger-mile of the 15 largest US transit agencies found in the 2022 study "An Economic Analysis of U.S. Public Transit Carbon Emissions Dynamics" by Huang and Kahn.[34] We used this figure for year one, declining to zero by 2050.[35]
6. We calculated emissions reductions from mode shift as VMT reduced multiplied by GHG emissions from gas-powered vehicles per mile minus marginal emissions from transit (i.e., VMT reduced times transit carbon intensity per passenger-mile; GHG Spreadsheet "Mode Shift" tab). This is a very conservative estimate, for the following reasons:

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[29] Cf. https://tpec.umn.edu/sites/tpec.umn.edu/files/2023-06/Motorization_June%202023.pdf p. 12.
[30] Cf. https://www.fhwa.dot.gov/policyinformation/statistics/2018/pdf/vm1.pdf.
[31] We note here that some studies have found lower rates of VMT reduction among users of carsharing; for example, a 2016 study by Shaheen and Martin found that US users of the car2go carsharing network reduced VMT by an estimated 11% (cf. https://innovativemobility.org/wp-content/uploads/2016/07/Impactsofcar2go_FiveCities_2016.pdf Table 9). These differing results are likely attributable to the diluting effect of higher member counts per vehicle as a result of a looser definition of membership by car2go. As noted above, the average ratio of members per vehicle for Shaheen and Martin's 2011 study and Yassine, Martin and Shaheen's 2023 study was 50:1. Car2go reported a member to vehicle ratio of >200:1 in 2017 (archived: https://web.archive.org/web/20200401120928/https://www.car2go.com/media/data/germany/microsite-press/files/factsheet-car2go_november-2017_en.pdf; 2.9 million members ÷ 14,000 vehicles = 207 members per vehicle). A 35% VMT reduction per member is therefore appropriate when assuming a 50:1 member to vehicle ratio.
[32] 0.88 pounds = 400 grams per mile driven; cf. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017FP5.pdf.
[33] https://www.dot.state.mn.us/sustainability/clean-transportation-fuel-standard-working-group.html.
[34] Cf. https://www.nber.org/system/files/working_papers/w29900/w29900.pdf Table 5.
[35] Metro Transit's 2022-2027 Zero Emission Bus ZEB) plan includes a target that at least 20% of Metro Transit's 40-foot bus replacement procurements will be electric. The plan includes a "Case study summary" benchmarking Metro Transit's plan against four comparably-sized transit agencies, all of which have commitments to achieve zero emissions in either 2035 or 2040. Reducing carbon intensity of transit to zero by 2050 is a reasonable estimate based on the evidence. Cf. https://www.metrotransit.org/Data/Sites/1/media/about/improvements/electric_buses/220210_zebtp_finalreport.pdf p. 4.

a. This calculation assumes that 100% of VMT are shifted from personally-owned vehicles to transit. In reality, some portion of these VMT would be shifted to walking, biking, and batched or foregone trips.
b. Because transit is generally underutilized, adding more riders is unlikely to result in increased marginal emissions, especially when these new riders are spread out over a wide area. For this reason, none of the studies of carsharing referenced above factor in marginal emissions from transit.

C. Accelerated Adoption of Personally-Owned Electric Vehicles (Increased Familiarity)

As a direct result of increasing the visibility and familiarity of electric vehicles through the carshare service, our project will facilitate accelerated adoption of electric vehicles. We estimate that implementing the carshare service will lead to adoption of 2,604 personally-owned electric vehicles by 2030 achieving CO_2e reduction of 25,672 mT, and 15,204 personally-owned electric vehicles by 2050, achieving CO_2e reduction of 688,617 mT (GHG Spreadsheet "Adoptions," "GHG Reduction" tabs). We arrived at this estimate as follows:

1. By making electric vehicles highly visible through the distinctive Evie Carshare brand, and by familiarizing thousands of residents with electric vehicles who otherwise would have been unlikely to try one due to high up-front cost, our project will have substantial "knock-on" effects in the form of increased adoption of EVs. Many users of electric carshare will eventually go on to purchase a vehicle because of a move or other life changes (Cf. "Paula's" story in the main narrative). These users have substantially increased likelihood of purchasing an electric vehicle; according to a study by JD Power and Associates, 46% people who have previously owned or leased an EV are "very likely" to purchase one in the future.[36] A recent study of the BlueLA electric carshare service in Los Angeles by Jonathan Lingober and Ruizi Song, aptly titled "Familiarity Facilitates Adoption," found that BlueLA "is associated with a 33% increase of new EV adoptions" in the zip codes where the service operates.[37] Averaging comparison effects from three different regression analyses,[38] this study found that the BlueLA service, which operated 100 shared electric vehicles during the period studied, [39] resulted in 137 induced adoptions per year, or 1.37 adoptions per vehicle, after the first year of operation.[40] Based on this analysis, we estimate that each electric carshare placed in service will result in 1.4 "induced" or accelerated adoptions per year beginning in the second year from vehicle in-servicing (GHG Spreadsheet "Assumptions" tab).
2. We calculated the GHG reductions for each EV adoption using the same methodology outlined above in the section above on "Accelerated Adoption of Electric Vehicles (Access to Public Charging)" 2.a-e: the emissions of a gas-powered vehicle driven 11,467 miles minus the emissions from electricity generation to power an electric vehicle driven the same number of miles (GHG Spreadsheet "Carbon Intensity of Fuels" tab).

[36] https://www.jdpower.com/business/press-releases/2021-us-electric-vehicle-consideration-evc-study
[37] https://arxiv.org/pdf/2211.14634.pdf
[38] Cf. "Induced Annual EV Adoption" in Table 4, "Comparison between Specifications, Main Results on the Influence of BlueLA Charging Stations on Adoption of EVs, Ibid. p. 20.
[39] The authors of the study erroneously state that BlueLA has "as of with [sic] currently over 300 cars." While BlueLA has plans to eventually expand to 300 vehicles, it has not to date reported operating more than 100 vehicles per year. In April 2019, BlueLA reported a fleet size of 68 vehicles with 100 planned for Phase 1 (cf. https://live-sumclearningcenter.pantheonsite.io/wp-content/uploads/NewFile_SUMC_04.15.19.pdf p.2, 3). As of August 2021, it was reporting a fleet size of 100 vehicles (cf. https://ww2.arb.ca.gov/sites/default/files/2021-07/discussiondoc_08042021.pdf p. 50). As of September 2022, it was still reporting a fleet size of 100 vehicles (cf. https://clkrep.lacity.org/onlinedocs/2021/21-0890_rpt_09-30-22.pdf p.3).
[40] "[W]hen analyzing the trend over time, we see that the effect takes approximately one year to show up." Ibid, p. 3.