Mobility Nexus: Integrating Mobility, Housing and Equity for Climate Action – Project GHG Methodology Technical Appendix

Introduction

The Metropolitan Transportation Commission (MTC) adopted Plan Bay Area 2050 (PBA50) in October, 2021. PBA50 meets state and federal requirements for a Regional Transportation Plan (RTP) and Sustainable Communities Strategy (SCS) that integrates transportation, land use and housing to meet greenhouse gas (GHG) targets set by the California Air Resources Board (CARB). The Project's methodologies and GHG emission reduction quantifications use the calculations from the CARB-approved PBA50, updated for 2024 latest and best research available. All GHG emission reductions estimates presented herein solely reflect reductions that will directly result from EPA CPRG funding and would not occur otherwise. The Project achieves 152,834 mtCO2e reduced by 2030, and 281,637 mtCO2e reduced by 2050, compared to the BAAQMD's PCAP estimates of 172,000 mtCO2e by 2030 and 471,000 mtCO2e by 2050. This is significant considering that the Project excludes several components submitted in the PCAP. Refer to the accompanying GHG emission reduction calculations spreadsheets for each measure listed below (six total).

Table 1. Summary of GHG Emissions Reductions & Cost-Effectiveness from Proposed Project GHG Reduction Measures

Measure	Estimated Cumulative GHG Emissions Reductions (2025-2030), mtCO2e	Cost-effectiveness (2025-2030), $/mtCO2e	Estimated Cumulative GHG Emissions Reductions (2025-2050), mtCO2e	Cost-effectiveness (2025-2050), $/mtCO2e
EV Chargers	**13,499**	737	**54,985**	181
Bikeshare	**3,627**	3,365	**8,369**	1,458
Outreach	**127,513**	20	**167,392**	15
Ebike Incentives	**3,226**	1,411	**16,200**	281
Mobility Hub Capital Improvements	**4,969**	16,589	**34,691**	2,376
TOTAL	**152,834**	766	**281,637**	416

Electric Vehicle Chargers at Mobility Hubs

Description: This measure will support the federal priority to decrease the use of fossil fuel vehicles by designing and installing dual-port Level 2 (L2) electric vehicle (EV) charging stations and Direct Current Fast Chargers (DCFC) at mobility hubs. Daytime use is expected from transit riders, with priority for the local community on nights and weekends. This grant-funded work will also include breaker space and electrical capacity for future ebike charging. Mobility hub charging infrastructure provides a public opportunity to charge vehicles away from home, and moreover, accelerates regional adoption of EVs and electric mobility devices amongst those without easy residential charging access. The latest U.S. Census Bureau data shows that 45% of residents in the San Francisco-Oakland-Hayward MSA are not homeowners (Data USA, n.d.), and are less likely to have access to convenient and affordable at-home charging. Research has also shown that every additional *EV charging station per capita* is associated with a 7.2% increase in EV purchases (Narassimhan & Johnson, 2018), indicating that accessible charging infrastructure remains a critical need.

Models/Tools Used: 2024 version of a CARB-approved EV charger GHG emission reduction calculator created by MTC, utilizing the latest CARB emission factors model (EMFAC2021, approved by US EPA for use in State Implementation Plan and transportation conformity analyses). Uses research by California Energy Commission in AB 2127 EV Charging Infrastructure Assessment (California Energy Commission, 2023) and (Borlaug, Yang, Pritchard, Wood, & Gonder, 2023).

Method and Implementation/Estimate Assumptions: This measure invests in charging infrastructure to expand the network of chargers to low-income communities surrounding BART stations. 386 L2 charging ports (via BART and SFMTA) and 20 DCFC charging ports (via Ava Community Energy) will be installed. As a result, the anticipated energy dispensed by these chargers offsets vehicle miles traveled (VMT) by the fleet average vehicle in the year the charging event takes place, according to EMFAC2021 fleet forecasts for engine types, fuel efficiency, and forecast miles driven by vehicle model year in the Bay Area. To quantify the GHG emission reductions from this measure, the analysis method employs the following steps, with assumptions detailed therein:

1. Determine the number of chargers by power level (L2, DCFCs, by output level in kW) that grant funds will fund, across proposed installation years.

