Carbon Reduction Analysis for CSAH 2 Improvements including the Installation of 2 EVCS, Redwood County, Minnesota

Methodology

Installing electrical vehicle charging stations (EVCS) encourages and facilitates the use of electric vehicles (EV) and can therefore serve as a mitigation for greenhouse gas (GHG) emissions, primarily carbon dioxide (CO_2). Plug-in electric vehicles (and plug-in hybrid electric vehicles) use electricity to propel the vehicle rather than an internal combustion engine that utilizes fossil fuels such as gasoline or diesel. While there are still GHG emissions related to the off-site fuel generation for EVs (usually referred to as upstream emissions), these are more than off-set by the reduction of tailpipe emissions compared to conventional vehicles.

Methodology for evaluating EVCS as part of carbon reduction or GHG emission mitigation has been well-established by programs such as the California Environmental Quality Act (CEQA), where there is a longer history of emissions reporting and quality standards.[1] Similar methodology is utilized here to evaluate the impact in carbon reduction in Redwood County by installing 2 EVCS (1 Level 2 station with 2 ports and 1 Level 3 station with 2 ports) as part of the proposed County State Aid Highway (CSAH) 2 Improvements Project. Under this approach, evaluating carbon reduction associated with the installation of an EVCS assesses the following variables:

- Location
  - This is primarily in relation to the average vehicle usage for the area and the number of conventional fossil-fuel vehicles versus EVs. A recent study found that the location of EVCS is not a significant factor in the utilization of the station, except in cases where the charging station may reflect utilization by an associated commercial fleet (i.e. by a corporate building with dedicated EVs).[2]
- Charger Type and Utilization
  - As it relates to energy demand and the amount of time required for the charger to fully charge a standard EV.
- Average Fuel Efficiency
  - Expressed as miles per gallon for gas-powered vehicles (26mpg as of 2022)
  - Expressed as kWh per mile for electric vehicles (0.45 kWh per mile as of 2022)
- Total Emissions
  - The sum of both tailpipe and upstream emissions
  - Totals expressed as average annual metric tons of CO_2 or CO_2 equivalent ($MTCO_2e$)

Location

While the exact locations for the proposed EVCS have not yet been determined, the project area includes approximately 9.8 miles along County State Aid Highway (CSAH) 2 from the junction of CSAH 2 and CSAH 24 to Reetz Street at the northern limits of the City of Morgan in Redwood County, Minnesota. CSAH 2 is the primary roadway between the City of Morgan and the Lower Sioux Indian Community. Land use in this area is primarily agricultural with associated farmsteads, but also includes the Dacotah Ridge Golf Course, located on the west side of CSAH 2, and part of the Lower Sioux Indian Community in the northwestern part of the project area. Wabasha Creek crosses CSAH 2 and enters into

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[1] ICF. 2018. "Electric Vehicle Charging Stations as CEQA Mitigation: Greenhouse Gas Reductions and Cost Effectiveness." Submitted to Santa Clara County. Electronic document, https://dtnz.sccgov.org/sites/g/files/exjcpb481/files/Task-3D-EV-Charging-Stations-as-GHG-Mitigation-Mechanism-under-CEQA_White-Paper.pdf, accessed February 2023.

[2] Brennan Borlaug, Fan Yang, Ewan Pritchard, Eric Wood, and Jeff Gonder. 2023. Public electric vehicle charging station utilization in the United States. *Transportation Research Part D: Transport and Environment*, Vol. 114. Electronic document, https://doi.org/10.1016/j.trd.2022.103564, accessed January 2024.

the area of the golf course in the northern half of the project area. The Minnesota River is located approximately 0.25 miles to the north and the Cedar Mountain Scientific and Natural Area is located approximately 0.3 miles to the east.

