Appendix B

Greenhouse Gas Emissions Inventory and Forecasts

Memo

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Date: August 2023

To: Lani Lee Ho, Santa Clara Valley Transportation Authority

From: Brenda Hom, Fred Hochberg, Lisa Fenton, and Honey Walters

Subject: GHG Emissions Inventory and Forecast for Countywide Transportation and VTA Transit Operations (Revised Final)

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

The Santa Clara Valley Transportation Authority (VTA) is working with Ascent to prepare a climate action and adaptation plan (CAAP) that identifies specific actions VTA can take to minimize contributions to climate change, as well as adapt and build resilience to long-term climate impacts. The first objective of this project is to quantify greenhouse (GHG) emissions from countywide transportation and VTA's transit operations. For the purposes of this assessment, "countywide transportation" emissions are limited to surface transportation modes (i.e., rail and on-road transportation). The second objective of this project is to identify actions VTA can take to reduce its operational emissions, as well as actions it can take in partnership with other agencies and the community to reduce communitywide vehicle miles traveled (VMT). The final objective is to conduct a vulnerability assessment that identifies the risks that climate change impacts pose to transportation assets and actions that can be taken to protect these assets for the public good.

1.2 PURPOSE AND DESCRIPTION

This memorandum meets the first objective of the project and presents the estimated GHG emissions generated by countywide transportation in Santa Clara County and VTA's own transit operations. The countywide transportation inventory quantifies emissions from all surface transportation use in Santa Clara County and the transit operations inventory quantifies emissions from VTA's operational activity across five activity sectors: buildings and facilities, revenue and non-revenue fleet, employee commute, water, and waste. This memorandum presents the data, methods, and resulting estimates for each inventory. It also presents emissions forecasts for 2030, 2035, 2040, 2045, and 2050.

In addition to establishing a foundation for the CAAP, the transit operations inventory also provides an update on the progress VTA has made towards the emissions reduction targets set in their sustainability goals.

1.3 DATA QUALITY AND ACCURACY

When preparing a GHG emissions inventory, the goal is to use the best available data and methodologies to develop the most accurate picture of a community's emissions. However, some degree of inaccuracy is inherent to all inventories. As described by the Community Protocol, "While no community inventory is fully comprehensive (some emissions cannot be estimated due to a lack of valid methods, a lack of emissions data, or for other reasons), community inventories often aim to provide as complete a picture of GHG emissions associated with a community as is feasible" (ICLEI 2019:12). The accuracy of a countywide GHG emissions inventory is primarily dependent on activity data (e.g., VMT) and emissions factors (e.g., grams of carbon dioxide [CO_2] per VMT). Development of this GHG emissions inventory was a robust and comprehensive process rooted in industry standards and best practices, and it included extensive research and consultation with VTA and County staff as well as regional and State agencies to ensure data were as accurate as feasible.

1.4 ORGANIZATION OF THIS MEMORANDUM

This memorandum consists of five parts:

- Introduction
  - Project Overview
  - Purpose and Description
  - Data Quality and Accuracy
  - Organization of this Memorandum
  - Summary of Results
- GHG Emissions Inventory and Forecast for Countywide Transportation
  - Background
  - Inventory Overview
  - Data, Methods, and Assumptions
  - Inventory Results for Countywide Transportation
  - Forecast for Countywide Transportation
- GHG Emissions Inventory and Forecast for Transit Operations
  - Background
  - Inventory Purpose and Overview
  - Inventory Results for Transit Operations
  - Forecast for Transit Operations
- References
  - Attachment 1 – VMT Process Technical Memo
  - Attachment 2 – Communitywide Transportation Calculations

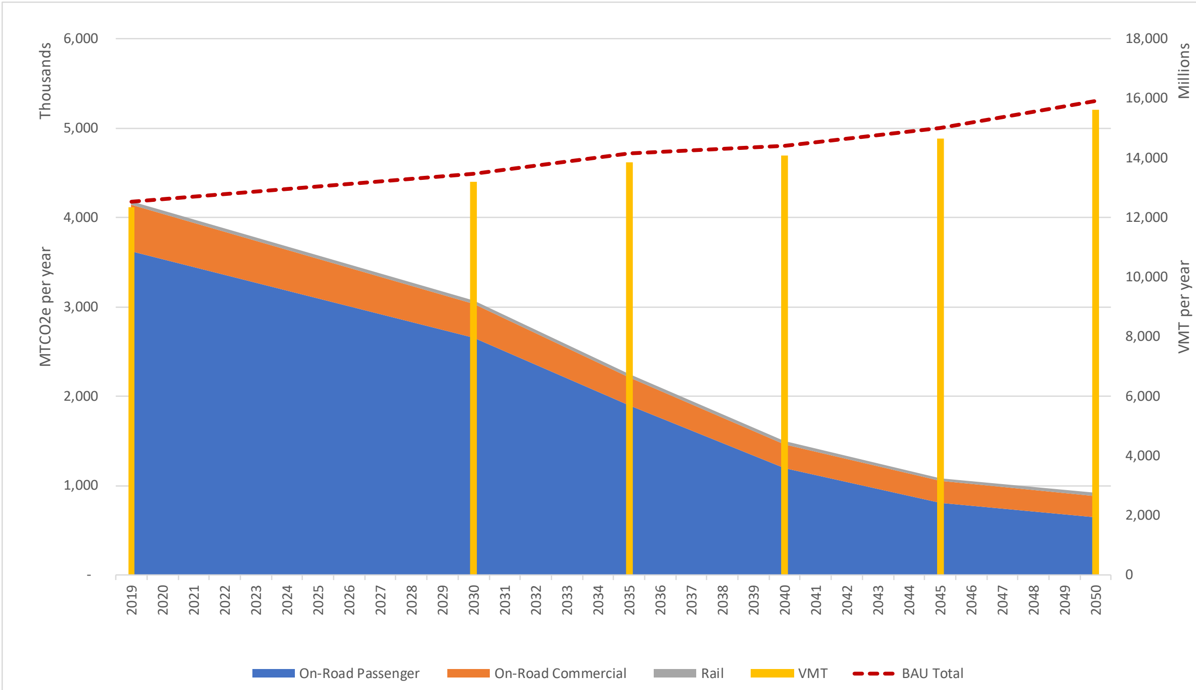
1.5 SUMMARY OF RESULTS

1.5.1 Countywide Transportation

Based on the modeling conducted, Santa Clara County's surface transportation sector, representing on-road and rail transportation modes, emitted 4.2 million metric tons of carbon dioxide equivalent ($MTCO_2e$) in calendar year 2019 countywide. Ninety-nine percent of these emissions are associated with on-road vehicles. For on-road modes, modeling was based on VMT data provided by the Metropolitan Transportation Commission (MTC) and processed by VTA and county-specific vehicle emission factors, available from the California Air Resources Board's (CARB) 2021 EMissions FACtor (EMFAC2021) model. For rail modes, emissions were estimated based on available emissions data from each rail provider and scaled to the county based on relative train miles in the county, accounting for any plans for conversion to renewable fuels or electrification. Based on the modeling conducted and regulatory trends toward lower emissions, the County's transportation emissions are anticipated to decline by up to 78 percent from 2019 levels by 2050. Most of these reductions are due to advances in vehicle technology policies (e.g., zero emission vehicle mandates under the Advanced Clean Cars II Regulations) and forecasted reductions in VMT as estimated by MTC (e.g., with implementation of Senate Bill [SB] 743 and a focus of growth in Priority Development Areas and multi-modal transportation programs and infrastructure in alignment with long-term regional planning to reduce driving).

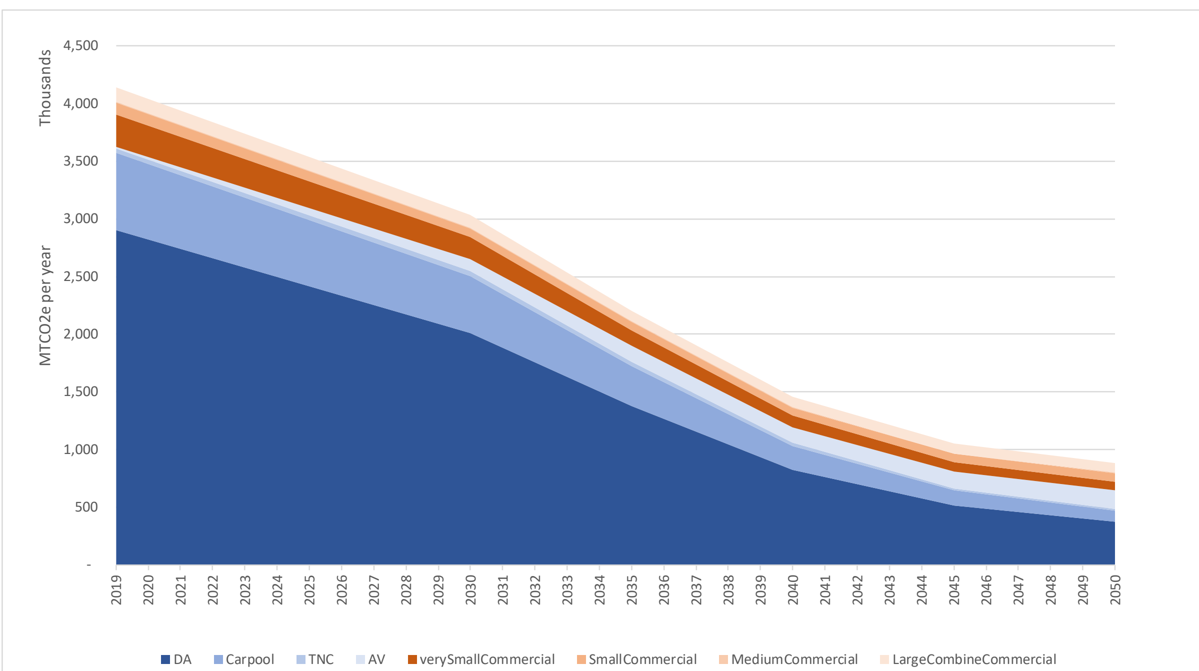
Based on the results the countywide transportation emissions inventory, Figure 1 presents two forecast scenarios that estimate future GHG emissions from transportation in the county: a Business-As-Usual (BAU) scenario, shown as the red dotted line, and a legislative-adjusted BAU forecast, shown as the stacked area in blue, orange, and gray, representing on-road passenger, on-road commercial, and rail emissions, respectively. The BAU forecast illustrates how transportation emissions would increase due to population and economic growth without additional legislative regulations that reduce emissions. The legislative-adjusted BAU scenario accounts for emissions reductions from laws and regulations enacted by regional, State, and federal agencies as well as rail provider sustainability plans; it does not reflect local actions to reduce GHG emissions. Examples of local actions to reduce emissions include adoption of reach codes for energy efficiency and city ordinances to ban natural gas in new construction. GHG emissions forecasts provide insights to the scale of additional regional and local reductions needed to achieve GHG emissions reduction targets. Additionally, Figure 1 also presents the VMT estimates upon which these emission forecast scenarios were developed, shown as the yellow bars. The trends in the BAU forecasts are inherently proportional to the BAU forecasts because no additional reductions to emissions rates are assumed.

The legislative-adjusted BAU forecast for on-road transportation is comprised of emissions from eight different vehicle groups, representing two vehicle categories and various classes and modes. These groupings were based on the available modeling data provided by MTC. Passenger vehicle emissions are split into four modes: drive alone (DA); autonomous vehicle (AV); carpool; transportation network company (TNC) (e.g., ride hailing operations like Uber and Lyft). Commercial vehicle emissions are split into four vehicle classes: large, medium, small, and very small. Table 4 in Section 2.2.3 describes the definition of these vehicle groups in more detail. The breakdown of emissions by vehicle category is shown in Figure 2. For rail modes, rail emissions include those from VTA, Caltrain, Amtrak, and Union Pacific Railroad (UP). Emissions from Altamont Corridor Express (ACE) were excluded due to lack of available data and Bay Area Rapid Transit (BART) emissions were excluded because activity in the county did not begin until 2020. The legislative-adjusted BAU forecast emissions were based on a combination of activity forecasts from the 2018 State Rail Plan, individual rail provider forecasts and long range plans, sustainability plans (e.g., electrification of Caltrain), and accounting of carbon neutral electricity emission factors by 2045 under SB 100.



Source: Compiled by Ascent Environmental in 2022.

Figure 1 Santa Clara County Transportation GHG Emissions (2019-2050) – Legislative Adjusted BAU Forecast



Notes: DA = drive alone, AV = autonomous vehicle, TNC = transportation network company, VMT = vehicle miles traveled, $MTCO_2e$ = metric tons of carbon dioxide equivalent. All values shown in chart are presented in $MTCO_2e$ except for VMT, which is presented in miles per year.

Source: Compiled by Ascent Environmental in 2022.

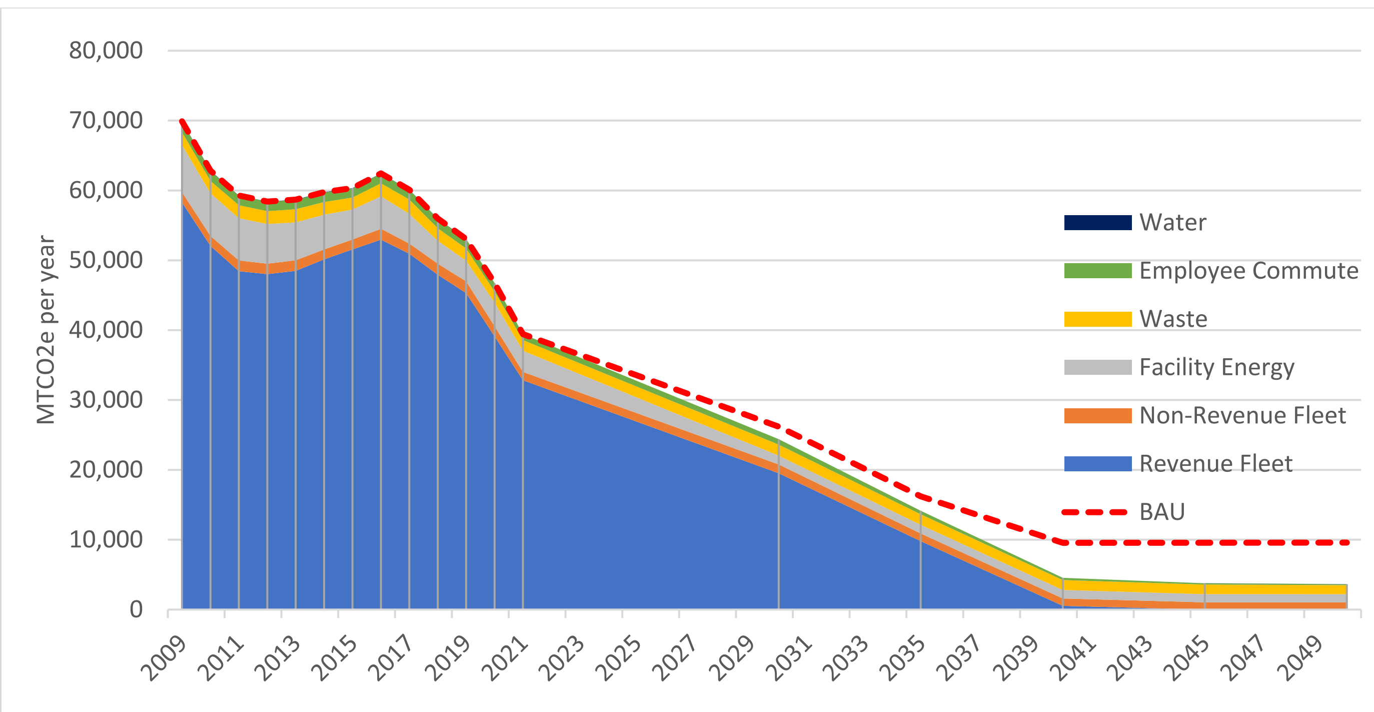
Figure 2 Santa Clara County On-Road Transportation GHG Emissions by Vehicle Group (2019-2050) – Legislative Adjusted BAU Forecast

1.5.2 Transit Operations – 2021 Inventory Update and Forecast

Based on the modeling conducted from data provided by VTA from 2009 through 2021, VTA's transit operations generated 39,431 $MTCO_2e$ per year in 2021, which is 44 percent below 2009 levels. From 2021, transit operation emissions would continue to decline by another 91 percent by 2050. These changes are largely due to VTA's Zero Emissions Bus Program, as well as additional legislative reductions, such as Advanced Clean Cars 2 and utility-scale carbon neutrality targets by 2045.

Similar to Figure 1, Figure 3 presents two trend scenarios: a BAU forecast, shown as the red dotted line, and a legislative-adjusted BAU forecast, shown in the colored stacked area. However, specific to the transit operations emissions, historical emissions are presented alongside forecasts in this chart. Emissions between 2009 and 2021 are the same in both scenarios based on existing activity data available from VTA. These emissions are broken out into six main categories: revenue fleet, non-revenue fleet, facility energy, waste, employee commute, and water. These emissions categories are consistent with those used in VTA's past sustainability reports and recommended by the American Public Transportation Association (APTA) for annual reporting on sustainability commitments. Fleet-related emissions result from the combustion of diesel, natural gas, gasoline, and electricity used in buses, maintenance and administrative vehicles, paratransit, and other related fleet vehicles. Facility energy-related emissions are generated from on-site natural gas and propane combustion and indirectly at power plants or other sources that supply electricity to VTA facilities. Waste-related emissions result from the anaerobic decay of organic material disposed at landfills, generating methane. Employee commute activities also generate emissions from fuel combustion in vehicle trips. Water consumption generates emissions indirectly through the conveyance, treatment, and distribution of water.

As shown in Figure 3, emissions are projected to decrease over the time horizon of the analysis. Bus emissions, which account for over 75 percent of fleet emissions in FY 2021, are anticipated to continue to decline through 2050 due to the Zero Emissions Bus Program. Additional details can be found under Section 3.



Source: Compiled by Ascent Environmental in 2023.