2. Calculate the total estimated energy dispensed from the chargers using the expected number of charging events per day based on latest research (Borlaug, Yang, Pritchard, Wood, & Gonder, 2023) and the latest CEC AB2127 report (California Energy Commission, 2023). It is assumed that one charging event can dispense sufficient energy to fully replenish the typical daily electricity demand of an electric vehicle. The mean daily EV consumption (in kWh) is calculated (California Air Resources Board, 2021).

$$\begin{aligned} &\mathit{Energy\ Dispensed} \\ &= \sum_i \mathit{Charging\ Events/Day}_i \times \mathit{Num\ Chargers}_i \\ &\times\ \mathit{Mean\ Daily\ EV\ consumption} \sum_i \mathit{Charge\ Events/Day}_i \times \mathit{Num\ Chargers}_i \\ &\times\ \mathit{Mean\ Daily\ EV\ consumption} \end{aligned}$$

3. Calculate the average energy consumption rates for plug-in hybrid vehicles (PHEVs) and battery electric vehicles (BEVs) based on EMFAC2021. EMFAC assumes that the kWh per mile used by BEVs and PHEVs does not change year to year.

4. Calculate the total VMT of PHEVs and BEVs from total energy dispensed and average energy consumption rates. The daily energy dispensed is converted into PHEV and BEV VMT using EMFAC's average BEV and PHEV efficiencies (miles/kWh) and the VMT fraction from the last step. The fraction of VMT from BEVs and PHEVs is calculated using by comparing the total VMT of PHEVs to that of BEVs for each year, finding that BEVs make up around 71% of VMT from electrified vehicles.

$$VMT_{BEV} = \mathit{Energy\ Dispensed} \times \eta_{BEV} \times \mathit{BEV\ Share} \times (\frac{\eta_{PHEV}}{\eta_{BEV}})/\mathit{Adjustment\ Factor}$$

$$VMT_{PHEV} = \mathit{Energy\ Dispensed} \times \eta_{PHEV} \times\ \ (1 - \mathit{BEV\ Share})/\mathit{Adjustment\ Factor}$$

Here, the adjustment factor is a constant which helps ensure that the VMT estimate accurately reflects the energy input and matches the VMT share input.

$$\mathit{Adjustment\ Factor} = \mathit{BEV\ Share} \times \left(\frac{\eta_{PHEV} - \eta_{BEV}}{\eta_{BEV}}\right) + 1$$

These two VMTs are summed to find a total amount of cVMT (conventional VMT) displaced by zero emission vehicles.

$$cVMT_{displaced} = \ VMT_{BEV} + VMT_{PHEV}$$

5. Calculate daily mtCO2e emissions reduction as the fleet average emissions factors multiplied by the VMT supported by public infrastructure deployment.

$$\mathit{Emissions\ Reduced} = \ cVMT_{displaced} \times EF_{Light-duty}$$

6. Calculate cumulative mtCO2e reduced by the grant over the performance periods (2025-2030, 2025-2050) by multiplying daily reductions by 365, and cumulatively summing yearly reductions.

With the charger station capital costs covered by the grant and operations and maintenance costs required to operate the chargers long term covered by the Project Coalition, GHG reductions over the life of the Project are shown below.

Table 2. GHG Emissions Reduced and Magnitude in metric tons (mtCO2e) – EV Chargers at Mobility Hubs:

Value	2025	2026	2027	2028	2029	2030	2031...	...	2050
Yearly mtCO2e reduced	1,438	2,061	2,638	2,539	2,451	2,372	2,305	...	1,820
Cumulative mtCO2e reduced	1,438	3,499	6,137	8,677	11,127	**13,499**	15,804	...	**54,985**

Note: cumulative vs. yearly numbers above may not sum perfectly due excel-based rounding. For more calculation details, see "EVChargers.xlsx" spreadsheet included with grant application.

Cost-effectiveness in ($/mtCO2e reduced): 737 for cumulative emissions by 2030, 181 by 2050.

Bay Wheels Bikeshare at Mobility Hubs

Description: Bikeshare systems provide bicycles that members of the public can use for limited durations, usually in exchange for a fee, and are borrowed from and returned to designated bicycle docking stations (bikeshare stations). Bay Wheels is the Bay Area's existing bikeshare provider and offers electric bikes (ebikes) as well as conventional bikes, enabling a wide variety of trip distances and purposes to be accomplished by bicycle rather than car. This grant funding will allow Bay Wheels to expand with new ebikes, new stations, including station electrification, and provide reduced-cost memberships to residents in the selected mobility hubs in CEJST and EPA's IRA Disadvantaged Communities.