The Minnesota Department of Transportation (MnDOT) provides data on the average annual daily traffic (AADT) on CSAH 2, based on data collected in 2019, for the following segments: City of Morgan to CSAH 11 (AADT = 900), CSAH 11 to Ranch Ave (AADT = 750), Ranch Ave to CSAH 13 (AADT = 1,250), and CSAH 13 to TH 19 (AADT = 2,450).[3] The average AADT based on data from all of these segments is 1,338. To determine the number of vehicles in the area that are EVs and how many are conventional fossil-fuel vehicles, data on vehicle registration in 2022 provided by EValuateMN was referenced. According to this resource, as of November 2023, there were 47,682 EVs registered in Minnesota (0.64% of light-duty vehicles) with the vast majority in the metro area. This is likely a reflection of the fact that the majority of EVCS are also in the metro area. Only 16 EVs were registered in Redwood County (0.07% of light-duty vehicles), compared to 22,748 gas-powered light-duty vehicles that were registered in the same time frame (99.93%).[4]

Charger Type and Utilization

EVCS are categorized under the following types based on charger capability:[5,6]

- Level 1- Uses standard 120 VAC outlet and requires 7-29+ hours to fully charge; typically can only support single use
- Level 2- Uses 208-240 VAC outlet and requires 2-10+ hours to fully charge (on average provides 25 miles of range added per hour); typically can support multiple daily charges (often partial charges); most common type of public EVCS
- Level 3 (or DC fast-charge station)- Uses 400-600 VAC outlet and requires as little as 30 minutes to fully charge (on average provides 250 miles of range added per half-hour); can support multiple full charges daily; often have associated fees for use at public EVCS

The type of EVCS to be installed as part of the proposed project has yet to be determined. However, as Level 1 EVCS are typically only suitable for private use, the charger type will be either Level 2 or Level 3. For this reason, both types are considered for emission calculations.

A study published in 2023 found that public Level 2 EVCS utilization averages 5.6 kWh per port per day (0.42 sessions per port per day with 13.44 kWh per session) and public Level 3 EVCS utilization averages 13.5 kWh/port/day (0.69 sessions/port/day with 19.52 kWh per session). Utilization of free EVCS influences utilization, particularly for Level 2 stations and Level 2 stations were found to be more sensitive than Level 3 stations to the size of the local EV charging network.[7]

Average Fuel Efficiency and Emissions

EValuateMN was further referenced for county-specific information on the average fuel efficiency of currently registered vehicles in Redwood County. **Table 1** provides the make and model for the 16 currently registered EVs (including all-electric vehicles and plug-in hybrids) in Redwood County, the average fuel efficiency for each type in miles per gallon equivalent (MPGe, calculated based upon 33.7 kWh = 1 gallon of gasoline), and the average total emissions for each vehicle type. To calculate the average emissions for EVs, the U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency (EPA)'s Electric and Plug-in Vehicle Greenhouse Gas Emissions Calculator (the Calculator) was

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[3] Minnesota Department of Transportation. 2019. Official AADT: Sequence #20746. Traffic Mapping Application. Electronic document, https://mndot.maps.arcgis.com/apps/webappviewer/index.html?id=7b3be07daed84e7fa170a91059ce63bb, accessed January 2024.

[4] Atlas Public Policy. 2023. EValuateMN. Electronic document, https://atlaspolicy.com/evaluatemn/, accessed January 2024.

[5] Mogile Technologies. 2024. Guide on How to Charge Your Electric Car with Charging Stations. Electronic document, https://chargehub.com/en/electric-car-charging-guide.html, accessed January 2024.

[6] Borlaug et al. 2023.

[7] Borlaug et al. 2023.

used.[8] This resource requires the following input: vehicle year, make/model, and ZIP Code in which the vehicle is used. Vehicle year was assumed to be 2023, except in cases where the specific make and model of the vehicle registered in Redwood County is no longer available. In these instances, the most recent model year available was utilized. The ZIP Code utilized was one central to the project area: 56270. Data on fuel efficiency was also provided by the DOE and EPA.[9] Although hybrid vehicles report fuel efficiency in both MPGe and MPG, only MPGe is included below in order to calculate a total average with all-electric vehicles.