Figure 3 VTA Transit Operations GHG Emissions (2009-2050)

2 GHG EMISSIONS INVENTORY AND FORECAST FOR COUNTYWIDE TRANSPORTATION

This section presents the GHG emissions inventory and forecast for the countywide transportation sector, assuming an updated baseline year of calendar year 2019 forecasted through 2050. Section 2.1 presents a background discussion of previous county transportation emissions estimates to provide context for the current baseline update and for comparison to the previous methods used and the emissions estimates. Sections 2.2 and 2.3 present the foundational protocols and boundaries of this analysis as well as the data, methods, and assumptions used. Sections 2.4 and 2.5 present the resulting inventory and forecasted emissions estimates for the county's transportation sector.

2.1 BACKGROUND

2.1.1 Previous County Transportation Emissions Quantification

In 2021, the County of Santa Clara completed a communitywide GHG inventory and forecast. The report includes an emissions inventory for 2017 from activities within the unincorporated area of the County as well as the incorporated jurisdictions within the County. The inventory and forecast serve as part of the preparation for the County's forthcoming Climate Roadmap 2030, the County's first climate action plan, which will outline actions the County can take to reduce GHG emissions. According to the County's report, on-road transportation emissions from 2017 totaled approximately 4,853,000 $MTCO_2e$ for the County as a whole and 41,500 $MTCO_2e$ for the unincorporated areas of the County (County of Santa Clara 2021). Emissions from the on-road transportation sector accounted for 45 percent of countywide GHG emissions. The County's report accounted for rail emissions through CARB's OFFROAD2017 model and did not consider actual rail activity or emissions.

Although the County's 2017 inventory provided a countywide emissions estimate, it aggregated the on-road transportation emissions from each of the incorporated jurisdictions. To provide context of the contributions of each of the 15 incorporated jurisdictions and the unincorporated area, Table 1 compares the most recent on-road transportation emissions reported for ten incorporated jurisdictions within the County that have also independently calculated on-road transportation emissions as part of their climate action and sustainability plans for other years within the last decade. (The City of Santa Clara and the Town of Los Altos Hills also developed climate action plans but did not specify exact emissions resulting from on-road transportation. The cities of Campbell, Gilroy, and Monte Sereno have not developed climate action plans for their jurisdictions.) Table 1 presents the reported on-road transportation emissions estimates from each jurisdiction as well as the respective data sources and methods used.

Table 1 Recent On-Road Transportation Emissions Estimates for Jurisdictions throughout Santa Clara County

Jurisdiction	Year	Population[13]	$MTCO_2e$/year	$MTCO_2e$/capita	Data Source	Method
County of Santa Clara[1]	2017	88,545	41,464	0.468	VMT: SVCE EF: EMFAC2017	RTAC
City of San Jose[2]	2019	1,793,112	2,463,770	1.374	VMT: Google EIE EF: EMFAC2017	RTAC[12]
City of Mountain View[3]	2012	74,447	478,986	6.434	VMT: Not specified EF: Not specified	Not specified
City of Sunnyvale[4]	2016	149,596	387,200	2.588	VMT: Not specified EF: Not specified	Not specified
City of Palo Alto[5]	2019	66,573	293,413	4.407	VMT: Fehr & Peers EF: Not specified	RTAC

Jurisdiction	Year	Population[13]	$MTCO_2e$/year	$MTCO_2e$/capita	Data Source	Method
City of Milpitas[6]	2019	79,517	259,627	3.265	VMT: MTC EF: EMFAC2021	RTAC
Town of Los Gatos[7]	2008	28,878	248,150	8.593	VMT: Fehr & Peers EF: EMFAC2011	Not specified
City of Cupertino[8]	2018	60,614	206,634	3.409	VMT: MTC EF: EMFAC2021	RTAC
City of Saratoga[9]	2017	31,013	56,847	1.833	VMT: MTC EF: EMFAC2017	RTAC
City of Morgan Hill[10]	2020	44,789	58,757	1.312	VMT: Not specified EF: Not specified	Not specified
City of Los Altos[11]	2018	30,588	56,555	1.849	VMT: SVCE EF: Not specified	RTAC

Notes: EF = emissions factor; EIE = Environmental Insights Explorer; RTAC = Regional Targets Advisory Committee; VMT = vehicle miles traveled, $MTCO_2e$ = metric tons of carbon dioxide equivalent; SVCE – Silicon Valley Clean Energy; EMFAC = California Air Resources Board's EMissions FACtor model.

1 County of Santa Clara 2021
2 City of San Jose 2021
3 City of Mountain View 2015
4 City of Sunnyvale 2019
5 City of Palo Alto 2020
6 City of Milpitas 2022
7 Town of Los Gatos 2012
8 City of Cupertino 2022
9 City of Saratoga 2020
10 City of Morgan Hill 2021
11 City of Los Altos 2022
12 2019 emissions were calculated by adding up 100% of EIE in-boundary emissions for the automobile category and 50% of inbound and outbound automobile emissions
13 County of Santa Clara and census.gov

Source: Data compiled by Ascent Environmental in 2023.

With respect to the County's countywide GHG estimates specifically, the 2017 inventory was completed using the U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions Version 1.2 (ICLEI CP) and focused on CO_2, methane (CH_4), and nitrous oxide (N_2O) emissions—the three GHGs most relevant to operations in the County. For the on-road transportation sector, GHG emissions from the operation of passenger and commercial vehicles were assessed based on VMT. According to the County, the 2017 VMT data were provided by Silicon Valley Clean Energy (SVCE) for the unincorporated County and the incorporated jurisdictions within SVCE's service area, including Campbell, Cupertino, Gilroy, Los Altos, Los Altos Hills, Los Gatos, Milpitas, Monte Sereno, Morgan Hill, Mountain View, Saratoga, and Sunnyvale. The VMT provided by SVCE was based on aggregated data queried from MTC. (Although Los Altos Hills and Los Gatos are considered towns, for the purposes of this discussion all incorporated jurisdictions are referred to as "cities".) Transportation data for the cities outside of SVCE's territory—Palo Alto, San Jose, and Santa Clara—were sourced from each of the city's travel demand models. Data for 2017 were not available for the City of Santa Clara, so 2016 data was used as a proxy. To calculate emissions, VMT data was multiplied by the emissions factor for mileage (g CO_2e/mile). VMT data was aggregated for all the incorporated areas of the County and the unincorporated area was presented separately. VMT data for both the incorporated and unincorporated areas were disaggregated by vehicle type using the output of CARB's EMFAC2017. (County of Santa Clara 2021).

2.1.2 Regional Transportation Planning

In 2021, the Bay Area adopted a long-range regional plan—Plan Bay Area 2050—that provides a roadmap and shared vision for the nine counties within the San Francisco Bay Area. One of the key focus areas of the plan is transportation. Plan Bay Area 2050 aims to build a well-connected transportation network, reduce transportation-related GHG emissions, and advance transportation equity through three key regional transportation strategies: *Maintain and Optimize the Existing Transportation System, Create Healthy and Safe Streets, and Build a Next-Generation Transit Network* (MTC & ABAG 2021a). VTA plays a key role in supporting these strategies due to its wide-ranging authority and influence over transportation in Santa Clara County. VTA provides bus, light rail, and paratransit services and is responsible for transit development and operations, congestion management, funding, highway design and construction, real estate and transit-oriented development, and bicycle and pedestrian planning (VTA 2017). VTA strives to provide sustainable, accessible, community-focused transportation options that are innovative, environmentally responsible, and promote the vitality of the region (VTA 2019).

2.2 INVENTORY OVERVIEW

2.2.1 Protocols and Methodologies

ON-ROAD TRANSPORTATION

This inventory follows the International Council for Local Environmental Initiatives (ICLEI) methodologies for quantifying on-road transportation emissions, specifically, the *U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions* Version 1.2 (Community Protocol). The Community Protocol was selected because it is the industry standard for local governments and agencies developing GHG emissions inventories and offers accuracy and consistency in reporting.

Following the recommended guidance from the Community Protocol, the RTAC origin-destination method was used to calculate VMT within the county. The RTAC method includes VMT estimates associated with trips that begin and/or end in the county. VMT estimates include 100 percent of vehicle trips that both originate from and end in the county (i.e., fully internal trips) and 50 percent of trips that either end in or depart from the county (i.e., internal-external or external-internal trips). Vehicle trips that are simply passing through the County boundaries without stopping (i.e., external-external, or “pass-through,” trips) are not included. Table 2 provides a summary of what is included and excluded in the RTAC method.

Table 2 RTAC Method Summary

On-Road Transportation	Included	Excluded	Protocol(s)
On-Road Transportation	Emissions from 100 percent of trips within the County (internal-internal) and 50 percent of trips starting or ending outside the County (internal-external and external-internal)	Emissions from 100 percent of pass-through trips starting and ending outside the County (external-external)	ICLEI/RTAC

Notes: ICLEI = ICLEI – Local Governments for Sustainability; RTAC = Regional Targets Advisory Committee.

Source: Compiled by Ascent Environmental in 2022.

RAIL TRANSPORTATION

Unlike on-road transportation, ICLEI recommends that passenger and freight rail emissions be based on the activity generated within the boundary of the jurisdiction, measured in train miles, rather than by using the origin and destination method (ICLEI 2019: Appendix D). Train miles (i.e., the number of miles travelled per locomotive) can be calculated using the product of total track miles within the county and number of annual trains passing through the county. ICLEI then recommends multiplying the train miles by the respective fuel mileage of each vehicle type (e.g., gallons of diesel per train mile), then by the GHG emission factors per unit of fuel. However, apart from VTA’s own light rail activity, fuel mileage data was not readily available from most of the rail providers operating in the county. As an alternative, total locomotive GHG emissions for non-VTA rail providers were scaled to the county based on their relative train miles in the county. Although recommended by ICLEI, this method does not consider the variability in efficiencies between different train trips, which may carry heavy or lighter loads. These variabilities, however, are inconsequential when considering that total rail emissions are a very small percentage of total transportation emissions.

2.2.2 Boundaries

This inventory quantifies GHG emissions from surface transportation in the County, which includes on-road and rail transportation-related emissions generated by the unincorporated areas of the County and the 15 incorporated jurisdictions within the County, for 2019. This 2019 baseline year is then used to estimate future emissions under BAU and legislative-adjusted BAU scenarios for the years 2030, 2035, 2040, 2045 and 2050. These years are based on baseline and forecast years included in MTC's transportation model and GHG reduction target years included in the State's climate policies (e.g., SB 32, SB 100, Assembly Bill [AB] 1279).

With respect to on-road transportation emissions, this inventory is primarily based on the RTAC method for attributing vehicle emissions to a certain jurisdiction. This method is the same method recommended by RTAC to Metropolitan Planning Organizations, like MTC, to calculate VMT per the SB 375 GHG emission reduction target setting process developed in 2010 (CARB 2019: 42). Under this method, only on-road vehicle activity generated by the targeted jurisdiction is included in the jurisdiction's inventory, thereby excluding any trips solely passing through the jurisdiction.

With respect to rail emissions, this inventory includes those from VTA, Caltrain, Amtrak, and UP for activity occurring within the boundary of the county, per ICLEI recommendations. ACE and BART emissions were excluded from the 2019 communitywide transportation inventory because data was not readily available from ACE, and BART did not begin operations in the county until 2020. The Milpitas and Berryessa BART stations began operations in July 2020.

2.2.3 Data, Methods, and Assumptions

OVERVIEW OF ACTIVITY DATA, YEARS, AND EMISSIONS FACTORS

For on-road transportation, the basic calculation for estimating GHG emissions involves two primary inputs: activity data and emissions factors (Table 3). Activity data refers to the relevant measurement of a community's activity resulting in emissions, and emissions factors represent the amount of a GHG emitted on a per unit of activity basis. Emissions factors are applied to activity data (i.e., the two values are multiplied together) to estimate GHG emissions. However, for rail activity, these emission factors were not readily available. Thus, a scaling approach was used to estimate county-level emissions from systemwide rail operations, described further below.

Table 3 Summary of Data Inputs

On-Road Transportation	Input Type	Description and Data Sources
On-Road Transportation	Activity data	VMT data provided by VTA, based on MTC's travel demand model under Plan Bay Area 2050.
	Emissions factor	County of Santa Clara specific emissions factors from CARB
Rail Transportation	Passenger Rail Emissions	Except for emissions from VTA's light rail system, total emissions for each rail service provider were scaled to the county based on the relative number of train miles in the county. VTA emissions were taken from the transit emissions inventory directly.
	Freight Rail Emissions	Total emissions for UP scaled to the county based on the relative track miles in the county compared to systemwide.

Notes: CARB = California Air Resources Board; VMT = vehicle miles traveled, MTC = Metropolitan Transportation Commission; VTA = Valley Transportation Authority; UP = Union Pacific

Source: Compiled by Ascent Environmental in 2022.

ON-ROAD TRANSPORTATION

To prepare for the CAAP, VTA worked with MTC to provide trip-based VMT for the entire County. Daily VMT was provided for 2015, 2035, and 2050 for passenger trips and commercial trips. Passenger VMT was provided by mode and aggregated into the following groups: DA, Carpool, TNC, and AV. According to MTC, AV activity is assumed to represent those generated by autonomous vehicles (e.g., vehicles that are driven without a physical driver on-board) operated by households. TNCs represent light duty ride hailing modes, similar to taxis, Uber, and Lyft. MTC assumes that TNCs are all autonomous after 2035 (Leung, pers. comm., 2022). Commercial VMT was provided by vehicle category and included Very Small, Small, Medium, and Large commercial vehicles. A description for each vehicle group can be found in Table 4 and a detailed methodology for how VMT was calculated can be found in Attachment 1 (Section 5).

MTC VMT data were based on modeling representative of the MPO's latest regional transportation plan: Plan Bay Area 2050. Plan Bay Area 2050 accounted for short-term COVID impacts, but only did so for its economic assessments, similar to the impact of a recession, and did not account for these impacts with respect to travel behavior, which would impact VMT estimates. Although MTC does not account for COVID impacts in its VMT estimates (e.g., increased percentage of workers working from home), MTC assumes a normal growth pattern beyond 2030. Thus, COVID impacts are not anticipated to have a significant effect on VMT forecasts after 2030.

Consistent with the methodology used in the Plan Bay Area 2050 Environmental Impact Report, an average annualization factor of 300 days per year was applied to daily VMT to get annual VMT (MTC & ABAG 2021b). This factor accounts for lighter traffic levels on weekends compared to weekdays.

Table 4 Vehicle Group Descriptions

Vehicle Groups	Description
Passenger – Drive Alone (DA)	Trips taken by single-occupant vehicles
Passenger - Carpool	Trips taken with two or more occupants in a vehicle
Passenger – Transportation Network Company (TNC)	Trips taken by Transportation Network Companies (e.g., Uber and Lyft); includes customer and deadhead VMT
Passenger – Autonomous Vehicle (AV)	Trips taken by a driverless vehicle; includes customer and deadhead VMT
Commercial – Very Small[1]	Two-axle, four-tire vehicles
Commercial – Small[1]	Two-axle, six-tire vehicles
Commercial – Medium[1]	Three-axle vehicles
Commercial – Large[1]	Four-or-more-axle vehicles

Note: Deadhead VMT refers to VMT from trips without a customer, taken in anticipation of the next customer trip.

[1] Bay Area Metro

Source: Bay Area Metro 2017, Leung, pers. comm., 2022; and Ascent Environmental 2022.

For the purposes of the CAAP, annual VMT estimates for each vehicle group, except for AVs, were linearly interpolated for 2019 using the RTAC origin-destination method established through SB 375 and CARB recommendations. AV VMT for 2019 were calculated based on a best fit logarithmic growth curve that aligns with MTC's VMT estimates for AVs in 2015, 2035, and 2050, to reflect AV's current early stages of research and adoption. These VMT estimates are associated with trips that begin and/or end in the County and exclude wholly pass-through trips, as explained in Section 2.1.1.

Emissions rates for countywide VMT were derived from EMFAC2021, CARB's statewide mobile source emissions inventory model. The eight vehicle groups provided by VTA were assigned an appropriate EMFAC2021 vehicle category, as shown in Table 5. EMFAC2021 was then used to generate emission rates specific to the County for the calendar year 2019 for all vehicle groups using aggregated model years, speeds, and fuel types. The countywide $MTCO_2e$ per mile emissions factor was calculated based on the distribution of VMT for each vehicle group and its emissions factor based on the assigned EMFAC vehicle categories.