Models/Tools Used: 2024 version of a CARB-approved Bikeshare GHG emission reduction calculator created by MTC, utilizing the latest version of CARB's emission factors model (EMFAC2021, approved by US EPA for use in State Implementation Plan and transportation conformity analyses). Uses most recent Bay Wheels data. Population growth estimates are from MTC's Travel Model 1.5, a CARB-approved activity-based travel model replicated by MTC's counterparts statewide. Uses research by (Volker, Handy, Kendall, & Barbour, 2020) and (Rzepecki, 2019).

Method and Implementation/Estimate Assumptions: This measure funds 508 ebikes, 35 additional non-charging stations (needed for additional ebikes to have space to park at their destinations), outreach to and signup of 17,500 discounted annual memberships along with ebike credits, and electrification of 7 existing non-charging stations. CARB's EMFAC2021 emission factor model is used to estimate the GHG reductions, in which the emission factors account for fleet forecasts for engine types, fuel efficiency, and forecast miles driven by vehicle model year in the Bay Area, as well as the varying rates of emission for miles driven versus vehicle starts/stops (i.e., engine cold-starts). To quantify the GHG emission reductions from this measure, the analysis method is broken into two components (new grant-funded ebikes and memberships) with distinct steps and then summed, with assumptions detailed therein:

Ebikes Component:

1. Calculate background population growth from base year (2023) to all performance years using model outputs from MTC's Travel Model 1.5 (a CARB-vetted activity-based travel demand model) and linear interpolation between these model output years.

2. Calculate average ebike utilization for base year (2023) by dividing average bike share trips per day in base year by average daily ebikes on the ground in base year, both from existing Bay Wheels program data.

3. Calculate number of ebike trips per day in future years resulting from the grant. Multiply the number of grant-funded ebikes by year (deployment starting 2026) by average base year ebike utilization, and then scale trips by the rate of natural population growth predicted for the Bay Area in that year, compared to the base year.

4. Calculate the daily VMT avoided by the predicted daily ebike trips in each year, using a formula developed from (Volker, Handy, Kendall, & Barbour, 2020) and (Rzepecki, 2019). Multiply the predicted trips by the average ebike trip length (2.6 miles) and the CARB-approved adjustment factor (0.5) to account for the fact that some such ebike trips may be non-vehicle-replacing (such as induced ebike trips or recreational trips that wouldn't have been taken by car).

5. Calculate the daily mtCO2e reduced using the adjusted-daily-VMT avoided and number of daily ebike trips multiplied by EMFAC2021 emission factors for regional running exhaust emissions and trip end emissions factor, respectively (accounts for engine-running emissions and engine start/stop emissions as well as CARB-predicted

future vehicle fleets in the Bay Area).

6. Calculate cumulative mtCO2e reduced by the grant over performance periods (2025-2030, 2025-2050) by multiplying daily reductions by 365, and cumulatively summing yearly reductions.

Bay Wheels Bikeshare Membership Component:

1. Determine the number of rides per day per member in the base year (2023). Divide total number of trips taken by annual members in base year by 365 and divide by the number of total annual members in base year, according to Bay Wheels program data.

2. Calculate the number of new daily bike share trips predicted in future years due to grant-funded memberships. Multiply the number of rides per day per member by the number of grant-funded memberships to distribute that year (3,500 each year; 500 for each of the seven selected mobility hubs areas each year).

3. Calculate the number of grant-funded membership trips estimated to be retained year over year using Lyft program data on retention rates for members receiving reduced-price memberships. Iteratively multiply this conservative retention rate (30%) for each year going forward, even though Lyft's program data shows much higher retention rates after the initial year. Cumulatively count these retained trips by year and add to the predicted daily ebike trips in each year.

4. Determine the percentage of trips on ebike (69%) vs. conventional bike (31%) for members in base year (2023), based on Bay Wheels program data. Linearly interpolate the transition from 69% ebike trips in 2023 to 100% ebike trips by 2035 (conservative assumption, since MTC's RTP/SCS aims for an even earlier transition and new grant-funded ebikes help accomplish this goal but are conservatively omitted from consideration here).

5. Calculate the predicted number of bike trips to occur by ebike vs. conventional bike by applying the year over year percentage e-bike vs. percentage conventional trips to the number of predicted daily bike trips.

6. Calculate the daily VMT displaced by the predicted daily bike trips in each year, using a formula developed from (Volker, Handy, Kendall, & Barbour, 2020) and (Rzepecki, 2019). Multiply the percentage of trips predicted on ebike by the average ebike trip length (2.6 miles) and the percentage of trips predicted on conventional bike by the average conventional bike trip length (1.5 miles), both multiplied by the CARB-approved adjustment factor (0.5) to account for the fact that some bike trips may be non-vehicle-replacing (such as induced ebike trips or recreational trips that wouldn't have been taken by car).