Table 1: Redwood County EVs

Make/Model (Electric/Hybrid)	Average Fuel Efficiency (MPGe)	Average Total Emissions (g/mi)
Chevy Bolt EV (Electric)	120	140
Chevy Bolt EUV (Electric)	115	146
Ford F-150 (Electric)	70	245
Ford Mustang Mach-E (Electric)*	103	180
Nissan Ariya (Electric)	103	182
Nissan Leaf (Electric)	111	151
Tesla Model 3 (Electric)	132	128
Volkswagen ID.4 (Electric)	107	156
Chevy Volt (2019 Hybrid)	106	182
Chrysler Pacifica (Hybrid)*	82	272
Mercedes Benz GLC Class (2020 Hybrid)*	68	346
Ford Fusion (2020 Hybrid)	103	210
Jeep Grand Cherokee (Hybrid)	56	374

*2 vehicles of same type registered

In addition to the 16 EVs registered in Redwood County, 22,748 light-duty gas-powered vehicles were also registered as of November 2023. **Table 2** summarizes the overall data on average total emissions and average fuel efficiency for vehicles in Redwood County as calculated by EValuateMN based on vehicle registration. The average total emissions for gas-powered vehicles was calculated using the equations provided by the EPA.[10]

Table 3: Redwood County Average Fuel Efficiency and Emissions

Vehicle Type	No. Registered in Redwood County	Average Fuel Efficiency (MPGe/MPG)	Average Total Emissions (g/mi)
All-Electric	9	108.01	167.6
Hybrid	7	76.54	286
Gas	22,748	20.09	445.6

[8] U.S. Department of Energy and U.S. Environmental Protection Agency. 2024. Greenhouse Gas Emissions from Electric and Plug-in Hybrid Vehicles. Electronic document, https://fueleconomy.gov/feg/Find.do?action=bt2, accessed January 2024.

[9] U.S. Department of Energy and U.S. Environmental Protection Agency. 2024. Fuel Economy. Electronic document, https://www.fueleconomy.gov/, accessed January 2024.

[10] U.S. Environmental Protection Agency. 2024. Greenhouse Gases Equivalencies Calculator – Calculations and References. Electronic document, https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references, accessed January 2024.

Finally, in order to provide an idea regarding trends in EV sales and the emissions related to the most popular EV models, information regarding the ten best-selling EVs in 2022 and 2023, as well as the average emissions for each vehicle, is provided in **Table 3**. Average emissions were again calculated utilizing the Calculator with the ZIP Code 56270.[11] If multiple varieties of a vehicle make/model were available to choose from in the Calculator, the AWD/Long Range variety was selected to represent a maximum emissions value, as Standard Range vehicles typically produce less emissions.

Table 3: Best-Selling EVs 2022 – 2023

2022[12] Make/Model (Total Emissions)	**2023**[13] Make/Model (Total Emissions)
Tesla Model Y (137 g/mi)	Tesla Model Y (137 g/mi)
Tesla Model 3 (128 g/mi)	Tesla Model 3 (128 g/mi)
Ford Mustang Mach-E (180 g/mi)	Chevy Bolt EV (140 g/mi)
Chevy Bolt EV (140 g/mi)	Ford Mustang Mach-E (180 g/mi)
Tesla Model S (140 g/mi)	Volkswagen ID.4 (156 g/mi)
Tesla Model X (164 g/mi)	Hyundai IONIQ 5 (170 g/mi)
Hyundai IONIQ 5 (170 g/mi)	Rivian R1S (267 g/mi)
Volkswagen ID.4 (166 g/mi)	Ford F-150 Lightning (245 g/mi)
Kia EV6 (157 g/mi)	Tesla Model X (164 g/mi)
Rivian R1T (239 g/mi)	BMW i4 (210 g/mi)
Average: **162 g/mi**	Average: **180 g/mi**