Table 5 EMFAC2021 Vehicle Category Assignment

Vehicle Groups	EMFAC2021 Vehicle Category
Passenger - DA	LDA, LDT1, LDT2, MH, and MCY
Passenger - Carpool	LDA, LDT1, and LDT2
Passenger - TNC	LDA, LDT1, and LDT2
Passenger - AV	LDA, LDT1, and LDT2
Commercial – Very Small	LDA, LDT1, LDT2, and MDV
Commercial - Small	MDV
Commercial - Medium	LHD1, LHD2, and MDV
Commercial - Large	T6 CAIRP Heavy, T6 CAIRP Small, T6 Instate Heavy, T6 /instate Small, T6 OOS Heavy, T6 OOS Small, T6 Public, T6 Utility, T6TS, T7 CAIRP, T7 NNOOS, T7 NOOS, T7 Other Port, T7 POAK, T7 POLA, T7 Public, T7 Single, T7 SWCV, T7 Tractor, T7 Utility, T7IS, Motor Coach, OBUS, PTO, SBUS, and UBUS

Notes: DA = Drive Alone; TNC = Transportation Network Company; AV = Autonomous Vehicles; GVWR = Gross Vehicle Weight Rating; LDA = Passenger Cars; LDT1 = Light-Duty Trucks (GVWR* <= 3750 lbs.); LDT2 = Light-Heavy-Duty Trucks (GVWR 10001-14000 lbs.); MDV = Medium-Duty Trucks (GVWR 5751-8500 lbs.); MH = Motor Homes; MCY = Motorcycles; T6 CAIRP Heavy = Medium-Heavy Duty CA International Registration Plan Truck (GVWR 26001- 33000 lbs.); T6 CAIRP Small = Medium-Heavy Duty CA International Registration Plan Truck (GVWR 14001- 26000 lbs.); T6 Instate Heavy = Medium-Heavy Duty Tractor, Delivery or Other Truck (GVWR 26001-33000 lbs.); T6 Instate Small = Medium-Heavy Duty Tractor, Delivery or Other Truck (GVWR 14001-26000 lbs.); T6 OOS Heavy = Medium-Heavy Duty Out-of-state Truck (GVWR 26001-33000 lbs.); T6 OOS Small = Medium-Heavy Duty Out-of-state Truck (GVWR 14001-26000 lbs.); T6 Public = Medium-Heavy Duty Public Fleet Truck (GVWR 14001-33000 lbs.); T6 Utility = Medium-Heavy Duty Utility Fleet Truck (GVWR 16001-33000 lbs.); T6TS = Medium-Heavy Duty Truck; T7 CAIRP = Heavy-Heavy Duty CA International Registration Plan Truck (GVWR 33001 lbs. and over); T7 NNOOS = Heavy-Heavy Duty Non-Neighboring Out-of-state Truck (GVWR 33001 lbs. and over); T7 NOOS = Heavy-Heavy Duty Neighboring Out-of-state Truck (GVWR 33001 lbs. and over); T7 Other Port = Heavy-Heavy Duty Drayage Truck at Other Facilities (GVWR 33001 lbs. and over); T7 POAK = Heavy-Heavy Duty Drayage Truck in Bay Area (GVWR 33001 lbs. and over); T7 POLA = Heavy-Heavy Duty Drayage Truck near South Coast (GVWR 33001 lbs. and over); T7 Public = Heavy-Heavy Duty Public Fleet Truck (GVWR 33001 lbs. and over); T7 Single = Heavy-Heavy Duty Single Unit Concrete/Transit Mix, Dump or Other Truck (GVWR 33001 lbs. and over); T7 SWCV = Heavy-Heavy Duty Solid Waste Collection Truck (GVWR 33001 lbs. and over); T7 Tractor = Heavy-Heavy Duty Tractor Truck (GVWR 33001 lbs. and over); T7 Utility = Heavy-Heavy Duty Utility Fleet Truck (GVWR 33001 lbs. and over); T7IS = Heavy-Heavy Duty Truck; OBUS = Other Buses; PTO = Power Take Off; SBUS = School Buses; and UBUS = Urban Buses.

Source: CARB 2021 and Ascent Environmental 2022.

RAIL TRANSPORTATION

Emissions from rail transportation in 2019 are represented by activity from four rail providers: VTA, Caltrain, Amtrak, and UP. Passenger rail activity in the county in 2019 was comprised of VTA, Caltrain, Amtrak, and ACE trains. As mentioned, ACE and BART emissions are excluded for 2019 as ACE data was not readily available and BART did not begin operations in the county until 2020. Freight rail activity in the county was comprised of UP trains.

VTA Light Rail

Emissions generated from VTA's light rail activity in 2019 were calculated as part of VTA's transit operations GHG inventory and described under Section 3.

Caltrain

Although Caltrain has a plan to electrify its locomotive fleet, in 2019, Caltrain locomotives were still powered by diesel. According to Caltrain's 2021 Sustainability Report, Caltrain operations generated 43,253 $MTCO_2e$ in 2019, 97 percent of which was associated with diesel use in their revenue fleet operations (Caltrain 2022). Thus, it is assumed that Caltrain's locomotives generated 41,955 $MTCO_2e$ in 2019. To scale these emissions to the county level, the total train miles were calculated by using Caltrain's weekly schedule and noting the number of northbound and southbound trains within certain segments between county stations (from Palo Alto through Gilroy) and multiplying those trains by the track miles between each segment in the county. These calculations are shown in Attachment 2. Based on these calculations; it was estimated that county accounted for 27 percent of train miles across the Caltrain system. This percentage was applied to the 41,955 $MTCO_2e$ to estimate 17,600 $MTCO_2e$ associated with Caltrain locomotive activity in the county in 2019.

Amtrak

According to Amtrak's FY2021 Sustainability Report, Amtrak's Scope 1 emissions accounted for 686,984 $MTCO_2e$ in FY2019 across its operations throughout the country. For the purposes of the communitywide inventory, FY2019 emissions are used in place of calendar year 2019 emissions. For Amtrak, Scope 1 emissions primarily refer to diesel combustion emissions in locomotives. Across the country, Amtrak operated a total of 30 million train miles in 2019, according to the Federal Railway Administration (FRA) (FRA 2023a,b). Approximately, 6 million train miles are associated with electrified rail lines in the Northeast Corridor. In county, Amtrak operates two main lines: the Capitol Corridor and Coast Starlight, both of which are currently diesel-powered only. The Capitol Corridor operates about 11 track miles within the county and Coast Starlight operates approximately 49 miles within the county. According to the train schedules for both lines, a total of 5,306 Amtrak trains pass through the county each year. Based on these assumptions, Amtrak operations in the county account for 35,770 train miles per year, or 0.4 percent of Amtrak's systemwide non-electrified operations in 2019. This percentage was applied to the 686,984 $MTCO_2e$ to estimate 2,400 $MTCO_2e$ associated with Amtrak locomotive activity in the county in 2019.

Union Pacific

Freight railroad activity in the county is provided by UP. According to UP's 2020 Carbon Disclosure Project (CDP) Climate Report, UP's locomotive emissions accounted for 9.7 million $MTCO_2e$ in 2019 across its operations throughout the country (UP 2019). Systemwide, UP operated a total of 270 million train miles in 2019 (UP 2019). In the county, UP operates 108 miles of freight railway. According to FRA's railroad crossing reports, 12 trains traveled through the county daily in 2019, for a total of 4,380 trains per year (FRA 2023a,b). Based on these assumptions, UP operations in the county account for 473,040 train miles per year, or 0.18 percent of UP's systemwide operations in 2019. This percentage was applied to the total emissions per year to estimate 17,000 $MTCO_2e$ associated with UP locomotive activity in the county in 2019.

A summary of assumptions used to calculate emissions from Caltrain, Amtrak, and UP operations in the county is presented in Table 6. The methods used for Caltrain, Amtrak, and UP have the disadvantage of being based on consolidated GHGs under a CO_2 equivalent. Individual GHG pollutant emissions were not available from these providers, thus any differences in Global Warming Potential (GWP) assumptions are not accounted for in the resulting emissions scaled to the county level. VTA light rail emissions are quantified separately, as presented in Section 3.

Table 6 2019 Rail Emissions Calculations for Caltrain, Amtrak, and Union Pacific

	Caltrain[1]	*Amtrak Capitol Corridor*[2]	*Amtrak Coast Starlight*[2]	Total Amtrak	Union Pacific[3]
Total Locomotive Emissions ($MTCO_2e$)	41,955	*686,984*	*686,984*	686,984	9,683,378
Total Train Miles per year	1,435,824	*30,122,522*	*30,122,522*	30,122,522	269,909,640
Track Miles in Santa Clara County	46	*11*	*49*	60	108
Annual trains through Santa Clara County	13,356	*4,576*	*730*	5,306	4,380
Train Miles in Santa Clara County	618,384	*50,336*	*35,770*	86,106	473,040
Percent Train Miles in Santa Clara County	43%	*0.21%*	*0.15%*	0.35%	0.18%
Train Emissions in Santa Clara County ($MTCO_2e$)	17,600	1,400	1,000	2,400	17,000

Note: $MTCO_2e$ = metric tons of carbon dioxide equivalent. Totals may not sum due to rounding. See Attachment 2 for detailed calculations.

1 Locomotive emissions taken from Caltrain's 2021 Sustainability Report Update (Caltrain 2022). See Attachment 2 for sources used to calculate train miles per year by location.

2 Scope 1 emissions from Amtrak's FY2021 Sustainability Report assumed for total locomotive emissions (Amtrak 2022). Total train miles from Federal Railroad Administration and adjusted for electrified train miles in the Northeast Corridor based on train schedules and a total alignment

of 457 miles in that corridor (FRA 2023a,b). County-level train miles and annual trains based on mileage of Capitol Corridor and Coast Starlight tracks in Santa Clara County and the respective train schedules through the county.

[3] Locomotive emissions taken from Union Pacific's 2020 Carbon Disclosure Project Climate Report (CDP 2020). Total train miles from UP (UP 2019). Santa Clara county train miles based UP track length in the county and 12 daily trains, per FRA crossing reports (FRA 2023a,b).

Source: Compiled by Ascent Environmental in 2023.

2.2.4 Global Warming Potentials

GHG emissions other than CO_2 generally have a stronger insulating effect and thus, a greater ability to warm the Earth's atmosphere through the greenhouse effect. This effect is measured in terms of a pollutant's GWP. CO_2 has a GWP factor of one while all other GHGs have GWP factors measured in multiples of one relative to the GWP of CO_2. This conversion of non-CO_2 gases to one unit enables the reporting of all emissions in terms of carbon dioxide equivalent (CO_2e), which allows for the consideration of all gases in comparable terms and makes it easier to communicate how various sources and types of GHG emissions contribute to climate change. The standard unit for reporting emissions is metric tons of carbon dioxide equivalent ($MTCO_2e$).

Consistent with the best available science, these inventories use GWP factors published in the Sixth Assessment Report from IPCC, where CH_4 and N_2O have GWP factors of 27.9 and 273, respectively (IPCC 2021). These values represent the GWP of GHG on a 100-year time horizon. This means that CH_4 is approximately 28 times stronger than CO_2 and N_2O is 273 times stronger than CO_2 in their potential to warm Earth's atmosphere over the course of 100 years. The use of 100-year GWP values is consistent with CARB methods and reflects the long-term planning horizon of the CAP.

2.3 COUNTYWIDE TRANSPORTATION GHG EMISSIONS INVENTORY RESULTS FOR 2019

2.3.1 Summary of Results

Based on modeling conducted, transportation in the County in 2019 emitted approximately 4.2 million $MTCO_2e$ in 2019. Approximately 99 percent of these emissions were from on-road transportation, while the remaining one percent was attributable to rail activity in the county. Annual VMT and GHG emissions from on-road and rail transportation are shown by source in Table 7.

Table 7 2019 On-Road Transportation VMT and GHG Emissions by Vehicle Group

On-Road Transportation Source	Annual VMT	Percent VMT	GHG Emissions ($MTCO_2e$)	Percent Emissions
Passenger - DA	8,991,351,330	73%	2,905,000	69%
Passenger - Carpool	2,075,863,530	17%	669,000	16%
Passenger - TNC	104,907,270	<1%	34,000	0.4%
Passenger - AV	53,628,058	1%	17,000	1%
Commercial – Very Small	817,666,890	7%	279,000	7%
Commercial - Small	219,336,690	2%	104,000	2%
Commercial - Medium	14,299,110	<1%	8,000	0.2%
Commercial - Large	75,046,320	1%	128,000	3%
On-Road Transportation Total	**12,352,099,198**	**100%**	**4,143,000**	**99%**
Rail - Freight	NA	NA	17,000	0.4%
Rail - Passenger	NA	NA	22,000	0.5%

On-Road Transportation Source	Annual VMT	Percent VMT	GHG Emissions ($MTCO_2e$)	Percent Emissions
Rail Total	NA	NA	39,000	1%
Total	**12,352,099,198**	**100%**	**4,182,000**	**100%**

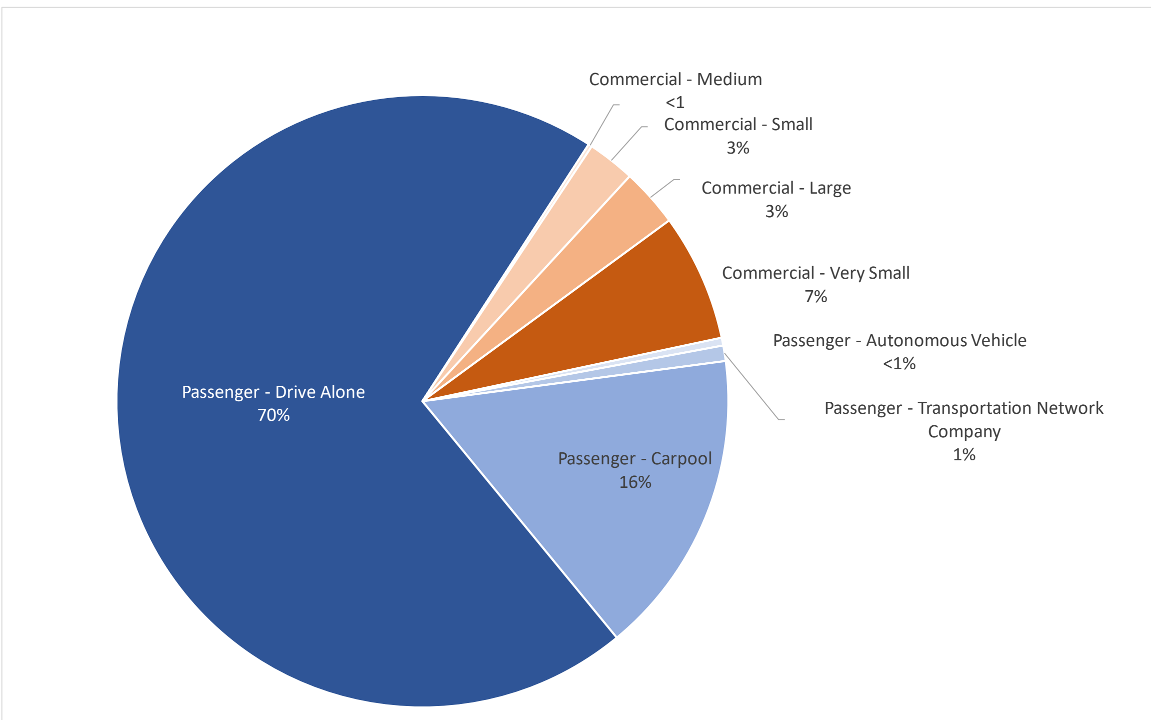
Notes: Except for AVs, VMT for 2019 were linearly interpolated from VMT data provided through MTC for 2015 and 2035. AV VMT is estimated based on a logarithmic growth curve based on VMT data provided through MTC for 2015, 2035, and 2050. GHG = greenhouse gas emissions; $MTCO_2e$ = metric tons of carbon dioxide equivalent; VMT = vehicle miles traveled; DA = Drive Alone; TNC = Transportation Network Company; AV = Autonomous Vehicles. Totals may not sum due to rounding. Emissions results shown are rounded to account for variability with actual emissions.

Source: VTA and Ascent Environmental 2022.

ON-ROAD TRANSPORTATION

In 2019, passenger trips generated 11 billion VMT and resulted in 3.6 million $MTCO_2e$, approximately 86 percent of total on-road transportation emissions. Drive Alone trips produced the largest source of passenger emissions with 2.9 million $MTCO_2e$, followed by Carpool trips with 669,000 $MTCO_2e$, TNC trips with 34,000 $MTCO_2e$, and AV trips with 17,000 $MTCO_2e$.

Commercial trips accounted for 1 billion VMT in 2019 and resulted in 519,000 $MTCO_2e$, approximately 12 percent of total on-road emissions for the year. The largest source of commercial emissions came from Very Small commercial vehicles with 279,000 $MTCO_2e$, followed by Large commercial vehicles with 128,000 $MTCO_2e$, Small commercial vehicles with 104,000 $MTCO_2e$, and Medium commercial vehicles with 8,000 $MTCO_2e$. Overall, the largest source of on-road emissions from all vehicle groups in 2019 was from Drive Alone passenger trips, which accounted for 70 percent of total on-road emissions. Annual emissions in percentage by vehicle group are shown in Figure 4.



Source: Compiled by Ascent Environmental in 2022.

Figure 4 2019 Passenger and Commercial Transportation Emissions – by Vehicle Group

RAIL TRANSPORTATION

Rail transportation accounted for one percent of total transportation emissions in 2019. A total of 2.8 million train miles operated in the county generated 38,800 $MTCO_2e$ in 2019. Passenger rail (e.g., VTA, Caltrain, and Amtrak) accounted for 56 percent of total rail emissions, while freight rail accounted for the remaining 44 percent of total rail emissions. With respect to total countywide transportation emissions, passenger rail accounted for 0.5 percent of total communitywide transportation emissions and freight rail accounted for 0.4 percent of total emissions. A summary of the data used to estimate rail emissions in 2019 is shown in Table 8 below.

Table 8 2019 Rail Emissions Assumptions and Calculations

Rail Provider	Mode Type	System Wide Locomotive Emissions ($MTCO_2e$/year)	Annual Train Miles in Santa Clara County	Percent of Train Vehicle Miles in Santa Clara County	Santa Clara County Locomotive Emissions ($MTCO_2e$)	Percent of Total Rail Emissions
VTA	Passenger	1,330	2,284,831	100%	1,300	3%
Caltrain	Passenger	41,955	13,356	43%	18,100	47%
Amtrak	Passenger	686,984	86,106	0.35%	2,400	6%
Union Pacific	Freight	9,683,378	473,040	0.18%	17,000	44%
				Total	38,800	100%

Notes: VTA = Valley Transportation Authority; $MTCO_2e$ = metric tons of carbon dioxide equivalent. Altamont Corridor Express emissions excluded due to lack of data. Totals may not sum due to rounding. Emissions results shown are rounded to account for variability with actual emissions. See Table 6 for data sources and calculation assumptions.

Source: Compiled by Ascent Environmental in 2023.

2.4 COUNTYWIDE TRANSPORTATION GHG EMISSIONS FORECASTS

2.4.1 Overview

Using the results of the 2019 countywide transportation emissions inventory, two forecast scenarios are provided to estimate future GHG levels from transportation in the county. The first scenario, Business-As-Usual (BAU), is based on a continuation of current trends in activity and does not account for GHG emissions reductions resulting from laws and regulations adopted by local, regional, State, or federal agencies; it illustrates how much emissions would increase due to population and economic growth if no actions to reduce emissions were taken. The second scenario, a legislative-adjusted BAU scenario, shows emissions reductions from laws and regulations enacted by regional, State, and federal agencies; it does not reflect local actions to reduce GHG emissions. GHG emissions forecasts provide insights to the scale of regional and local reductions needed to achieve GHG emissions reduction targets.