7. Calculate the daily mtCO2e reduced, using the adjusted-VMT avoided and number of daily bike trips multiplied by EMFAC2021 emission factors for regional running exhaust emissions and trip end emissions factor by year, respectively (accounts for engine-running emissions and engine start/stop emissions as well as CARB-predicted future vehicle fleets in the Bay Area).

8. Calculate cumulative mtCO2e reduced by the grant over performance periods (2025-2030, 2025-2050) by multiplying daily reductions by 365, and cumulatively summing yearly reductions.

This measure conservatively estimates GHG reductions excluding the following effects:

- These major bikeshare improvements around hubs would also likely increase transit ridership as residents can more easily access stations and reach their destination without driving.
- Station electrification will reduce the miles driven by vans swapping ebike batteries that will now automatically charge at the electrified docking stations.
- New membership retention rates are assumed to be 30% exponentially for each year, but Lyft bikeshare program data from Columbus, Ohio shows that 30% of free-membership recipients renewed to a paid membership after the initial year, with higher retention thereafter.

With the capital costs of the new docking stations and ebikes covered by the grant, and the operations and maintenance costs required to operate this equipment long term covered by the Project Coalition, the expansion enabled by the grant is intended to last beyond the period of performance. In addition, these grant-funded improvements will help catalyze ridership in the system which will further grow the system in the future. Summing the two methodologies of this measure leads to the GHG reductions over the life of the Project shown below.

Table 3. GHG Emissions Reduced and Magnitude in metric tons (mtCO2e) – Bikeshare at Mobility Hubs:

Value	2025	2026	2027	2028	2029	2030	2031...	...	2050
Yearly mtCO2e reduced	363	680	721	739	750	373	260	...	263
Cumulative mtCO2e reduced	363	1,043	1,764	2,503	3,253	**3,627**	3,886	...	**8,369**

Note: cumulative vs. yearly numbers above may not sum perfectly due excel-based rounding. For more calculation details, see "Bikeshare.xlsx" spreadsheet included with grant application.

Cost-effectiveness in ($/mtCO2e reduced): 3,365 for cumulative emissions by 2030, 1,458 by 2050.

Outreach in Mobility Hub Areas

Description: Behavioral mode shift has been recognized for its high GHG reduction potential and cost-effectiveness, especially given technological advances and evolving community outreach. This measure will employ a transformative Power-building and Engagement (Pb+E) model of outreach to disadvantaged communities within a half mile of selected mobility hubs. Outreach will be targeted to households eligible for Clipper START – a program created and run by MTC that provides 50% off transit fares to individuals with a household income of 200% of the federal poverty level or less. Transportation demand-management initiatives in neighboring states have shown that even basic outreach with educational materials and a single-use transit voucher can decrease single-occupancy vehicle use by an average of 12%, with the behavior change persisting for five years on average. This grant would fund much more extensive and transformative outreach, empower community leaders, organize events to build street-level community resiliency, distribute informative and educational materials, and enroll the qualifying persons in the program.

Models/Tools Used: 2024 version of a CARB-approved Outreach GHG emission reduction calculator created by MTC, utilizing the latest version of CARB's emission factors model (EMFAC2021, approved by US EPA for use in State Implementation Plan and transportation conformity analyses). Several supporting numbers rely on model outputs from MTC's Travel Model 1.5, a CARB-approved activity-based travel model that has been replicated by MTC's counterparts statewide. Uses most recent program findings and program data from existing Clipper START program, provided by MTC.

Method and Implementation/Estimate Assumptions: This measure funds one full-time equivalent (FTE) MTC staff person over the first performance period, who focuses entirely on effective outreach to low-income households eligible for Clipper START (MTC will fund the Clipper START discounts) as well as in-depth community engagement. Using a new Pb+E outreach model that engages community leaders and respected community-based organizations (CBOs) for transformative and lasting change, this measure will reduce GHG emissions as more households receive Clipper START passes and drive less as a result. This program goes above and beyond many other transportation demand management programs boasting impressive results (Regional Travel Options program by Portland, OR Metro, the SmartTrips program by the City of Portland, and the In Motion program by King County, WA). To quantify the GHG emission reductions from the measure, the analysis method employs the following steps, with assumptions detailed therein:

1. Determine how many households a grant-funded FTE can conduct Clipper START outreach to per year, based on Clipper START 2-year program evaluation.