As demonstrated in **Table 3**, the average emissions for the top ten best-selling EVs increased from 2022 to 2023 as heavier duty electric vehicles (such as the Ford F-150 Lighting) gained in availability and popularity. However, at least one of the models that continued to sell well from 2022 to 2023, the Volkswagen ID.4, decreased its average emissions, most likely due to an increase in fuel efficiency. Therefore, to account for increasing fuel efficiency as well as trends in heavier duty electric vehicles, the average of both years, 171 g/mi, is suggested as a standard for average emissions produced by current EVs. This number is only slightly higher than the average calculated for Redwood County (167.6 g/mi), indicating that the County is following national trends for EV vehicles.

Existing EVCS in the Area

While public EVCS are not common in this area, there are some existing locations within a 15-mile radius of the project area (**Figure 1**).[14,15] As some connectors are standardized and some are specific to particular EV models (such as Tesla), the type of connector as well as the level are provided here:

- Dacotah Ridge Golf Club (31042 CSAH 2, Morton)
  - 2 Level 2 Tesla Connectors (16kW)
- Jackpot Junction Casino (39375 County Road 24, Morton)
  - 2 Level 2 Standardized J1772 Connectors (10kW)
  - 4 Level 2 Tesla Connectors (16kW)

[11] U.S. DOE and EPA 2024.

[12] Cox Automotive. 2023. Kelley Blue Book Electric Vehicle Sales Report Q4 2022. Electronic document, https://www.coxautoinc.com/wp-content/uploads/2023/01/Kelley-Blue-Book-EV-Sales-and-Data-Report-for-Q4-2022.pdf, accessed January 2024.

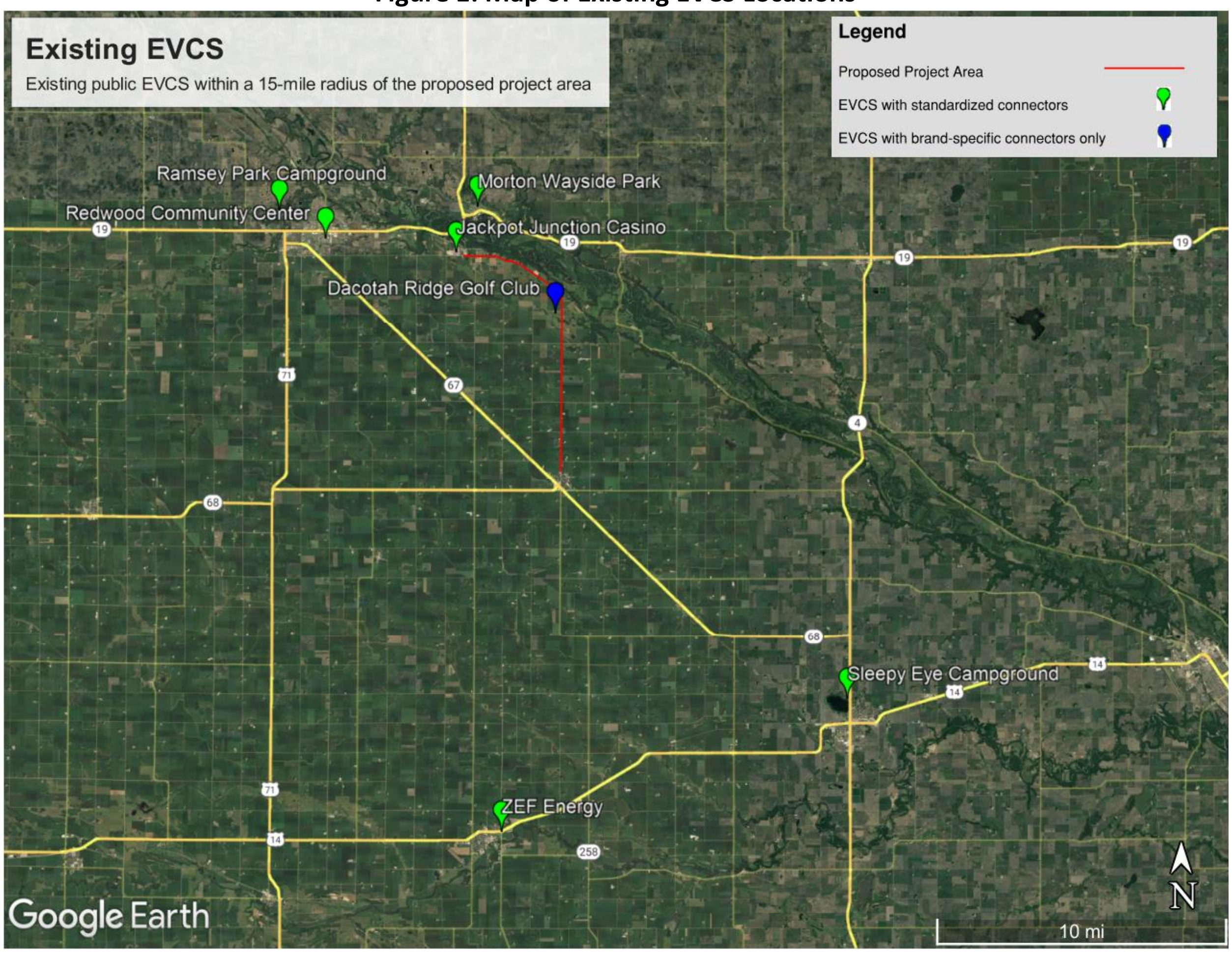
[13] Peter Johnson. 2024. 2023's best-selling EVs – Rivian R1S outsells Tesla Model X and Ford F-150. Electrek. Electronic document, https://electrek.co/2024/01/10/best-selling-evs-2023/, accessed January 2024.