2.4.2 VMT Projections

Annual VMT projections were provided by MTC and processed by VTA for 2035 and 2050 for each of the same passenger and commercial vehicle groups that were provided for the 2019 inventory. Passenger VMT included projections for DA, Carpool, TNC, and AV. Commercial VMT included projections for Very Small, Small, Medium, and Large commercial vehicles. Annual VMT projections for all groups, except for AVs, were interpolated for 2030, 2040, and 2045 using the data from 2035 and 2050. As with the 2019 estimates, AV forecasts were based on a best fit growth curve using MTC's 2015, 2035, and 2050 data. Consistent with the 2019 inventory, the RTAC origin-destination method was used in all VMT projections. Total VMT is projected to increase each year, as shown in Table 9. Compared to 2019, VMT is projected to increase 7 percent by 2030, 12 percent by 2035, 14 percent by 2040, and 19 percent by 2045. By 2050, annual VMT is projected to be 15.6 billion, a 26 percent increase from 2019. These growth forecasts reflect MTC's travel modeling under Plan Bay Area 2050 which accounts for increases in population, economic activity and transportation costs, transportation infrastructure and program investments (e.g., roadway and transit networks), changes in land use, job-housing balance, and other variables (MTC & ABAG 2021c).

Table 9 County of Santa Clara 2019 and Projected VMT (million vehicle miles per year)

On-Road Transportation Source	2015	2019	2030	2035	2040	2045	2050
Passenger - DA	8,927	8,991	9,168	9,248	8,887	8,526	8,165
Passenger - Carpool	2,008	2,076	2,261	2,345	2,267	2,189	2,111
Passenger - TNC	65	105	215	264	295	326	357
Passenger - AV	0	54	477	934	1,521	2,469	3,788
Commercial – Very Small	829	818	787	773	800	826	853
Commercial - Small	222	219	212	209	216	224	231
Commercial - Medium	14	14	15	15	15	16	16
Commercial - Large	74	75	78	79	82	86	89
Total	12,140	12,352	13,212	13,868	14,084	14,662	15,610
Percent change from 2019	*-1.7%*	*N/A*	7%	12%	14%	19%	26%

Notes: VMT for 2019, 2030, 2040, and 2045 was interpolated from VMT data provided by VTA for 2015, 2035, and 2050. VMT = vehicle miles traveled; DA = Drive Alone; TNC = Transportation Network Company; AV = Autonomous Vehicles.

Source: VTA and Ascent Environmental 2022.

2.4.3 Rail Activity Projections Forecasts

VTA Light Rail

VTA estimates future light rail activity to increase by at least 26 percent from 2019 levels by 2030 and stay constant from 2030 through 2050. VTA light rail activity projections are discussed in further detail under Section 3.4.

Caltrain

Caltrain activity projections are based on Caltrain's 2040 Long Range Service Plan (Caltrain 2019). Under this plan, service across the peninsula would increase by 182 percent, or nearly three times, between 2019 and 2040. It is assumed that after 2040, service would then remain constant.

Amtrak

Amtrak does not have long term activity projections for either Capitol Corridor or Coast Starlight. In absence of these plans, Amtrak activity in California, and in the county, is assumed to be proportional to the State's overall plan for passenger rail under the 2018 State Rail Plan. The 2018 State Rail Plan estimates that passenger rail trips in the state will increase by 11 times from 2018 to 2040, from 115,000 to 1.3 million trips per day (California Department of Transportation 2018:213). Amtrak activity in the county is expected to increase proportionally to this and remain constant after 2040.

BART

BART began operations in the county in 2020. However, according to their 2021 Sustainability Report, starting in 2021, 100 percent of BART's electricity is purchased from GHG-free sources (BART 2021). This commitment is assumed to continue in perpetuity. Given that BART's trains are all electrified, this means that regardless of increases in activity in the future, GHG emissions from BART traction power will continue to be zero.

Union Pacific

Like Amtrak, UP does not have long term activity projections for its operations in California. In absence of these plans, UP activity in California, and in the county, is assumed to be proportional to the State's overall plan for freight rail under the 2018 State Rail Plan. The 2018 State Rail Plan estimates that freight rail volumes in the state will nearly double from 2013 to 2040, from 161 to 319 million tons (California Department of Transportation 2018:170). UP activity in the county is expected to increase proportionally to this and remain constant after 2040.

2.4.4 BAU Emissions Forecasts

The following BAU GHG emissions forecasts provide an assessment of how emissions generated by surface transportation use will change over time without further local, State, or federal action. If no action is taken, emissions are projected to increase each forecast year, as shown in Table 10. Compared to 2019 levels, emissions are projected to increase by 7 percent by 2030, 13 percent by 2035, 15 percent by 2040, and 20 percent by 2045. Under a BAU scenario, emissions are projected to reach 5,313,000 $MTCO_2e$ by 2050, an increase of 27 percent from 2019 levels.

Table 10 County of Santa Clara Transportation GHG Inventory 2019 and BAU Forecasts 2030 through 2050 ($MTCO_2e$)

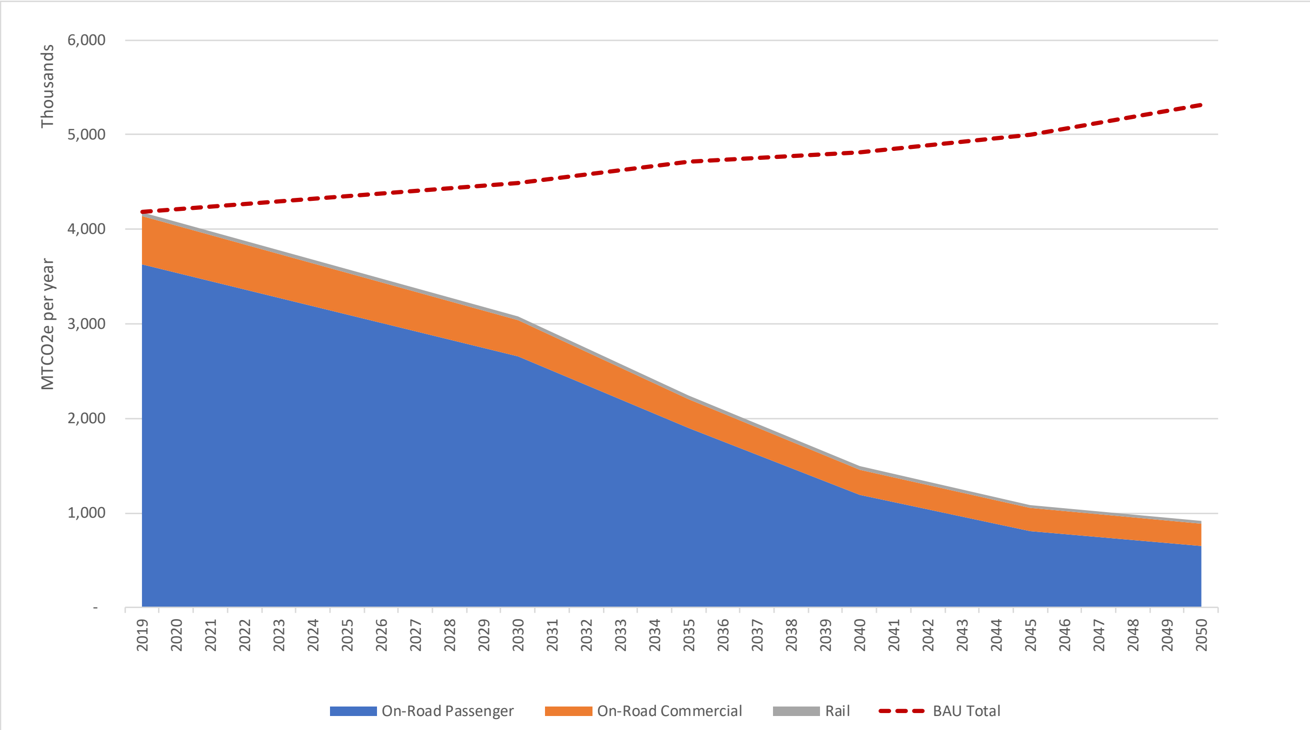
On-Road Transportation Source	2019	2030	2035	2040	2045	2050
Passenger - DA	2,905,000	2,962,000	2,988,000	2,871,000	2,754,000	2,638,000
Passenger - Carpool	669,000	729,000	756,000	730,000	705,000	680,000
Passenger - TNC	34,000	69,000	85,000	95,000	105,000	115,000
Passenger - AV	17,000	154,000	301,000	490,000	796,000	1,220,000
Commercial – Very Small	279,000	268,000	263,000	272,000	282,000	291,000
Commercial - Small	104,000	101,000	99,000	103,000	106,000	110,000
Commercial - Medium	8,000	8,000	8,000	8,000	9,000	9,000
Commercial - Large	128,000	132,000	134,000	140,000	146,000	151,000
Total On-Road Transportation	**4,143,000**	**4,423,000**	**4,635,000**	**4,710,000**	**4,903,000**	**5,214,000**
Rail - Freight	17,000	23,000	25,000	28,000	28,000	28,000
Rail - Passenger	22,000	47,000	59,000	71,000	71,000	71,000
Total Rail	39,000	70,000	84,000	98,000	98,000	98,000
Total	**4,182,000**	**4,492,000**	**4,719,000**	**4,809,000**	**5,001,000**	**5,313,000**
Percent change from 2019	*N/A*	*7%*	*13%*	*15%*	*20%*	*27%*

Notes: BAU = business-as-usual; GHG = greenhouse gas; $MTCO_2e$ = metric tons of carbon dioxide equivalent; DA = Drive Alone; TNC = Transportation Network Company; AV = Autonomous Vehicles. Totals may not sum due to rounding. Emissions results shown are rounded to account for variability with actual emissions.

Source: Ascent Environmental 2022.

2.4.5 Legislative-Adjusted BAU Emissions Forecasts

With legislative adjustments, countywide transportation emissions would decrease by 78 percent from 2019 through 2050. Reductions in on-road transportation emissions from passenger vehicles contribute to a large part of this reduction, as shown in Figure 5. A detailed breakdown of the legislative adjusted BAU emissions forecasts is presented in Table 11.



Source: Ascent Environmental 2022.

Figure 5 Santa Clara County Transportation GHG BAU Emissions and Legislative-Adjusted Forecast Emissions (2019-2050)

Table 11 County of Santa Clara Transportation GHG Inventory 2019 and Legislative-Adjusted BAU Forecasts 2030 through 2050 ($MTCO_2e$)

On-Road Transportation Source	2019	2030	2035	2040	2045	2050
Passenger - DA	2,905,000	2,010,000	1,377,000	823,000	517,000	374,000
Passenger - Carpool	669,000	493,000	346,000	206,000	129,000	93,000
Passenger - TNC	34,000	47,000	39,000	27,000	19,000	16,000
Passenger - AV	17,000	104,000	138,000	138,000	145,000	167,000
Commercial – Very Small	279,000	188,000	135,000	100,000	80,000	72,000
Commercial - Small	104,000	77,000	71,000	70,000	71,000	73,000
Commercial - Medium	8,000	6,000	6,000	5,000	5,000	5,000
Commercial - Large	128,000	110,000	94,000	87,000	84,000	84,000
Total On-Road	4,143,000	3,036,000	2,205,000	1,457,000	1,051,000	883,000
Rail - Freight	17,000	23,000	25,000	28,000	28,000	28,000
Rail - Passenger	22,000	18,000	17,000	16,000	8,000	8,000
Total Rail	39,000	41,000	42,000	43,000	36,000	36,000
Total	4,182,000	3,077,000	2,247,000	1,501,000	1,087,000	919,000
Percent change from 2019	*N/A*	*-26%*	*-46%*	*-64%*	*-74%*	*-78%*

Notes: BAU = business-as-usual; GHG = greenhouse gas; $MTCO_2e$ = metric tons of carbon dioxide equivalent. DA = Drive Alone; TNC = Transportation Network Company; AV = Autonomous Vehicles. Totals may not sum due to rounding. Emissions results shown are rounded to account for variability with actual emissions.

Source: Compiled by Ascent Environmental in 2023.

ON-ROAD TRANSPORTATION

In addition to accounting for countywide growth under a BAU scenario, a legislative-adjusted BAU forecast was prepared, which includes adopted legislative and regulatory actions at the local, State, and federal levels that would affect emissions without any additional action. These include regulatory requirements to increase the percentage of zero-emission vehicles in new vehicle sales and improve vehicle fuel efficiency standards. It is important to note that the legislative-adjusted BAU emissions forecasts only include emissions reductions associated with implementation of federal, State, and local legislation and regulations that are adopted and do not include goals established by executive orders or targets established by federal or State agencies. There are several legislative actions (e.g., Advanced Clean Fleet) currently in draft form that could result in further reductions for future inventory updates once adopted. In addition, local VMT reductions associated with Senate Bill (SB) 743 are already accounted for in the MTC data and thus are not included in Table 12. The GHG emissions forecasts are aligned with various legislative actions, as shown in Table 12.

Table 12 Legislative Reductions Summary for Communitywide Transportation Emissions Forecasts

Source	Legislative Reduction	Description
State	Advanced Clean Car I Regulations	Establishes GHG emission reduction standards for model years 2017-2025 that are more stringent than federal CAFE standards.
State	Advanced Clean Car Standards II Regulations	Establishes a target for all new passenger cars, trucks, and SUVs sold in California to be 100 percent zero-emission vehicles by 2035.
State	Truck and Bus Regulation	Requires diesel trucks and buses that operate in California to be upgraded to reduce GHG emissions by 2035.
State	Innovative Clean Transit Rule	Requires 100 percent of new purchases by transit agencies to be zero emissions starting in 2029 and achieving full transition to ZEBs by 2040.
Federal	Fuel Efficiency Standards for Medium- and Heavy-Duty Vehicles	Establishes fuel efficiency standards for medium- and heavy-duty engines and vehicles.

Notes: CAFE = Corporate Average Fuel Economy; GHG = greenhouse gas; SB = Senate Bill; SUV = sport utility vehicle; ZEB = zero-emission bus

Source: Ascent Environmental in 2022.

With respect to the legislative adjustments included in this forecast, State and federal laws and regulations incorporated in the on-road transportation sector include the ACC Regulatory Program (ACC I and II) and fuel efficiency standards for medium- and heavy-duty vehicles. All of these policies, with the exception of Advanced Clean Cars II, are included in EMFAC2021's emissions factor estimates and forecast. Advanced Clean Cars II was included in an off-model adjustment and accelerates the State's climate goals by requiring that all new light duty vehicle sales be zero emissions by model year 2035, with increased intermediate targets starting for model year 2026. The Low Carbon Fuel Standard was excluded in EMFAC2021 forecasts because the emissions benefits originate from upstream fuel production and do not directly reduce vehicle tailpipe emissions that affect the county's GHG emissions forecasts. Table 13 summarizes the scaling factors and legislative reductions used to forecast on-road transportation emissions.

Table 13 On-Road Transportation Emissions Forecast Methods

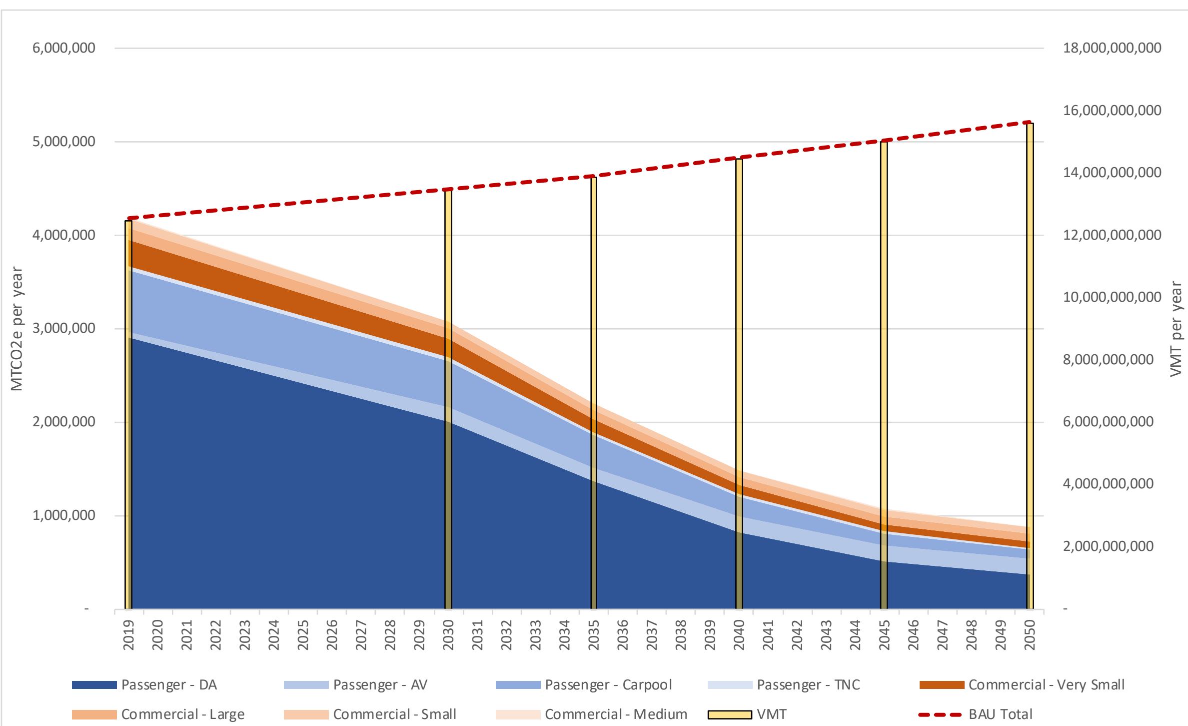
Forecast Methods	
Growth Factor	**Applied Legislative Reductions**
Scaled by VMT estimates provided by VTA and MTC.	EMFAC2021 forecasts vehicle fleet distributions by vehicle type and the emissions factors anticipated for each vehicle category based on both vehicle emissions testing and approved legislative reductions. EMFAC2021's forecasts incorporate the effects of the ACC I Standards, federal CAFE standards, and fuel efficiency standards for medium- and heavy-duty vehicles, as well as truck and bus regulations. Legislative actions that are anticipated to impact the number of electric vehicles in the future are incorporated into the emissions factors obtained from EMFAC2021. Per ACC II, additional adjustments were made to the EMFAC2021 emission factors to account for accelerated proportion of new light duty vehicles that are zero emissions starting in model year 2026 and fully transitioning by model year 2035.