2. Determine the average success rate of Clipper START signups in the short-term and the long-term, based on Clipper START 2-year program evaluation.

3. Calculate background population growth and average one-way trip length from base year (2023) to all performance years using model outputs from MTC's Travel Model 1.5 (a CARB-vetted activity-based travel demand model) and linear interpolation between these model output years.

4. Determine the total number of households eligible for Clipper START around the selected mobility hub areas using GIS data and scale this number for background population growth for future years.

5. Calculate the number of households that change driving behavior as a result of outreach by multiplying the number of households receiving outreach by the average short-term success rate of Clipper START signups.

6. Calculate the total daily vehicle trip reductions by multiplying the number of households changing behavior by the average number of one-way driving trips per household living near transit (from MTC Travel Model) and the average reduction in single-occupancy vehicle mode share for households participating in Clipper START (based on Clipper START 2-year program evaluation).

7. Calculate the total daily VMT reductions by multiplying total daily vehicle trip reductions by the average one-way trip length for all trips (from MTC Travel Model).

9. Calculate the daily mtCO2e reduced, using the VMT reduced and number of vehicle trips avoided multiplied by EMFAC2021 emission factors for regional running exhaust emissions and trip end emissions factor by year, respectively (accounts for engine-running emissions and engine start/stop emissions as well as CARB-predicted future vehicle fleets in the Bay Area).

10. Calculate cumulative mtCO2e reduced by the grant over performance periods (2025-2030, 2025-2050) by multiplying daily reductions by 365, and cumulatively summing yearly reductions, assuming that household behavior changes resulting from this grant funding only last for five years (assumption based on research by San Diego Association of Governments).

The GHG estimates assume that after grant funding for the FTE runs out in 2029, no new grant-funded outreach occurs. As a result, GHG reductions begin tailing off in 2030 (behavior changes from prior outreach only persist for five years). This means GHG reductions are highly concentrated in the first performance period and not very durable over the second. However, this measure offers the significant GHG reductions shown below, due to the sizable low-income populations within the vicinity of the mobility hubs combined with the proven appeal and impact of Clipper START.

Table 4. GHG Emissions Reduced and Magnitude in metric tons (mtCO2e) – Outreach in Mobility Hub Areas:

Value	2025	2026	2027	2028	2029	2030	2031...	...	2050
Yearly mtCO2e reduced	6,769	13,502	20,198	26,857	33,478	26,709	19,976	...	0
Cumulative mtCO2e reduced	6,769	20,271	40,469	67,326	100,804	**127,513**	147,490	...	**167,392**

Note: cumulative vs. yearly numbers above may not sum perfectly due excel-based rounding. For more calculation details, see "Outreach.xlsx" spreadsheet included with grant application.

Cost-effectiveness in ($/mtCO2e reduced): 20 for cumulative emissions by 2030, 15 by 2050. This impressive cost-effectiveness is due to all Clipper START passes (50% transit fares) being funded by MTC rather than grant funds (the dedicated staff person to distribute those passes), thus the cost-effectiveness excludes these costs borne by MTC.

Ebike Incentives in Mobility Hub Areas

Description: Electric bicycles (ebikes) offer a more convenient and accessible way for people to get where they need to compared to a conventional bicycle. Ebikes hold promise to reduce VMT by making it possible for a larger portion of the population to use bikes and for more types of trips in place of car trips. This measure provides grant-funded incentives to income-qualifying community members around the mobility hub areas to spur ebike adoption and reduce VMT. This measure would be implemented by Project Coalition members, Ava Community Energy and Contra Costa Transportation Authority (CCTA). CCTA surveyed recipients of their ebike incentive pilot program and found that 85% of incentive recipients routinely replace vehicle trips with e-biking. Responses indicate the ebikes are being used for shopping, errands, appointments, restaurants, and visiting friends, as well as commuting to work, volunteer jobs, school, classes, and transit. Over 50% of respondents indicated they would have traveled to their destination by automobile instead "if [their] ebike had not been available for their most recent e-bike ride." Program data shows the average round trip for non-recreational destination-bound ebike trips is 9 miles. This measure would provide grant-funded ebike incentives to low-income communities within three miles of selected mobility hubs, making the short distances there (or elsewhere) achievable without a car.

Models/Tools Used: 2024 submission to CARB of an Ebike GHG emission reduction calculator created by MTC, utilizing the latest version of CARB's emission factors model (EMFAC2021, approved by US EPA for use in State Implementation Plan and transportation conformity analyses). Uses research by (Johnson, Fitch-Polse, & Handy, 2023).