[14] Mogile Technologies. 2024. Map. ChargeHub.com Electronic document, https://chargehub.com/en/charging-stations-map.html, accessed January 2024.

[15] Recargo, Inc. 2024 PlugShare. Electronic document, https://www.plugshare.com/, accessed January 2024.

- Morton Wayside Park (124 E. 3rd St., Morton)
    - 1 Level 2 Standardized NEMA 14-50 Connector (10kW)
- Redwood Community Center (901 E. Cook St., Redwood Falls)
    - 1 Level 3 Standardized Combined Charging System (CCS) Connector (50kW)
    - 1 Level 3 Standardized CHAdeMO (High-power DC) Connector (50kW)
    - 4 Level 2 Standardized J1772 Connectors (11.5kW)
- Ramsey Park Campground (99 E. Oak St., Redwood Falls)
    - 1 Level 2 Standardized NEMA 14-50 Connector (10kW)
- Sleepy Eye Campground (1000 3rd Ave NW, Sleepy Eye)
    - 1 Level 2 Standardized NEMA 14-50 Connector (10kW)
- ZEF Energy (601 E. Rock St., Springfield)
    - 1 Level 3 Standardized CCS Connector (50kW)
    - 1 Level 3 Standardized CHAdeMO Connector (50kW)
    - 2 Level 2 Standardized J1772 Connectors (12kW)

Figure 1: Map of Existing EVCS Locations



It is apparent based on this information that there is not an existing public EVCS adjacent to the project area, particularly in the southern half near the City of Morgan, that provides standardized connectors. This may be a limiting factor for EV usage in the area as it restricts the type of EV that may be practical based on proximity to an EVCS. The closest public Level 2 EVCS to the project area is located at the Jackpot Junction Casino, approximately a 0.4-mile drive from the project area. The closest public Level 3 EVCS is located at the Redwood Community Center, a 5.8-mile drive from the project area.