Notes: ACC = Advanced Clean Cars; CAFE = Corporate Average Fuel Economy; EMFAC2021 = California Air Resources Board's EMisson FACtor 2021 model; VMT = vehicle miles traveled; MTC = Metropolitan Transportation Commission.
Source: Ascent Environmental 2022.

Table 11 and Figure 6 show the 2019 inventory and legislative-adjusted BAU forecasted emissions from on-road transportation for 2030, 2035, 2040, 2045, and 2050. When compared to the 2019 baseline year, the County's legislative-adjusted BAU emissions are anticipated to decrease for each of the forecast years. In 2030, emissions are projected to decrease 27 percent from the baseline year, producing 3,036,000 $MTCO_2e$. In 2035, emissions are projected to decrease 47 percent, producing 2,205,000 $MTCO_2e$. In 2040, emissions are anticipated to decrease approximately 65 percent, producing 1,457,000 $MTCO_2e$. In 2045, emissions are projected to decrease 74 percent, producing 1,051,000 $MTCO_2e$. Projections show a 78 percent decrease for 2050, with emissions estimated to be 883,000 $MTCO_2e$.

Based on the results the countywide transportation emissions inventory, Figure 6 presents two forecast scenarios that estimate future GHG emissions from transportation in the county: a Business-As-Usual (BAU) scenario, shown as the red dotted line, and a legislative-adjusted BAU forecast, shown as the stacked area in blue and orange. The BAU forecast illustrates how transportation emissions would increase due to population and economic growth without additional legislative regulations that reduce emissions. The legislative-adjusted BAU scenario accounts for emissions reductions from laws and regulations enacted by regional, State, and federal agencies; it does not reflect local actions to reduce GHG emissions. GHG emissions forecasts provide insights to the scale of additional regional and local reductions needed to achieve GHG emissions reduction targets. Additionally, Figure 6 also presents the VMT estimates upon which these emission forecast scenarios were developed, shown as the yellow bars. The trends in the BAU forecasts are inherently proportional to the BAU forecasts because no additional reductions to emissions rates are assumed.

The legislative-adjusted BAU forecast is comprised of emissions from eight different vehicle groups, represented by two vehicle categories (passenger and commercial) and various classes and modes. These groupings were based on the available modeling data provided by MTC. Passenger vehicle emissions are split into four modes: drive alone (DA); autonomous vehicle (AV); carpool; transportation network company (TNC) (e.g., ride hailing operations like Uber and Lyft). Commercial vehicle emissions are split into four vehicle classes: large, medium, small, and very small. Table 4 in Section 2.2.3 describes the definition of these vehicle groups in more detail.



Source: Ascent Environmental 2022.

Figure 6 Santa Clara County On-Road Transportation GHG BAU Emissions, Legislative-Adjusted Forecast Emissions, and VMT (2019-2050)

RAIL TRANSPORTATION

Rail emissions, accounting for legislative reductions, are expected to decline by a modest seven percent by 2050 from 2019 levels. The applied legislative reductions are discussed below for each rail operator.

VTA Light Rail

VTA's future light rail emissions under the legislative adjusted BAU forecast account for the increase of procurement of electricity from GHG-free sources, as all VTA light rail operations are electric. These emissions projections are discussed in further detail under Section 3.4.3.

Caltrain

Caltrain plans to electrify its entire passenger rail line by 2025 projections per Caltrain's Electrification project timeline (Caltrain 2023). According to the Environmental Impact Report for the electrification project, by 2040 emissions from Caltrain's locomotives would be 72 percent lower than the no project alternative (Caltrain 2014: Table 3.7-4). In 2040, locomotive emissions would be represented by both electric and diesel emissions, as Caltrain will continue to use diesel for railyard operations. However, by 2045, all electricity-related emissions are assumed to be zero pursuant to the carbon neutrality target for electric utilities under SB100. Thus, by 2045, it is estimated that Caltrain electrification will result in a 97 percent reduction relative to a no project condition, or a BAU. These calculations are shown in Attachment 2. These percentage reductions are applied to the forecasted BAU emissions to estimate legislative adjusted forecasts from Caltrain rail emissions in the county.

Amtrak

Amtrak plans to use 100 percent renewable diesel on its Capitol Corridor line by 2030 (Amtrak 2022). However, Amtrak does not have similar plans for Coast Starlight. Based on this information, Capitol Corridor GHG emissions are expected to be zero starting in 2030, due to renewable diesel's biogenic sources. This means that the forecasted emissions from Amtrak operations in the county starting in 2030 will only be representative of activity of the Coast Starlight line, which is assumed to continue to operate on traditional petroleum-based diesel. No legislative adjustments would be made to emissions forecasts for the Coast Starlight line, which is scaled by the passenger rail forecasts under the 2018 State Rail Plan.

BART

BART began operations in the county in 2020. However, according to their 2021 Sustainability Report, starting in 2021, 100 percent of BART's electricity is purchased from GHG-free sources (BART 2021). This commitment is assumed to continue in perpetuity. Given that BART's trains operating in the county are all electrified, this means that regardless of increases in activity in the future, GHG emissions from BART traction power in the county will continue to be zero.

Union Pacific

UP has not identified any concrete plans to convert to using renewable fuels or electrification of their lines within the county or elsewhere throughout its system in the future. As such, no legislative adjustments are made to emissions forecasts for UP operations in the county.

3 GHG EMISSIONS INVENTORY AND FORECAST FOR TRANSIT OPERATIONS

This section presents an updated inventory and forecast for GHG emissions from VTA's transit operations, drawing from historical data available from fiscal years (FY) 2009 through 2021 and forecasting these emissions through 2050. VTA's fiscal year is the 12-month accounting period that starts on July 1 and ends on June 30. Fiscal year is often abbreviated FY, and the year referenced is the end of that period. For example, FY 2021 covers from July 1, 2020 to June 30, 2021. The countywide transportation emissions estimates in the previous section inherently includes emissions from the fleet and employee commute portion of the transit operations inventory, but transit operations emissions also include emissions from building energy use, waste generation, and water consumption. A background discussion (Section 3.1) of VTA's previous sustainability efforts and emissions tool development explains the approach to this update to VTA's transit operations emissions inventory and forecasts. Section 3.2 presents the purpose behind the inventory and an explanation of the methodology used for the inventory. Section 3.3 presents the results of the transit operations emissions inventory update. Section 3.4 presents the transit operations emissions forecast, including a discussion of the forecast methodology by emissions sector (e.g., fleet, building energy).

3.1 BACKGROUND

Ascent previously worked with VTA to create sustainability trends and targets for the development of VTA's Sustainability Plan (Plan), which was approved in 2020. As part of the Plan's development, Ascent prepared a Sustainability Inventory, Goals, and Targets Tool (Tool) to track VTA's sustainability metrics, starting from FY 2009, and to develop sustainability targets based on those metrics and other influencing factors. The Tool tracks five main sustainability metrics (energy use, GHG emissions, criteria air pollutant emissions, water use, and waste disposal tonnage) across six activity sectors (i.e., buildings and facilities, revenue and non-revenue fleet, employee commute, displaced and avoided trips, water, and waste). The Plan showed results through FY 2019.

The Tool developed for the Plan was designed to produce results showing trends in resource consumption and emissions since FY 2009. These results can be used to identify where progress on achieving sustainability goals has occurred to date and areas where additional progress could be made. Progress is determined by reductions in GHGs, criteria air pollutants, resource consumption (e.g., water and energy), and by increases in activities associated with enhanced sustainability (e.g., recycling and waste diversion). The tool allows for a more comprehensive analysis by compiling data for multiple years rather than a single year (VTA 2017). The Tool also offers the flexibility to track progress in future years as additional data become available. The ability to accurately track future progress allows VTA to establish and work toward quantitative targets for future years that are aligned with internal agency objectives, goals set by municipal and state agencies, and targets from non-profit organizations such as the Sustainability Commitment Guidelines from the American Public Transportation Association (APTA).

3.2 INVENTORY PURPOSE AND OVERVIEW

This inventory updates and quantifies GHG emissions from VTA's transit operations in FY 2020 and FY 2021. Ascent used the existing Tool—described in Section 3.1—to update the inventory through FY 2021. While the Tool was previously used to track five sustainability metrics (energy use, GHG emissions, criteria air pollutant emissions, water use, and waste disposal tonnage), the purpose of this inventory is to prepare for VTA's CAAP and is therefore solely focused on tracking GHG emissions. GHG emissions are assessed across the five activity sectors highlighted in the Tool (i.e., buildings and facilities, revenue and non-revenue fleet, employee commute, water, and waste). Avoided emissions from displaced and avoided trips, which were included in the Tool, were not included in this inventory because that sector was originally required to meet APTA's sustainability metrics and is calculated using APTA mode shift assumptions. Displaced and avoided trips were also excluded because these offsets are outside of VTA's direct jurisdiction. Short-term GHG emissions that result from material processing and transportation, on-site construction equipment, and traffic delays due to construction of projects, are also excluded. These construction-related GHG emissions are based on project-specific information (e.g., equipment needs, construction phasing, duration, frequency) and are evaluated as part of the environmental review process for that project.

A detailed methodology can be found in the VTA Sustainability Plan Technical Memorandum prepared by Ascent in 2020. Only updates to any methodologies or emissions factors relevant for the inventory are highlighted in this memorandum. All other assumptions can be found in the 2020 VTA Sustainability Plan Technical Memorandum. Herein going forward to be consistent with the previous inventory conducted, all reference to years are assumed to be in fiscal years.

3.3 TRANSIT OPERATIONS GHG EMISSIONS INVENTORY UPDATES

3.3.1 GHG Emissions Inventory Updates

Table 14 details emissions by year and sector. Based on the modeling conducted, VTA's transit operations generated approximately 39,431 $MTCO_2e$ in FY 2021. Overall, emissions decreased by 44 percent compared to the 2009 baseline year. This decline in emissions is largely attributed to the significant declines in ridership VTA experienced in FY 2021 due to the Novel Coronavirus 2019 (COVID-19) pandemic which started in March 2020 with a shelter-in-place order issued for Santa Clara County. For FY 2021, overall ridership was down by 58 percent compared to the prior fiscal year. Limited vehicle capacity seating was imposed, and service adjustments were implemented to address passenger pass-ups in accordance with social distancing guidelines. No special event service was provided this year because large gatherings were not permitted. School service was reduced as most schools adopted distance learning programs. Commute trips decreased as most offices and businesses allowed employees to work from home and online shopping was substituted for in-person trips. At the time of this writing, efforts to restore transit to pre-pandemic levels are underway and bus ridership is nearing 80 percent of what it was before COVID-19.

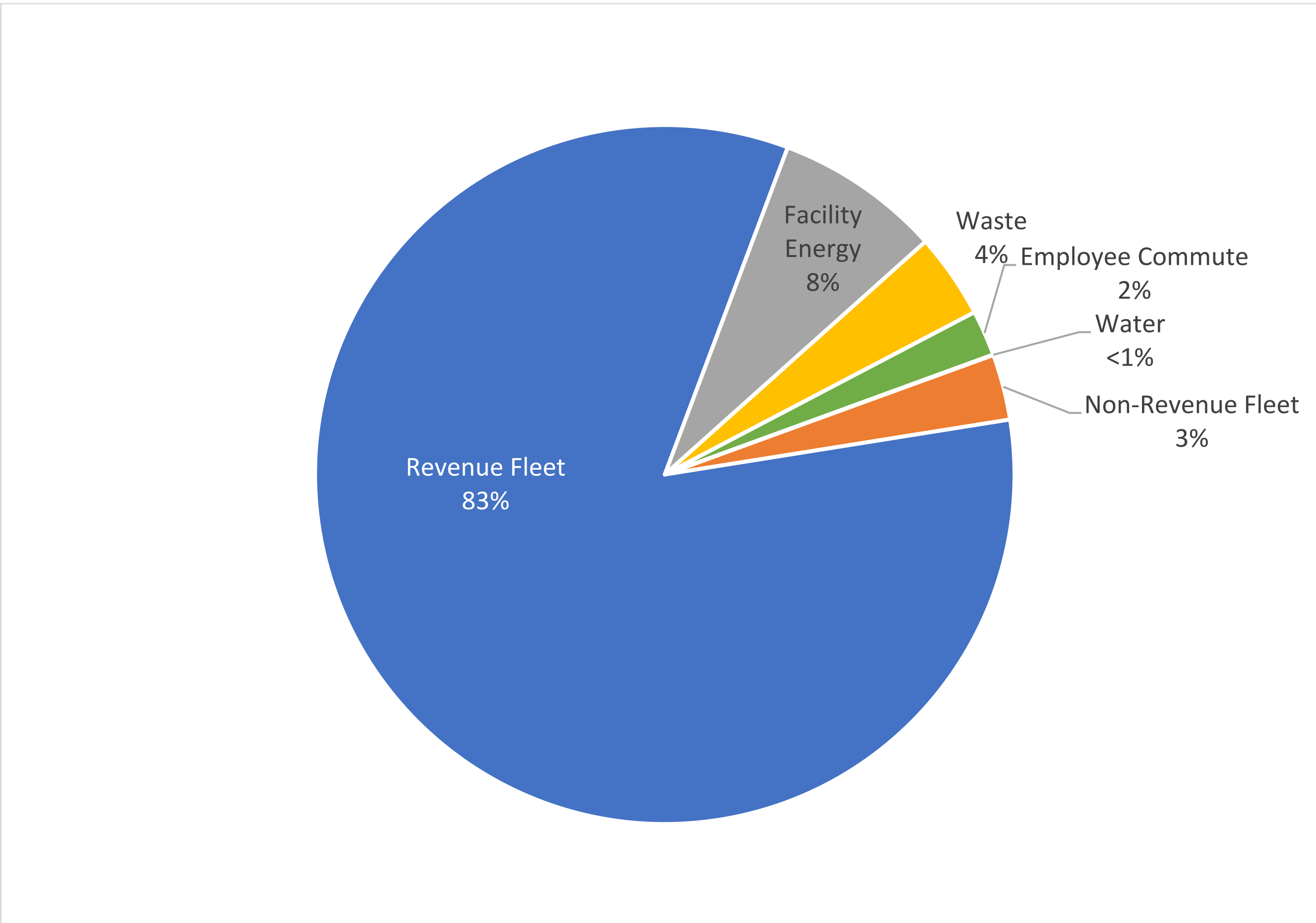
Table 14 VTA's Transit Operations Emissions by Fiscal Year and Sector

Fiscal Year	Fleet ($MTCO_2e$)	Building Energy ($MTCO_2e$)	Waste ($MTCO_2e$)	Employee Commute ($MTCO_2e$)	Water ($MTCO_2e$)	Total ($MTCO_2e$)	Percent Change from FY 2009
2009	59,747	6,777	1,803	1,507	61	69,895	n/a
2010	53,486	6,115	1,754	1,442	39	62,835	-10%
2011	49,962	6,060	1,851	1,378	28	59,278	-15%
2012	49,517	5,692	1,817	1,366	27	58,418	-16%
2013	49,999	5,424	1,875	1,344	32	58,675	-16%
2014	51,557	4,976	1,806	1,368	43	59,750	-15%
2015	52,975	4,280	1,724	1,313	38	60,330	-14%
2016	54,508	4,652	1,853	1,416	20	62,449	-11%
2017	52,405	4,249	2,048	1,380	13	60,095	-14%
2018	49,503	3,280	1,793	1,385	13	55,974	-20%
2019	46,999	2,962	1,726	1,341	8	53,036	-24%
2020	40,559	3,381	1,586	1,215	5	46,746	-33%
2021	34,019	3,024	1,548	832	8	39,431	-44%

Note: $MTCO_2e$ = metric tons of carbon dioxide equivalent; FY = fiscal year. Totals may not sum total due to rounding.

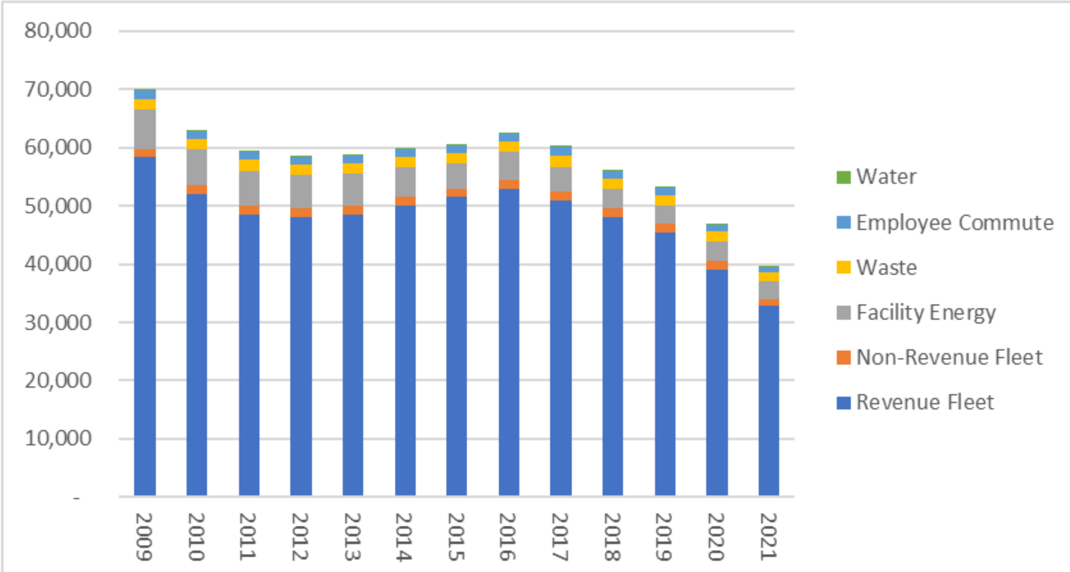
Source: Ascent Environmental in 2022.