Implementation and GHG Reduction Estimate Assumptions: This measure funds incentives for up to 3,608 ebikes (64% to standard ebikes for $1,000 each and 36% to cargo ebikes or adaptative ebikes for persons with mobility issues for $1,500 each). Low-income populations living within three miles of the selected mobility hub areas would be eligible for these ebike incentives (along with bike helmets, locks, and visibility gear), which would enable these cost-burdened households to own an ebike and make less vehicle trips. To quantify the GHG emission reductions from this measure, the analysis method employs the following steps, with assumptions detailed therein:

1. Determine the number of ebike purchases incentivized by the grant funding by dividing the total amount of funding by the average incentive amount (3,608 ebikes expected, with an average incentive of $1,181).
2. Determine the number of "incentive-caused" purchases by multiplying the number of purchases by the fraction of incentives going to buyers who wouldn't have purchased without the incentive. This number is conservatively assumed to be 90%, based on information from Denver's ebike program which similarly targeted income-qualified populations and found that 98% of recipients wouldn't have purchased an ebike without the incentive.
3. Calculate the estimated short-term reduction in VMT of grant-funded ebikes by multiplying the number of purchased bikes by the rate of car-replacing VMT ebike trips based on latest research by (Johnson, Fitch-Polse, & Handy, 2023).
4. Calculate the estimated long-term reduction in VMT by multiplying the estimated short-term reductions by a "dis-use" factor of 50% to account for long term reversion to car trips amongst ebike incentive recipients.
5. Calculate the daily mtCO2e reduced by multiplying the VMT avoided by the EMFAC2021 emission factor for regional running exhaust emissions by year (accounts for engine-running emissions as well as CARB-predicted future vehicle fleets in the Bay Area).
6. Calculate cumulative mtCO2e reduced by the grant over performance periods (2025-2030, 2025-2050) by multiplying daily reductions by 365, and cumulatively summing yearly reductions.

It is assumed that after the first year, incentive recipients continue to use their ebikes 50% as much as the first year. Since ebikes and ebike incentive programs are relatively novel, long-term program data does not yet exist to confirm or refute this calculation assumption. The result is durable GHG reductions, as shown below.

Table 5. GHG Emissions Reduced and Magnitude in metric tons (mtCO2e) – Ebike Incentives in Mobility Hub Areas:

Value	2025	2026	2027	2028	2029	2030	2031...	...	2050
Yearly mtCO2e reduced	258	387	516	645	774	646	646	...	650
Cumulative mtCO2e reduced	258	645	1,160	1,806	2,580	**3,226**	3,872	...	**16,200**

Note: cumulative vs. yearly numbers above may not sum perfectly due excel-based rounding. For more calculation details, see "EbikeIncentives.xlsx" spreadsheet included with grant application.

Cost-effectiveness in ($/mtCO2e reduced): 1,411 for cumulative emissions by 2030, 281 by 2050.

Mobility Hub Capital Improvements

Description: MTC's Transit-Oriented Communities (TOC) Policy and BART's Transit-Oriented Development (TOD) Policy reduces GHG emissions and encourages denser housing and commercial development within walking distance of BART stations. TOC/TOD produces 50% fewer auto trips than conventional development.[1] Supporting housing and jobs near BART stations also reduces per capita driving and its associated pollution and safety impacts compared with growth in auto-oriented areas. Additionally, people living near BART drive 13% to 32% fewer miles per year than the countywide average, and household GHG near BART is at least 12% lower than the regional average.[2] Capital investment is necessary to make TOD possible and attract more transit ridership at mobility hubs. It is also a necessary precursor to providing affordable housing or other development at these areas, which would further help transit ridership and GHG reductions.

This grant funding will transform the existing BART station areas into mobility hubs. The grant-funded work includes seven core components: community plazas, wayfinding, bus shelters, lighting, Americans with Disability Act (ADA) improvements, real-time displays for transit information, and pedestrian and bicycle access improvements to improve the safety and customer experience of those accessing the selected stations. All ten stations will receive some combination of the seven categories of grant-funded improvements.

Models/Tools Used: GHG emission reduction calculator created by BART, utilizing the latest version of CARB's emission factors model (EMFAC2021, approved by US EPA for use in State Implementation Plan and transportation conformity analyses). Most recent program data from BART ridership is provided by BART. Uses research by National Institute for Transportation and Communities (NITC, [Impacts of Bus Stop Improvements]), American Public Transportation Association (APTA, [Quantifying Greenhouse Gas Emissions from Transit]), and (Hwang & Guhathakurta, 2022).