To compare the potential impact of adding additional EVCS, data compiled and displayed on EValuateMN was utilized. As mentioned previously, this resource utilizes data on EV registration and public EVCS as of November 2023. The table below provides some of the overview data for Redwood County as well as three other counties in Minnesota (Becker, Stevens, and Wabasha) in order to compare the difference additional EVCS may have on EV usage (**Table 4**). As this data may be influenced by the overall population differences between counties, information on the number of EVs per 1,000 people is provided, as well. Although the reported number of EVCS for Redwood County provided by EValuateMN does not match the number uncovered by this research, the EValuateMN data is displayed in the table to maintain consistency when comparing Redwood County with other counties included in this database. The results of this comparison indicate that even the addition of a single EVCS is likely to increase the amount of EVs on the road since Becker County, which has nearly double the population of Redwood County, has only one more Level 3 charger and the same number of Level 2 chargers as Redwood County, but has nearly double the percentage of EVs and roughly twice the number of EVs per 1,000 people in the county.

Table 4: EVs and EVCS in 4 Minnesota Counties

County	Redwood	Becker	Stevens	Wabasha
# of Level 2 Ports	2	2	4	4
# of Level 3 Ports	2	3	4	2
# of EVs on Road	16	74	25	89
EV % of Light-Duty Vehicles	0.07	0.14	0.20	0.24
Current Population	15,246	33,318	9,980	23,577
EVs per 1k People	1.05	2.22	2.51	3.77

<u>Total Emissions</u>

Utilizing the data on the 9.8-mile project location for average annual daily traffic, the percentage of EVs versus gas-powered vehicles, and the average emissions related to both vehicle types (167.6 g/mi for EVs and 445.6 g/mi for gas-powered vehicles), we can calculate the total emissions related to use of the project area. These calculations are provided below.

First, the average annual daily traffic (AADT), averaged across the four segments of CSAH 2 within the project area, is multiplied by the 9.8 miles of the project area and then multiplied by 365 in order to get an average annual vehicle miles traveled (VMT).

1,338 (AADT) x 9.8 (Project Miles) x 365 (Days/Year) = 4,786,026 VMT/Year

Next, the percentage of vehicle traffic made up of EVs (0.07%) versus gas-powered vehicles (99.93%) must be accounted for in the overall emissions total.

EVs – 0.07% of VMT = 3350.2182
Gas – 99.93% of VMT = 4,782,675.7818

Now in order to get the total current emissions for the project area, the average emissions for EVs must be multiplied by the portion of the VMT attributed to that vehicle type and added to the total of gas-powered vehicle emissions multiplied by the respective portion of VMT for this vehicle type.

(167.6 g/mi x 3350.2182) + (445.6 g/mi x 4,782,675.7818) = 2,131,721,824.94 g or 2,131.72 metric tons

Therefore, the current annual emissions associated with the 9.8 miles of CSAH 2 involved in the proposed project is 2,131.72 metric tons of CO_2 ($MTCO_2$). For comparison, if all the vehicles utilizing this project area were gas-powered, then the resulting emissions would be 2,132.65 $MTCO_2$. So, the current degree of EV usage has resulted in an annual reduction of 0.93 $MTCO_2$.

However, if we suppose that the percentage of EVs on the road in the project area will increase in relation to the availability of EVCS at rates similar to the utilization demonstrated by other counties (see **Table 4**), then the addition of 2 EVCS to the project area should result in an approximate increase to 0.19%. Now, if we perform the same calculations as before, but with EVs accounting for 0.19% of the annual VMT, we see an average annual reduction of 1.59 $MTCO_2$ compared to current conditions.