As shown in Table 14 and Figure 7 and 8, the top emitting sector in 2021 was revenue and non-revenue fleet, which has been the top emitting sector since the 2009 baseline year. Revenue and non-revenue fleet produced 34,019 $MTCO_2e$ and accounted for 86 percent of VTA's transit operations emissions in 2021. The second most emitting sector was building energy, which produced 3,024 $MTCO_2e$ and accounted for 8 percent of emissions. This sector was followed by waste which produced 1,548 $MTCO_2e$ and accounted for 4 percent, employee commute which produced 830 $MTCO_2e$ and accounted for 2 percent, and water which produced 8 $MTCO_2e$ and accounted for less than 1 percent of total emissions.



Source: Ascent Environmental 2023.

Figure 7 FY 2021 Transit Operations Percent Emissions by Sector



Source: Ascent Environmental 2022.

Figure 8 FY 2009 to FY 2021 GHG Emissions from Transit Operations by Sector

3.3.2 Methodology Updates by Sector

REVENUE AND NON-REVENUE FLEET

For revenue and non-revenue fleet, GHG emissions were estimated by multiplying the fleet activity, such as vehicle mileage or fuel use, with fuel- and vehicle-specific emission factors. The revenue fleet refers to vehicles used for revenue generating transit service. The non-revenue fleet refers to vehicles provided by VTA for employees to perform VTA business. For electric fleet (e.g., light rail, electric buses, electric non-revenue cars), the electricity used by the fleet was multiplied by utility-specific electricity emission factors for 2020, which varied depending on where the vehicles were being charged or powered. These factors are the same electricity-related emission factors used to calculate GHG emissions from electricity consumption in buildings and facilities, as shown in Table 13.

For light-duty vehicles, off-model adjustments were made to account for the increasing penetration of electric cars under ACC2.

Additionally, for Santa Clara County, EMFAC assumes that buses older than 14 years are decommissioned and no longer report emission factors for those buses; however, VTA did operate a few buses older than 14 years in limited capacity in FY 2021. Thus, to determine emissions factors for the decommissioned buses, statewide average emission factors for older bus model years were queried from EMFAC or were assumed to be equal to the emission factor in the latest year in which the older model year bus was operating.

BUILDING AND FACILITIES

Utility-specific emissions factors for electricity generation from buildings and facilities were updated to include emissions factors for 2020 and 2021. Table 15 shows a summary of the utilities serving VTA and the associated emissions factors. Utility-specific emissions factors, given in lb CO_2e/MWh, are publicly available from the CEC's utility Power Content Labels (PCL) for 2020. This data was then extrapolated to get 2021 emissions factors. As these emissions factors are presented by calendar year, for modeling purposes, it was assumed that the emission factors for the same years were applied to fiscal years directly (e.g., CY 2020 emission factor used for FY 2020).

Table 15 2020 Electricity GHG Emissions Factors by Utility

Utility	2020 Percent GHG-Free	2020 lb CO_2e/MWh	2021 Percent GHG-Free	2021 lb CO_2e/MWh
PG&E	84%	160	88%	121
SVP	75%	542	76%	520
SVCE[1] GreenStart	98%	7	98%	7
SVCE[1] GreenPrime	100%	0	100%	0
SJCE[1] GreenSource	89%	190	90%	171
CPAU	100%	0	100%	0

Notes: GHG = greenhouse gas; CO_2e = carbon dioxide equivalents, lb = pound, MWh = megawatt-hour, CPAU = City of Palo Alto Utilities, PG&E = Pacific Gas and Electric, SJCE = San Jose Clean Energy, SVCE = Silicon Valley Clean Energy, SVP = Silicon Valley Power. GreenPrime is a 100-percent renewable option.

1 Community Choice Aggregator

Source: Compiled by Ascent Environmental in 2022 using emission factors from each utility's Power Content Labels, CEC 2021

There were no changes to methodology for natural gas and propane emissions, as these emissions factors are not specific to utility and do not change from year to year. These emission factors can be found in the 2020 VTA Sustainability Plan Technical Memorandum.

WASTE

No methodological changes were made. Please refer to the 2020 VTA Sustainability Plan Technical Memorandum for the description of the original methodology and assumptions for the waste sector.

EMPLOYEE COMMUTE

Like the methodology used for revenue and non-revenue fleet, GHG emissions from employee commute were calculated using vehicle emission factors from EMFAC2021 and adjusted off-model for additional reductions expected under ACC2. For all VTA facilities, employee commute VMT data were based off survey results from FY 2015 and scaled to FY 2020 and FY 2021 based on the VTA's employee population in FY 2021 in comparison to FY 2015. The employee commute survey conducted in 2015 found that 70 percent of respondents drove alone, 15 percent take transit, 6.6 percent carpool, and 2.4 percent bike to work. On June 30, 2021, the employee population was 2,078. For the River Oaks facility, it was assumed that for two months in FY 2020 and all of FY 2021, 100 percent of the 444 employees at that facility worked from home in accordance with COVID-19 directives. Note that discrepancies between estimated employee commute emissions and actual emissions are overshadowed by other emissions sectors. Employee commute accounts for less than four percent of total transit emissions in FY 2021 as shown in Table 18.

To calculate emissions, the annual employee commute VMT was multiplied by the per-mile emissions factors for an average light-duty gasoline passenger vehicle in Santa Clara County, available from EMFAC2021. See Table 16 for a summary of the GHG emission factors for 2020 and 2021. As these emissions factors are presented by calendar year, for modeling purposes, it was assumed that the emission factors for the same years were applied to fiscal years directly (e.g., CY 2020 emission factor used for FY 2020).

Table 16 2020 and 2021 Light-Duty Gasoline Vehicle GHG Emission Factors

Year	g CO_2e/mi
2020	334.77
2021	328.09

Notes: GHG = greenhouse gas; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalents; mi = mile. Emission factors are based on an average light-duty gasoline vehicle in Santa Clara County, across all vehicle speeds. EMFAC vehicle categories include LDA, LDT1, and LDT2.

WATER

To quantify emissions from the use of water, PG&E electricity emission factors for 2020 and 2021, shown in Table 13, were applied to the annual electricity demand for water. For consistency with the previous inventory, it was assumed that the upstream pumping and treatment electricity demand would continue to be supplied by PG&E.

The prior analysis did not account for emissions differences in potable versus non-potable water and had only accounted for treatment and distribution energy for both water types. This analysis corrects this for all years since FY 2009. Non-potable water-related energy intensity only includes energy used for treatment and distribution, while potable water includes energy use from conveyance, treatment, distribution, and wastewater treatment. The correction resulted in an increase in water-related emissions. The applied energy intensity factors are summarized in Table 17.

Table 17 Water Energy Action Energy Intensity Factors

Water Energy Action	Energy Intensity Factor	Units	Accounted for Potable Water	Accounted for Non-Potable Water
Conveyance Energy	150	kWh/MG	Yes	No
Treatment Energy	100	kWh/MG	Yes	Yes
Distribution Energy	1200	kWh/MG	Yes	Yes
Wastewater Treatment	2500	kWh/MG	Yes	No

Notes: kWh = kilowatt hour; MG = million gallons.

Source: CEC 2005.

3.4 TRANSIT OPERATIONS GHG EMISSIONS FORECASTS

3.4.1 Overview

Using the results of the FY 2021 VTA transit operations inventory, two forecast scenarios are provided that estimate future GHG levels from transit operations for FY 2030, FY 2035, FY 2040, FY 2045, and FY 2050. The first scenario, Business-As-Usual (BAU), is based on a continuation of current trends in activity and does not account for future (post-2021) GHG emissions reductions resulting from laws and regulations adopted by local, regional, State, or federal agencies; it illustrates how much emissions would increase due to population and economic growth if no actions to reduce emissions were taken. The second scenario, a legislative-adjusted BAU scenario, shows emissions reductions from laws and regulations enacted by regional, State, and federal agencies; it does not reflect local actions to reduce GHG emissions. GHG emissions forecasts provide insights to the scale of regional and local reductions needed to achieve GHG emissions reduction targets.

3.4.2 BAU Emissions Forecasts

The following BAU GHG emissions forecasts provide an assessment of how emissions generated by VTA's transit operations will change over time without further local, State, or federal action. If no action is taken, emissions are projected to decrease each forecast year, except for in 2045 and 2050, as shown in Table 18 and Figure 9. This slight increase in 2045 is due to the balance in forecasts for revenue and non-revenue fleet. Bus emissions, which account for over 75 percent of fleet emissions in FY 2021, are anticipated to continue to decline through 2050 due to the Zero Emissions Bus Program. Subsequent increases in BAU emissions from other fleet activity, due to anticipated fleet wide growth, would begin to dominate fleet emissions after 2040. Compared to FY 2021 levels, total emissions are projected to decrease by 34 percent by FY 2030, 59 percent by FY 2035, 76 percent by FY 2040, and 76 percent by FY 2045. Under a BAU scenario, emissions are projected to be 9,598 $MTCO_2e$ by FY 2050, a decrease of 76 percent from FY 2021 levels.

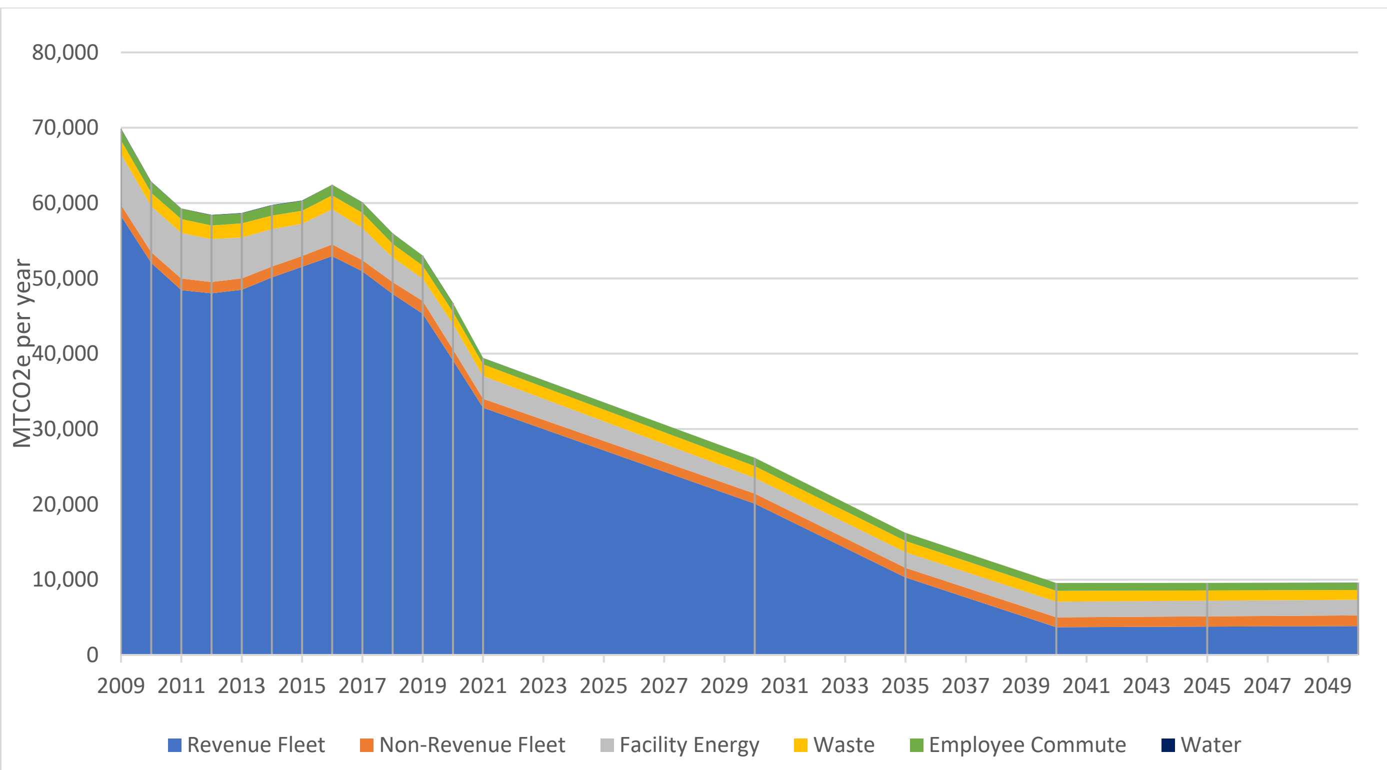
Table 18 VTA Transit Operations GHG Inventory and BAU Forecasts ($MTCO_2e$)

Fiscal Year	Revenue Fleet ($MTCO_2e$)	Non-Revenue Fleet ($MTCO_2e$)	Building Energy ($MTCO_2e$)	Waste ($MTCO_2e$)	Employee Commute ($MTCO_2e$)	Water ($MTCO_2e$)	Total ($MTCO_2e$)	Percent Change from FY 2021
2021	32,820	1,198	3,024	1,548	832	8	39,431	NA
2030	20,071	1,358	2,064	1,573	1,107	5	26,178	-34%
2035	10,283	1,285	2,067	1,504	1,072	5	16,216	-59%
2040	3,691	1,318	2,070	1,434	1,038	5	9,555	-76%
2045	3,766	1,365	2,073	1,364	1,003	4	9,575	-76%
2050	3,840	1,415	2,076	1,294	969	4	9,598	-76%

Note: $MTCO_2e$ = metric tons of carbon dioxide equivalent; NA = not applicable; GHG = greenhouse gas; BAU = business-as-usual; FY = fiscal year. Totals may not sum due to rounding.

Source: Ascent Environmental in 2022.

The large reduction in total emissions from FY 2030 to FY 2035, under this BAU scenario, is largely due to the reduction in emissions from revenue fleet, specifically buses. Under the Zero Emissions Bus Program, which targets a complete conversion of the bus fleet to zero emissions by FY 2040, the diesel bus population will dramatically decline by 61 percent from FY 2030 to FY 2035 to make way for electric buses, while total bus fleet activity remains constant. These and other forecast assumptions are discussed in Section 3.4.4.



Note: Forecasts modeled for years FY 2030, FY 2035, FY 2040, FY 2045, and FY 2050. FY = fiscal year

Source: Ascent Environmental 2023.

Figure 9 FY 2030 to FY 2050 GHG Emissions BAU Forecasts from Transit Operations by Sector

3.4.3 Legislative-Adjusted BAU Emissions Forecasts

In addition to accounting for countywide growth under a BAU scenario, a legislative-adjusted BAU forecast was prepared, which includes adopted legislative and regulatory actions at the local, State, federal levels that would affect emissions without any additional action. These include regulatory requirements to increase the percentage of zero-emission vehicles in new vehicle sales and improve vehicle fuel efficiency standards. It is important to note that the legislative-adjusted BAU emissions forecasts only include emissions reductions associated with implementation of adopted federal, State, and local legislation and regulations and do not include goals established by executive orders or targets established by federal or State agencies. The GHG emissions forecasts are aligned with various legislative actions, as shown in Table 19. There are several legislative actions (e.g., Advanced Clean Fleet) currently in draft form that could result in further reductions for future inventory updates once adopted.

Table 19 Legislative Reductions Summary for Transit Operations Emissions Forecasts

Source	Legislative Reduction	Description	Sectors Applied
State	Renewable Energy and Zero-Carbon Electricity Requirements (SB 1020 and SB 100)	Requires California energy utilities to procure 60 percent of electricity from eligible renewable and zero-carbon sources by 2030, 90 percent by 2035, 95 percent by 2040, and 100 percent by 2045.	Building Energy
State	Advanced Clean Car I Regulations	Establishes GHG emission reduction standards for model years 2017 through 2025 that are more stringent than federal CAFE standards.	Revenue and Non-Revenue Fleet
State	Advanced Clean Cars II Regulations	Establishes a target for all new passenger cars, trucks, and SUVs sold in California to be 100 percent zero-emission vehicles by 2035.	Revenue and Non-Revenue Fleet
State	Truck and Bus Regulation	Requires diesel trucks and buses that operate in California to be upgraded to reduce GHG emissions by 2035.	Revenue Fleet
State	Innovative Clean Transit Rule	Requires 100 percent of new purchases by transit agencies to be zero emissions starting in 2029 and achieving full transition to ZEBs by 2040.	Revenue Fleet
Federal	Fuel Efficiency Standards for Medium- and Heavy-Duty Vehicles	Establishes fuel efficiency standards for medium- and heavy-duty engines and vehicles.	Revenue and Non-Revenue Fleet

Notes: CAFE = Corporate Average Fuel Economy; CEC = California Energy Commission; EPA = U.S. Environmental Protection Agency; GHG = greenhouse gas; SUV = sports utility vehicle; SB = Senate Bill.

Source: Table compiled by Ascent Environmental in 2022.