Method and Implementation/Estimate Assumptions: This measure funds sets of capital improvements at each mobility hub location selected for the grant. Each mobility hub receives some combination of the following improvements listed above. As per the below methodology, each improvement is associated with a percentage increase in BART ridership that otherwise wouldn't occur without grant funding. To quantify the GHG emission reductions from this measure, the analysis method employs the following steps, with assumptions detailed therein:

1. Determine the forecasted ridership at the ten BART stations selected for the grant over the project period (2025-2030 and 2025-2050) assuming no station area improvements, based on data provided by BART.

2. Apply an increase to the forecasted ridership based on the improvements at each station. The ridership increases depend on which of the seven improvements will be implemented at that station. New community plazas and bike/pedestrian improvements are the most impactful improvements, assumed to increase ridership by less than a percent (0.6%), while all other improvement categories anticipate less (0.4%) -- this is based on the NITC study and (Hwang & Guhathakurta, 2022). For details on improvements expected at each station, see the spreadsheet "MobilityHubCapitalImprovements.xlsx" included with the grant application.

$$Forecasted\ ridership\ at\ station_i = BART\ forecasted\ ridership\ without\ station\ improvements * total\ increase\ in\ ridership\ given\ improvements\ at\ station_i$$

3. Calculate the increase in ridership attributable to the grant-funded improvements.

$$Forecasted\ ridership\ due\ to\ station_i\ improvements = forecasted\ ridership\ at\ station_i\ with\ improvements - forecasted\ ridership\ at\ station_i\ without\ improvements$$

4. Use the APTA mode shift factor to determine the number of riders who would have otherwise driven to BART. It is assumed that of the new transit riders, 30.2% would have driven to their destination, based on APTA default

[1] Arrington and Cervero, TCRP Report 128, Effects of TOD on Housing, Parking and Travel. http://ctod.org/pdfs/2007TCRP128.pdf. TOD multi-family housing produces 3.55 automobile trips a day compared to 6.77 for conventional multi-family and 10 for conventional single family.
[2] Ibid.

value for a transit agency with a greater than 1 million service area population[3]:

$$\# \ of \ avoided \ automobile \ trips = APTA \ mode \ shift \ factor * forecasted \ ridership \ due \ to \ station \ improvements$$

5. Calculate the average round trip distance of all BART trips. It is assumed that a displaced automobile trip would be a similar distance to the BART trip it would be replaced by:

$$Average \ round \ trip \ distance = average \ BART \ trip \ length * 2$$

6. Calculate the total vehicle miles traveled (VMT) avoided by riders accessing each station as a result of grant-funded improvements by multiplying the number of avoided trips by the average round trip distance of BART trips:

$$Avoided \ automobile \ VMT = \# \ of \ avoided \ automobile \ trips * average \ round \ trip \ distance$$

7. Calculate the yearly mtCO2e reduced by multiplying the VMT and number of trips avoided per year by the EMFAC2021 emission factors for regional running exhaust emissions and trip end emissions factor, respectively (accounts for engine-running emissions and engine start/stop emissions as well as CARB-predicted future vehicle fleets in the Bay Area).

8. Calculate cumulative mtCO2e reduced by the grant over performance periods (2025-2030, 2025-2050) by cumulatively summing yearly reductions.

This measure conservatively estimates GHG reductions, since these grant-funded improvements may have an outsized effect in recovering some of the large ridership losses from the COVID pandemic, yet the estimates here conservatively omit this possibility. Furthermore, some GHG reductions resulting from the types of capital investment included in the grant will improve over time. As new development and densities increase within the mobility hub area, transit ridership will increase further. New residents and visitors to the mobility hub will benefit from the capital investments proposed through this grant, further increasing transit ridership because of the access, safety, and place-making improvements.

It is assumed that these capital improvements would provide GHG reduction benefits for many decades to come, and BART would budget for the comparatively minor periodic operations and maintenance costs in the long term. Together, these factors lead to durable GHG reductions, as shown below.

Table 6. GHG Emissions Reduced and Magnitude in metric tons (mtCO2e) – Mobility Hub Capital Improvements:

Value	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031...**	**...**	**2050**
Yearly mtCO2e reduced	760	807	831	848	857	866	962	...	2,155
Cumulative mtCO2e reduced	760	1,567	2,398	3,246	4,103	**4,969**	5,931	...	**34,691**

Note: cumulative vs. yearly numbers above may not sum perfectly due excel-based rounding. For more calculation details, see "MobilityHubCapitalImprovements.xlsx" spreadsheet included with grant application.