EVs – 0.19% of VMT = 9093.4494
Gas – 99.81% of VMT = 4,776,932.5506
(167.6 g/mi x 9093.4494) + (445.6 g/mi x 4,776,932.5506) = 2,130,125,206.67 g or 2,130.13 $MTCO_2$

Since upstream emissions have already been factored into the average EV emissions, any emissions related to increased electricity generation from the additional EVCS are already factored into the new totals. Therefore, the only additional consideration in terms of carbon reduction related to the proposed installation of additional EVCS is to acknowledge that the estimated annual reduction of 1.59 MTCO2 only addresses emissions produced along the 9.8-mile project corridor. In actuality, the amount of electricity generated by the additional EVCS (estimated at 13.44 kWh per session for Level 2 EVCS and 19.52 kWh per session for Level 3 EVCS based on the 2023 study discussed previously[16]), will allow for EVs to travel further than 9.8 miles. Based on the average fuel efficiency of EVs provided in **Table 3** (108.01 MPGe), after a single charging session at a Level 2 EVCS, an EV can travel approximately 43 miles. After a single charging session at a Level 3 EVCS, an EV can travel approximately 62.5 miles.

Level 2 EVCS: 108.01 MPGe = 0.312 kWh/mile = 3.2 miles/kWh x 13.44 kWh = 43 miles
Level 3 EVCS: 108.01 MPGe = 0.312 kWh/mile = 3.2 miles/kWh x 19.52 kWh = 62.5 miles

If we then consider the reduction in emissions for the total mileage a single charging session at either level of EVCS, we can get an idea of the larger impact that the addition of the proposed EVCS may have on the area. Using the same AADT from the previous calculations (1,338), we substitute the total mileage of 43 miles for a Level 2 EVCS, then apply the current percentage of EVs to gas-powered vehicles to determine the current level of annual emissions from this length of driving in Redwood County. The approximate total is 9,353.47 $MTCO_2$.

1,338 (AADT) x 43 (Miles from Level 2 Charging Session) x 365 (Days/Year) = 20,999,910 VMT/Year
EVs – 0.07% of VMT = 14,699.937
Gas – 99.93% of VMT = 20,985,210.063
(167.6 g/mi x 14,699.937) + (445.6 g/mi x 20,985,210.063) = 9,353.47 $MTCO_2$

In comparison, if we calculate the emissions based upon the presumed additional EVs operating after the installation of additional EVCS, the total is 9,346.47 $MTCO_2$, a reduction in 7.0 $MTCO_2$ annually.

EVs – 0.19% of VMT = 39,899.829
Gas – 99.81% of VMT = 20,960,010.171
(167.6 g/mi x 39,899.829) + (445.6 g/mi x 20,960,010.171) = 9,346.47 $MTCO_2$

A Level 3 charger, with the ability to generate more kWh per session, would result in greater reductions. Currently, the emissions resulting from 62.5 miles of travel by 1,338 light-duty vehicles in Redwood County is approximately 13,595.16 $MTCO_2$. With the presumed additional EV usage, the annual emissions for the same distance would be 13,584.98 $MTCO_2$, a reduction of 10.18 $MTCO_2$.

VMT/Year = 30,523,125
EVs – 0.07% of VMT = 21,366.1875
Gas – 99.93% of VMT = 30,501,758.8125
(167.6 g/mi x 21,366.1875) + (445.6 g/mi x 30,501,758.8125) = 13,595.16 $MTCO_2$
EVs – 0.19% of VMT = 57,993.9375
Gas – 99.81% of VMT = 30,465,131.0625
(167.6 g/mi x 57,993.9375) + (445.6 g/mi x 30,465,131.0625) = 13,584.98 $MTCO_2$

[16] Borlaug et al. 2023.

Therefore, the estimated average annual reduction in emissions is 7.0 $MTCO_2$ from installing additional Level 2 EVCS and 10.18 $MTCO_2$ from installing additional Level 3 EVCS. As the proposed project involves the installation of 1 Level 2 EVCS with 2 ports and 1 Level 3 EVCS with 2 ports, the estimated average annual reduction in emissions is approximately **8.59 $MTCO_2$**. This calculation does not account for emissions related to other proposed project activities. However, construction activities are understood to be one-time emissions rather than the annual emissions related to regular vehicle usage and are therefore presumed to be minimal in comparison.