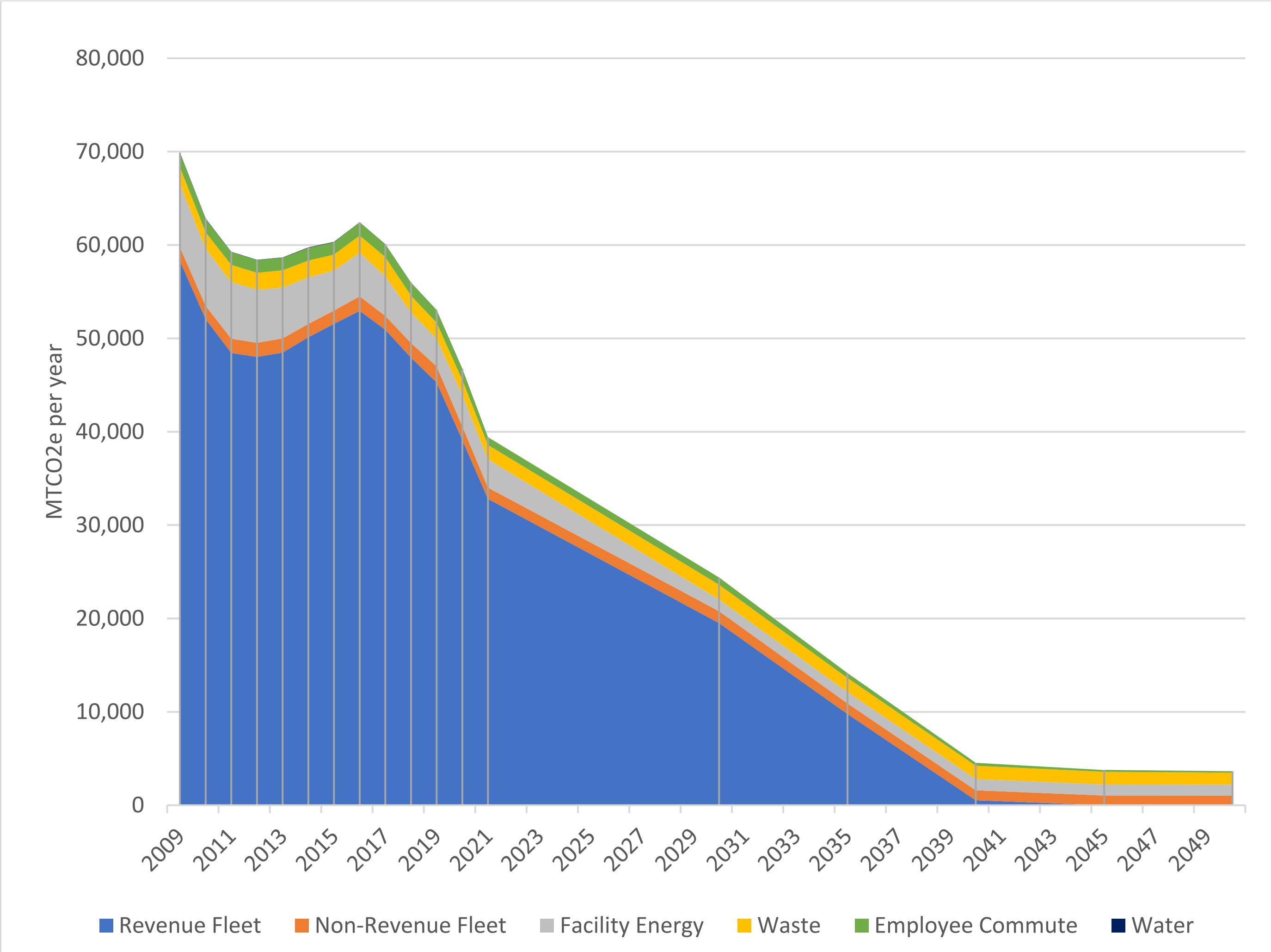
In the legislative-adjusted BAU forecast, emissions are projected to decrease each forecast year, though steadying by 2045, as shown in Table 20 and Figure 10. Compared to FY 2021 levels, emissions are projected to decrease 38 percent by FY 2030, 64 percent by FY 2035, 88 percent by FY 2040, and 90 percent by FY 2045. Under a legislative-adjusted BAU scenario, emissions are projected to be 3,629 $MTCO_2e$ in FY 2050, a decrease of 91 percent from FY 2021 levels.

Table 20 VTA Transit Operations GHG Inventory and Legislative-Adjusted BAU Forecasts ($MTCO_2e$)

Fiscal Year	Revenue Fleet ($MTCO_2e$)	Non-Revenue Fleet ($MTCO_2e$)	Building Energy ($MTCO_2e$)	Waste ($MTCO_2e$)	Employee Commute ($MTCO_2e$)	Water ($MTCO_2e$)	Total ($MTCO_2e$)	Percent Change from FY 2021
2021	32,820	1,198	3,024	1,548	832	8	39,431	NA
2030	19,506	1,273	1,261	1,573	779	3	24,396	-38%
2035	9,786	1,115	1,231	1,504	516	2	14,154	-64%
2040	541	1,058	1,201	1,434	311	1	4,546	-88%
2045	0	1,038	1,170	1,364	191	0	3,763	-90%
2050	0	1,041	1,161	1,294	133	0	3,629	-91%

Note: $MTCO_2e$ = metric tons of carbon dioxide equivalent; GHG = greenhouse gas; BAU = business-as-usual; NA = not applicable; FY = fiscal year. Totals may not sum due to rounding.

Source: Ascent Environmental 2023.



Note: Forecasts modeled for years FY 2030, FY 2035, FY 2040, FY 2045, and FY 2050.

Source: Ascent Environmental 2023.

Figure 10 FY 2030 to FY 2050 GHG Emissions Legislative-Adjusted Forecasts from Transit Operations by Sector

3.4.4 Forecast Methodology

To forecast emissions from each of VTA's GHG emissions sectors a two-phased approach was used. First, activity levels (e.g., VMT, energy consumption) were forecasted based on projected activity levels, and where activity projections were not available, historical trends were used to extrapolate activity levels into the future. Second, future emission factors were applied as available (e.g., vehicle emission factors from EMFAC2021, electricity emission factors as estimated for the various electric utilities serving VTA operations). Some emission factors are assumed to stay constant (e.g., waste, natural gas, propane). For the BAU forecasts, for all emissions sectors, emission factors were assumed not to change from those assumed in the FY 2021 inventory. For the legislative-adjusted forecasts, emission factors were assumed to reflect anticipated changes in future regulations (e.g., ACC2, SB 100). These especially effect on-road vehicle and electricity-related emission factors, which affect both facility energy-related emissions and indirect emissions from water delivery and treatment. Activity levels were multiplied by their respective emission factors to forecast emissions.

REVENUE FLEET

VTA's revenue fleet consists of its bus fleet, light rail, and paratransit fleet. VMT projections for the bus fleet and light rail operations were provided by VTA's service planning department. Paratransit fleet activity was forecasted based on historical trends in paratransit activity.

Bus Fleet Forecasts

Activity

To forecast bus fleet emissions, bus VMT projections by fuel type were provided by VTA's service planning manager that reflect VTA's plan to achieve its Zero Emissions Bus goal by FY 2040, as mandated under the California Air Resources Board's Innovative Clean Transit Regulation. As shown in Table 21, VTA's bus fleet is anticipated to gradually transition away from diesel to battery-electric buses by FY 2040. Table 21 shows the anticipated change in annual bus VMT by bus length and fuel type in FY 2030, FY 2035, and FY 2040. After FY 2040, it is assumed that bus VMT will remain constant.

Table 21 VTA's Zero 2040 Fleet Composition and Service Level VMT Projections

Bus Type by Vehicle Miles Traveled	FY 2030	FY 2035	FY 2040
40-Foot Hybrid Diesel Bus	12,000,118	5,156,156	0
60-Foot Hybrid Diesel Bus	1,298,313	0	0
40-Foot Battery-Electric Bus	3,950,580	10,794,542	15,950,698
60-Foot Battery-Electric Bus	1,298,313	2,596,625	2,596,625
Total	**18,547,323**	**18,547,323**	**18,547,323**

Notes: FY = fiscal year, VMT = Vehicle Miles Traveled

Source: Tyree, pers. comm., 2022.

Emission Factors

For diesel buses, future GHG emission factors through FY 2050 were obtained from EMFAC2021, which was run for Santa Clara County for the UBUS, or urban bus, vehicle category. These emission factors varied by calendar year and vehicle model year. For forecasting purposes, only average bus model years for each calendar year were used. To estimate the average model year for diesel buses, it was assumed that the average age of VTA's bus fleet by vehicle length would not change. Between FY 2009 and FY 2021, the average age of 40-foot and 60-foot buses at VTA has been approximately 9 years. This average age was assumed to continue through FY 2050 and was used to estimate the relative model years to be queried from EMFAC. The resulting average bus emission factors from EMFAC are anticipated to decrease by 36 percent from FY 2021 to FY 2030, as shown in Table 22. After FY 2035, VTA would no longer use diesel buses, as shown in Table 21 above. These emission factors were then multiplied by the forecasted diesel bus VMT shown in Table 21 to forecast emissions. As these emissions factors are presented by calendar year, for modeling purposes, it was assumed that the emission factors for the same years were applied to fiscal years directly (e.g., CY 2020 emission factor used for FY 2020).

Table 22 Forecasted Diesel Bus Emission Factors

Year	Average Model Year	Average Emissions Factors (g CO_2e/mi)
2021	2011	1,972
2030	2021	1,253
2035	2026	1,311

Notes: Emission factors represent diesel UBUS vehicles in Santa Clara County, as estimated in EMFAC2021. After 2030, diesel buses would no longer be used. $MTCO_2e$ = metric tons of carbon dioxide equivalent; g = gram; mi =miles.

Source: Ascent Environmental in 2022.

For electric buses, future legislative-adjusted GHG emission factors were derived from forecasted PG&E emission factors for each milestone year, based on historical purchase trends (FY 2030, FY 2035, FY 2040, FY 2045, and FY 2050). In FY 2021, all electric buses used electricity purchased from PG&E. This purchase arrangement was assumed to continue. PG&E's CO_2 emissions factor for each forecast year was calculated by interpolating 2020 emission factors (160.05 pounds [lb] of CO_2/megawatt-hour [MWh]) available from PG&E's Power Content Label, available from the California Energy Commission (CEC), and a zero emissions factor for 2045 (CEC 2021). This latter assumption assumes that PG&E would achieve carbon neutrality (i.e., 100 percent GHG-free electricity) by 2045, per SB 100. CH_4 and N_2O emission factors were calculated in a similar way. However, because these factors were not available for PG&E, 2020 California-specific electricity emissions factors for CH_4 and N_2O were obtained from the U.S. Environmental Protection Agency's (EPA's) Emissions & Generation Resource Integrated Database for the CAMX region (eGRID) (EPA 2021). Thus, the future CH_4 and N_2O emission factors were also interpolated between eGRID factors for 2020 and a zero emissions factor for 2045. In FY 2050, PG&E emissions factors are assumed to be 100 percent GHG-free, continuing the 2045 carbon neutrality mandate under SB100. PG&E's forecasted emissions factors are shown in Table 28.

These emission factors were then multiplied by the average fuel economy for each electric bus category (kWh/mi) then by the forecasted electric bus miles shown in Table 19 above. The 40-foot and 60-foot buses were assumed to have the same fuel economy as a Proterra 40' bus (e.g., ZX5+) and a BYD K11M 60' transit bus, respectively. The Proterra ZX5+ bus has an average fuel economy of 2.2 kWh per mile; the BYD K11M 60' transit bus has an average fuel economy of 3.0 kWh per mile, according to each manufacturer's specifications (Proterra 2022, BYD 2022).

Light Rail

Activity

Light rail forecasts were based on light rail service level projections of train car-miles through FY 2045, as provided by VTA's service planning manager. These growth projections were used to scale light rail electricity use from FY 2021 levels. This approach assumes light rail train efficiency would likely remain unchanged from FY 2021 through FY 2050, which has been confirmed by VTA's light rail department (Kim, pers. comm., 2023). However, VTA's light rail service projections for boardings and car-miles were only available starting in FY 2022. The inventory also did not estimate train car-miles. Instead, VTA's FY 2021 train car-miles were separately obtained from the National Transit Database (NTD) (NTD FY 2022). As shown in Table 23, VTA's light rail service levels are anticipated to increase by 26 percent from FY 2021 to FY 2030, accounting for the opening of the Eastridge to BART Regional Connector slated for FY 2027 and remain constant through FY 2045. After FY 2045, it is assumed that light rail activity will remain constant. It was assumed that light rail electricity use would also increase by the same rate from FY 2021.

Table 23 VTA's Light Rail Service Level Projections and Estimated Electricity Forecasts

	FY 2021	FY 2030	FY 2035	FY 2040	FY 2045
Annual Total Car-Miles	3,037,317[1]	3,818,726	3,818,726	3,818,726	3,818,726
% Change in Car-Miles from FY 2021	NA	26%	26%	26%	26%
Light Rail Electricity Use (kWh/year)	20,625,365[2]	25,931,640	25,931,640	25,931,640	25,931,640

Notes: NTD = National Transit Database; NA = not applicable; kWh = kilowatt-hour; FY = fiscal year

1 From NTD 2022 data

2 From VTA's 2021 GHG Inventory

Source: Tyree, pers. comm., 2022, NTD 2022.

Emission Factors

Future legislative-adjusted GHG electricity emission factors were based on forecasted utility emission factors (SJCE GreenSource, SVCE GreenStart, and SVP) for each milestone year (FY 2030, FY 2035, FY 2040, FY 2045, and FY 2050). In FY 2021, VTA procured 78 percent, 18 percent, and four percent of total light rail electricity demand from SJCE GreenSource, SVCE GreenStart, and SVP, respectively. This utility distribution was assumed to remain constant into the future. The forecasted emission factors for each utility are shown in Table 28.

Paratransit

Activity

VTA's paratransit activity has been characterized by a variety of vehicle types, makes, and models from light duty auto to small buses. By 2021, passenger cars and light-duty trucks with an equivalent test weight between 3,751 and 5,750 pounds (EMFAC types LDA and LDT2, respectively) were retired from the fleet. They were replaced by light-heavy-duty trucks with a gross vehicle weight between 10,001 and 14,000 pounds and light-duty trucks with an equivalent test weight of under 3,750 pounds (EMFAC types LHDT2 and LDT1, respectively). It was assumed that future VMT for the LHDT2 and LDT1 vehicles grew at a rate of 0.75 percent per year, which was the historical rate of population growth in Santa Clara county from 2009 to 2019 (2009 was chosen because it was the first year of the inventory; 2019 was chosen because it was the last year before COVID-19). Table 24 below shows both historical and future VMT for the paratransit fleet.

Table 24 VTA Paratransit Activity Historical Data and Projections (VMT per year)

Vehicle Category	FY 2009	FY 2021	FY 2030	FY 2035	FY 2040	FY 2045	FY 2050
LDA	3,678,018	0	0	0	0	0	0
LDT2	4,392,906	0	0	0	0	0	0
LDT1	838,722	1,678,020	2,704,473	2,798,720	2,892,966	2,987,213	3,081,460
LHDT2	505,539	1,039,106	1,664,278	1,722,276	1,780,273	1,838,271	1,896,268

Notes: All vehicles assumed to be gasoline powered. LDA = Passenger Cars; LDT2 = Light-Duty Trucks (Gross Vehicle Weight <= 6,000 lbs and Equivalent Test Weight between 3,751 and 5,750 lbs); LDT1 = Light-Duty Trucks (Gross Vehicle Weight <= 6000 lbs and Equivalent Test Weight <=3,750 lbs); LHDT2 = Light Heavy Duty Trucks with a gross vehicle weight between 10,001 and 14,000 lbs; VMT = vehicles miles travelled.; FY = fiscal year

Source: Ascent Environmental in 2023.

Emissions Factors

For the forecasted paratransit vehicles, future GHG emission factors through FY 2050 were obtained from EMFAC2021. These emission factors varied by calendar year and vehicle model year. For forecasting purposes, only average vehicle model years were used. The average model years for LDT1 in the future were calculated based on historical average LDT1 vehicle age from FY 2009 to FY 2021. The average age of LDT1 paratransit vehicles was assumed to be 8 years, based on the current average of the paratransit fleet in 2023 (Tran, pers. comm., 2023). Refer to Table 25 for the forecasted paratransit emission factor by forecast year.

For the legislative adjusted forecast, all paratransit vehicles were assumed to be gasoline vehicles from through FY 2035. Depending on the final types of vehicles purchased, the paratransit fleet may be subject to CARB's proposed Advanced Clean Fleets Regulation (ACFR), which would require medium- and heavy- duty fleets to be zero emissions by 2045. However, VTA's paratransit division is requesting a five year exemption from this regulation or until battery technology and charging infrastructure is improved. As such, ACFR is not considered in the forecasts for paratransit (Tran, pers. Comm., 2023). Even so, under ACC2, 100 percent of all new light duty vehicles sold by 2035 are required to be zero emission vehicles, with 82 percent required to be ZEVs by MY 2032. Starting in FY 2040, the paratransit fleet would be newer than the 2032 model year, based on the average fleet age. Thus, from FY 2040 onward, the paratransit fleet is assumed to only operate electric vehicles. As these emissions factors are presented by calendar year, for modeling purposes, it was assumed that the emission factors for the same years were applied to fiscal years directly (e.g., CY 2020 emission factor used for FY 2020).

These emission factors were then multiplied by the VMT shown in Table 24 to forecast emissions.

Table 25 Legislative-Adjusted Forecasted Paratransit Model Years Emission Factors

Vehicle Type	Fiscal Year	Average Model Year	Average Emissions Factors (g CO_2e/mi)
LDT1	2030	2022	295
LDT1	2035	2027	263
LDT1	2040	2032	0
LDT1	2045	2037	0
LDT1	2050	2042	0
LHDT2	2030	2022	870
LHDT2	2035	2027	848
LHDT2	2040	2032	0
LHDT2	2045	2037	0
LHDT2	2050	2042	0

Notes: Emission factors represent gasoline LDT1 and LHDT2 vehicles in Santa Clara County, as estimated in EMFAC2021. CO_2e = metric tons of carbon dioxide equivalent; g = grams; mi =miles; LDT1 = Light-Duty Trucks (Gross Vehicle Weight <= 6000 lbs and Equivalent Test Weight <=3,750 lbs); LHDT2 = Light Heavy Duty Trucks with a gross vehicle weight between 10,001 and 14,000 lbs.

Source: Ascent Environmental in 2023.

NON-REVENUE FLEET

Activity

Like paratransit, VTA's non-revenue fleet has been characterized by a variety of vehicle types, makes, models, and fuel types from light duty auto to heavy duty trucks serving a variety of functions at VTA, accounting for eight different vehicle categories. Two of these vehicle categories (heavy heavy-duty truck and medium duty vehicles, represented by the HHDT and MDV EMFAC categories) were removed from the forecast because their activity diminished between FY 2009 and FY 2021 to insignificant levels. The activity in remaining vehicle categories, except for light duty auto, were individually forecasted through FY 2050 based on historical trends in each category's respective non-revenue VMT.