Cost-effectiveness in ($/mtCO2e reduced): 16,589 for cumulative emissions by 2030, 2,376 by 2050.

Cost-Effectiveness

Cost-effectiveness of this grant request – calculated at **$766/mtCO2e over 2025-2030** and **$416/mtCO2e over 2025-2050** – is consistent with other transportation sector investments. Typical cost-effectiveness for GHG-reducing investments in the U.S. transportation sector ranges from $200/mtCO2e to over $27,000/mtCO2e, according to Georgetown Climate Center's Infrastructure Investment and Jobs Act (IIJA) research using a model created by Cambridge Systematics. By allocating the $599 billion as provided for in the IIJA and modeling the GHG reduction impact of each investment, the

[3] APTA, APTA Standards Development Practice: Recommended Practices, Quantifying Greenhouse Gas Emissions from Transit APTA-SUDS-CC-RP-001-09_Rev-1.pdf

average cost-effectiveness of a GHG-reducing transportation sector investment was found to be $5,038/mtCO2e (for more details, see the spreadsheet "Cost-Effectiveness.xlsx" included with the grant application). Comparing the sectoral average of $5,038/mtCO2e to the Project's $766/mtCO2e (first performance period, 2025-2030) demonstrates the strong cost-effectiveness of the grant proposal. This holds true even when comparing specific measures of the grant proposal to analogous strategies in the IIJA analysis and is further demonstrated by the Project's cost-effectiveness of $416/mtCO2e over the second period performance (2025-2050).

Furthermore, the overall GHG reduction and cost-effectiveness numbers presented in this grant application are conservative in that they capture only the primary GHG reductions resulting from these measures. There are secondary effects the estimates do not capture, such as potential synergistic effects between measures. For example, the Mobility Hub Capital Improvements measure's community plazas, wayfinding, bus shelters, lighting, ADA access, and upgraded pedestrian/bicycle access all serve to create a concentration of safer and more appealing non-driving mobility options, which may create a virtuous cycle with the EV Charger, bikeshare, outreach, and ebike Incentives measures. The capital improvements at mobility hubs may boost the effectiveness and impact of other measures beyond estimates by synergistically increasing public awareness, hastening user adoption, and expanding the user base beyond estimates by delivering one visible and cohesive major mobility improvement rather than piecemeal projects over time. However, any such synergistic effects between measures remain unquantified in the current estimates.

Secondly, each measure itself often contains unquantified GHG reductions. For example, the hub capital improvements may catalyze transit-oriented development due to the reduced financial and logistical burden on developers to make travel access improvements as a condition of development approval, or transit ridership may prove higher than projected as developers spend that spare capital on denser development. Similarly, the EV Charger measure doesn't claim credit for any induced EV adoption from installing much-needed public charging stations in disadvantaged communities and the bikeshare measure omits GHG reductions that result from electrifying ebike docking stations.

Thirdly, GHG reduction quantifications are adapted from the CARB-approved PBA50. As part of the approval process, MTC's GHG reduction estimations, quantification methodologies, justifying research, and cost-effectiveness numbers are rigorously examined by CARB for best research and sound justifications and result in conservative GHG reduction estimates.

Lastly, the GHG reduction estimates and cost-effectiveness numbers fail to capture the transformational impact of these measures in the long-term. For example, this grant will transform station areas into self-contained destinations, minimizing communities' reliance on long-distance driving to meet their needs, and reducing untold GHG in the long run. Moreover, the grant's positive impacts upon low-income and disadvantaged communities are incalculable in terms of quality-of-life improvements, lessened financial burdens, empowerment via thoughtful engagement, and resulting access to opportunity. This slowly reduces GHG over a long time span and cannot be effectively captured by any GHG reduction and cost-effectiveness numbers.

Although a select few sectors may have higher cost-effectiveness, the transportation sector is one of the most persistent and critical sectors to decarbonize, particularly in the U.S. As mentioned in the workplan, the transportation sector in California accounts for over 35% of all GHG emissions, in addition to myriad externalities such as congestion, lost time, particulate emission, collision-caused injuries and deaths, urban sprawl, physical barrier effects, and unequal access to opportunity. The Project proposes scalable solutions to directly address these problems. Grant funding would actualize the transformative transportation sector solutions proposed by the Project Coalition, uplift a model of strong regional collaboration, and demonstrate that GHG reduction in the transportation sector is at once critical and cost-effective.