Forecasts for light duty auto activity were first forecasted on a total VMT basis, using the historical trends in VTA's non-revenue light duty VMT across all fuel types. Between FY 2009 and FY 2021, total non-revenue light duty VMT increased by an average of seven percent annually. This was directly applied to all forecast years, assuming the distribution of light duty vehicle fuel types would remain the same as in FY 2021.

For the legislative-adjusted BAU forecasts, the distribution of forecasted light duty VMT across fuel types is expected to change over time in consideration of the trends toward increased ZEVs under the ACC2. Based on off-model ACC2 adjustments to CARB's EMFAC2021 model, it is anticipated that by 2050, electric VMT will account for 73 percent of light duty VMT, with the remainder from gasoline and hydrogen. The resulting assumed changes in proportions are shown in Table 26. Table 27 shows the VMT forecast assumptions by vehicle category.

Table 26 Forecasted Legislative-Adjusted Non-Revenue Light Duty Fleet Activity Proportions by Fuel Type (VMT/year)

EMFAC Vehicle Category	Fuel Type	FY 2021[1]	FY 2030[2]	FY 2035[2]	FY 2040[2]	FY 2045[2]	FY 2050[2]
LDA	Gasoline	92%	66%	40%	19%	7%	2%
LDA	Electric	1%	25%	45%	61%	70%	73%
LDA	Hydrogen	6%	9%	15%	20%	23%	24%

Notes: LDA = Light Duty Auto Passenger Cars

[1] Based on existing proportion of non-revenue light duty VMT by fuel type. This distribution is assumed to be constant for all forecast years under the BAU forecast.

[2] For gasoline and electric fuel types, changes in proportion of VMT are based on the average proportion of gasoline and electric vehicles in the countywide fleet of light duty vehicles, as expected in EMFAC 2021 and adjusted for the Advanced Clean Cars 2 rule. For hydrogen vehicles, EMFAC 2021 does not provide estimates for this fuel type, so hydrogen VMT were assumed to account for the remaining proportion (e.g., 100% - percent gasoline VMT – percent electric VMT).

Source: CARB 2021 and Ascent Environmental in 2022.

Table 27 VTA Non-Revenue Fleet Activity Projections (VMT/year)

EMFAC Vehicle Category	Fuel Type	FY 2021	FY 2030	FY 2035	FY 2040	FY 2045	FY 2050
All Forecast Scenarios							
LDT1	Gasoline	267,636	433,263	487,471	541,680	595,889	650,098
LDT2	Gasoline	238,868	197,093	173,853	150,614	127,374	104,135
LHDT1	Gasoline	185,481	239,871	247,941	256,011	264,081	272,151
LHDT1	Diesel	65,858	0	0	0	0	0
LHDT2	Gasoline	32,833	0	0	0	0	0
LHDT2	Diesel	397,833	521,959	492,757	463,556	434,355	405,154
MHDT	Gasoline	71,351	95,590	112,859	130,129	147,398	164,667
MHDT	Diesel	35,862	61,263	63,554	65,845	68,136	70,428
MDV	Gasoline	6,076	0	0	0	0	0
HHDT	Diesel	2,835	0	0	0	0	0
BAU Forecast Scenario							
LDA	Gasoline	637,300	1,169,142	1,295,143	1,421,144	1,547,147	1,673,148
LDA	Electric	9,989	18,325	20,300	22,275	24,250	26,225
LDA	Hydrogen	43,583	79,954	88,571	97,188	105,805	114,421
Legislative-Adjusted BAU Forecast Scenario							
LDA	Gasoline	637,300	840,748	555,917	290,022	125,164	44,660
LDA	Electric	9,989	316,950	634,578	938,385	1,166,387	1,330,512
LDA	Hydrogen	43,583	109,723	213,519	312,199	385,650	438,622

Duty Trucks (GVWR 10001-14000 lbs.); LHDT1 = Light-Heavy-Duty Trucks (GVWR 8501- 10000 lbs.); LHDT2 = Light-Heavy-Duty Trucks (GVWR 10001- 14000 lbs.); MHDT = Medium-Heavy Duty Public Fleet Truck (GVWR 14001-16000 lbs.); VMT = vehicle miles travelled.

Source: CARB 2021 and Ascent Environmental in 2022.

Emissions Factors

For the forecasted non-revenue fleet, future GHG emission factors through FY 2050 were obtained from EMFAC2021, which was run for Santa Clara County for the six vehicle categories shown in Table 26 above. These emission factors varied by calendar year and vehicle model year. For forecasting purposes, only average vehicle model years were used. The average model years in the future were calculated based on historical average vehicle age each vehicle category from FY 2009 to FY 2021. For the legislative-adjusted forecast, any light duty non-revenue vehicles with model years newer than 2035 were assumed to be electric. Under ACC2, 100 percent of new vehicles sold by 2035 are required to be zero emission vehicles. The assumed model years and emission factors are shown in Table 28.

These emission factors were then multiplied by the VMT shown in Table 27 to forecast emissions.

Table 28 Forecasted Non-Revenue Model Years

Vehicle Category	Fuel Type	FY 2030	FY 2035	FY 2040	FY 2045	FY 2050
Average Model Years						
LDA	Gasoline	2022	2027	2032	2037	2042
LDA	Hydrogen	2022	2027	2032	2037	2042
LDT1	Gasoline	2018	2023	2028	2033	2038
LDT2	Gasoline	2019	2024	2029	2034	2039
LHDT1	Gasoline	2018	2023	2028	2033	2038
LHDT2	Diesel	2020	2025	2030	2035	2040
MHDT	Diesel	2022	2027	2032	2037	2042
MHDT	Gasoline	2022	2027	2032	2037	2042
Legislative-Adjusted Average Emission Factors (g CO_2e/mi)[1]						
LDA	Gasoline	257	229	229	230	230
LDA	Hydrogen	0	0	0	0	0
LDT1	Gasoline	330	287	265	265	265
LDT2	Gasoline	339	290	276	276	276
LHDT1	Gasoline	867	755	756	756	756
LHDT2	Diesel	788	730	730	730	731
MHDT	Diesel	1,175	1,121	1,098	1,080	1,080
MHDT	Gasoline	1,630	1,582	1,554	1,534	1,532

Notes: Emission factors represent gasoline LDA and LDT1 vehicles in Santa Clara County, as estimated in EMFAC2021. LDA = Passenger Cars; LDT1 = Light-Duty Trucks (GVWR* <= 3750 lbs.); LDT2 = Light-Heavy-Duty Trucks (GVWR 10001-14000 lbs.); LHDT1 = Light-Heavy-Duty Trucks (GVWR 8501- 10000 lbs.); LHDT2 = Light-Heavy-Duty Trucks (GVWR 10001- 14000 lbs.); MHDT = Medium-Heavy Duty Public Fleet Truck (GVWR 14001-16000 lbs.); CO_2e = metric tons of carbon dioxide equivalent; g = grams; mi =miles; FY = fiscal year

Source: CARB 2021 and Ascent Environmental in 2022.

BUILDING AND FACILITIES

Electricity

Activity

VTA facilities include buildings (e.g., maintenance facilities, office buildings) and transit amenities (e.g., bus stops, transit stations), which are located throughout Santa Clara County across multiple utility/CCA service areas. To forecast the future electricity use at VTA facilities, the following assumptions were made regarding the distribution of electricity use amongst utilities. Per discussions with VTA's Environmental Program staff, future distribution of electricity consumption by utility is expected to reflect FY 2021 conditions, except for consumption from PG&E. By calendar year 2021, which starts in the second half of FY 2021, VTA no longer purchased electricity from PG&E and the remainder was purchased from SJCE GreenSource. This is assumed to continue into all future years. The proportion of electricity purchases between CPAU, SVCE GreenPrime, SVCE GreenStart, SVP are assumed to remain constant, at one, six, 16, and three percent of VTA's total facility-level electricity consumption, respectively, from FY 2030 through FY 2050. The remainder are assumed to be purchased from SJCE GreenSource, at 74 percent of total future electricity consumption. The resulting forecasted trends in electricity use by utility are shown in Table 29.

Table 29 Historical and Forecasted Distribution of Electricity Consumption by Utility

Fiscal Year	PG&E	CPAU	SJCE GreenSource	SVCE GreenPrime	SVCE GreenStart	SVP
2009	98.46%	0.65%	0.00%	0.00%	0.00%	0.89%
2010	98.48%	0.58%	0.00%	0.00%	0.00%	0.94%
2011	98.37%	0.62%	0.00%	0.00%	0.00%	1.01%
2012	98.69%	0.35%	0.00%	0.00%	0.00%	0.96%
2013	98.69%	0.27%	0.00%	0.00%	0.00%	1.05%
2014	98.67%	0.22%	0.00%	0.00%	0.00%	1.11%
2015	98.25%	0.37%	0.00%	0.00%	0.00%	1.38%
2016	98.19%	0.40%	0.00%	0.00%	0.00%	1.41%
2017	96.65%	0.45%	0.00%	1.57%	0.00%	1.33%
2018	86.56%	0.40%	0.00%	6.55%	5.02%	1.47%
2019	61.93%	0.41%	14.16%	6.31%	15.77%	1.43%
2020	25.76%	3.23%	43.40%	6.05%	15.67%	5.89%
2021	15.40%	0.45%	60.31%	6.37%	15.79%	1.69%
Forecasted Distribution						
2030	0%	1%	74%	6.0%	16.0%	3%
2035	0%	1%	74%	6.0%	16.0%	3%
2040	0%	1%	74%	6.0%	16.0%	3%
2045	0%	1%	74%	6.0%	16.0%	3%
2050	0%	1%	74%	6.0%	16.0%	3%

Notes: PG&E = Pacific Gas and Electric; CPAU = City of Palo Alto Utilities; SJCE = San Jose Clean Energy; SVCE = Silicon Valley Clean Energy; SVP = Silicon Valley Power.

Source: Ascent Environmental in 2022.

The distribution of utilities shown in Table 29 were applied to the overall forecast in total facility electricity use at VTA facilities. That is, VTA's historical total facility electricity use from FY 2009 to FY2021 was extrapolated to the future milestone years (FY 2030 through FY 2050), then the forecasted total usage was broken down to each utility based on usage trends across utilities from FY 2009, as shown in the first part of Table 29. Details on future facility expansions or construction (e.g., new building square footage, construction timelines) were not readily available. As such, the historical trend in agency-wide electricity use was used to extrapolate future electricity demand. Between FY 2009 and FY 2021, the average electricity use has increased by about 0.3 percent per year. Continuing this trend, it is anticipated that VTA's electricity use will increase from 12,422 MWh per year to 14,065 MWh per year by 2050, further shown in Table 30. Although legislative adjustments, such as new building energy efficiency standards could apply to new facilities constructed by VTA, without known concrete expansion or construction plans, it was conservatively assumed that the additional electricity usage would be used in existing facilities. Even with this conservative assumption, facility energy use is expected to make up no more than 25 percent of VTA's emissions by FY 2050, as shown in Table 20 and Figure 10.

Table 30 Forecasted VTA Electricity Use by Utility (MWh/year)

Fiscal Year	PG&E	CPAU	SJCE GreenSource	SVCE GreenPrime	SVCE GreenStart	SVP	Total
2009	84	12,695	0	0	0	115	12,893
2010	71	12,127	0	0	0	116	12,314
2011	76	12,173	0	0	0	125	12,375

Fiscal Year	PG&E	CPAU	SJCE GreenSource	SVCE GreenPrime	SVCE GreenStart	SVP	Total
2012	48	13,308	0	0	0	129	13,484
2013	33	12,196	0	0	0	129	12,358
2014	27	12,317	0	0	0	139	12,483
2015	47	12,357	0	0	0	173	12,577
2016	50	12,194	0	0	0	175	12,418
2017	54	11,712	0	190	0	161	12,118
2018	52	11,153	0	844	646	189	12,884
2019	55	8,337	1,907	849	2,123	192	13,462
2020	448	3,569	6,012	839	2,171	816	13,855
2021	56	1,913	7,492	791	1,962	209	12,422
Forecasted Distribution							
2030	0	133	9,849	799	2,129	399	13,309
2035	0	135	9,988	810	2,160	405	13,498
2040	0	137	10,128	821	2,190	411	13,687
2045	0	139	10,268	833	2,220	416	13,876
2050	0	141	10,408	844	2,250	422	14,065

Notes: MWh = megawatt-hours, CPAU = City of Palo Alto Utilities, PG&E = Pacific Gas and Electric, SJCE = San Jose Clean Energy, SVCE = Silicon Valley Clean Energy, SVP = Silicon Valley Power. GreenPrime is a 100-percent renewable option.

Source: Ascent Environmental in 2022.

Emission Factors

To calculate future electricity emissions for buildings and facilities, estimated future emissions factors were multiplied by estimated future electricity use for each utility. Future emissions factors for each utility were extrapolated from FY FY2021 data (refer to Table 31). As these emissions factors are presented by calendar year, for modeling purposes, it was assumed that the emission factors for the same years were applied to fiscal years directly (e.g., CY 2020 emission factor used for FY 2020).

Table 31 Electricity Emission Factors (lb CO_2e/MWh)

Year	PG&E	CPAU	SJCE GreenSource	SVCE GreenPrime	SVCE GreenStart	SVP
2021	121.4	0.0	171	0.0	6.7	520.3
2030	75.9	0.0	0	0.0	4.2	325.2
2035	50.6	0.0	0	0.0	2.8	216.8
2040	25.3	0.0	0	0.0	1.4	108.4
2045	0.0	0.0	0	0.0	0.0	0.0
2050	0.0	0.0	0.0	0.0	0.0	0.0

Notes: CO_2e = carbon dioxide equivalents, lb = pound, MWh = megawatt-hour, CPAU = City of Palo Alto Utilities, PG&E = Pacific Gas and Electric, SJCE = San Jose Clean Energy, SVCE = Silicon Valley Clean Energy, SVP = Silicon Valley Power. GreenPrime is a 100-percent renewable option.

Source: Ascent Environmental in 2022.

Natural Gas and Propane

Activity

In addition to electricity use, VTA facilities also consume natural gas and propane. Unlike electricity, the emission factors for natural gas and propane do not vary by source; thus, the evaluation of utilities is irrelevant to forecasting VTA natural gas and propane demand. Between FY 2032 and 2050, VTA's administrative building and four maintenance facilities are anticipated to be retrofitted, constructed, or moved to new locations to coincide with the opening of BART in Downtown San Jose and support the full transition to a ZEB fleet. However, there are currently no detailed plan information or budgetary commitments in place to support any assumptions regarding the size or scale of these buildings and facilities. Thus, the historical trend in agency-wide gas use was used to extrapolate future gas demand.

Between FY 2009 and FY 2021, the average annual natural gas and propane consumption has decreased on average by about 0.2 percent per year and 3.7 percent per year, respectively. Continuing this trend, it is anticipated that VTA's natural gas use would decrease from 166,062 therms per year by 20 percent to 134,323 therms per year by FY 2050. However, propane use is assumed to remain constant at around FY 2018 to 2021 average levels. This assumption represents recent usage levels, as there are no plans to convert the specific end uses that currently require propane (e.g., remote generators or heaters) to other fuel types. These forecasted trends in both natural gas and propane usage are shown in Table 32.

Table 32 Forecasted VTA Natural Gas and Propane Use by Utility

Fiscal Year	Natural Gas Use (therms/year)	Propane Use (gal/year)
2009	152,339	109,858
2010	167,749	107,753
2011	164,411	128,853
2012	149,909	122,674
2013	136,841	133,453
2014	130,380	113,503
2015	111,484	86,848
2016	136,820	111,727
2017	148,488	112,279
2018	141,842	79,387
2019	139,137	80,161
2020	157,827	88,716
2021	166,062	69,754
Forecasts		
2030	141,228	80,000
2035	139,502	80,000
2040	137,776	80,000
2045	136,049	80,000
2050	134,323	80,000

Notes: gal = gallons

Source: Ascent Environmental in 2022.

Emission Factors

To calculate emissions from natural gas and propane use, the same emission factors used in quantifying the inventory were used to calculate emissions from forecasted natural gas and propane use. Please refer to the 2020 VTA Sustainability Plan Technical Memorandum for the description of the original emission factors used to quantify emissions from natural gas and propane usage.

WASTE

Activity

Emissions from the waste sector are attributable to landfilled waste. Recycled and composted waste were not assumed to result in emissions, consistent with the assumptions used in quantifying the FY 2021 inventory. Absent major known changes in plans to VTA's operations, landfilled waste tonnages were forecast using historical trends. Between FY 2009 and FY 2021, VTA's landfilled waste generation declined by 0.8 percent per year on average. Extrapolating this trend into the future, VTA's landfilled waste generation would decline by 16 percent from 1,032 tons per year in FY 2021 to 863 tons per year in FY 2050. These trends and forecasts are shown in Table 33.

Table 33 Forecasted VTA Landfilled Waste Generation

Fiscal Year	Landfilled Waste Generation (tons/year)
2009	1,202
2010	1,169
2011	1,234
2012	1,211
2013	1,250
2014	1,204
2015	1,150
2016	1,235
2017	1,365
2018	1,195
2019	1,151
2020	1,058
2021	1,032
Forecasts	
2030	1,049
2035	1,002
2040	956
2045	909
2050	863

Source: Ascent Environmental in 2022.

Emission Factors

To calculate emissions from waste generation, the same emission factors used in quantifying the inventory were used to calculate emissions from forecasted waste generation. Please refer to the 2020 VTA Sustainability Plan Technical Memorandum for the description of the original emission factors used to quantify emissions from waste.

EMPLOYEE COMMUTE

Activity

Fundamentally, employee commute activity is affected by changes in employee numbers and commute behavior. According to VTA's most recent employee commute survey, conducted in November-December 2015, most (70%) employees drive alone to work. Due to VTA's work-from-home COVID-19 policies in FY 2020 and FY 2021, employee commute activity substantially declined in those years compared to years prior. Between FY 2020 and FY 2021, employee commute activity declined by 30 percent, whereas between FY 2009 and FY 2019, employee commute activity generally remained constant. According to discussions with VTA, these depressed employee commute trends have persisted in FY 2022, particularly for those working in offices. It is likely that during the pandemic, more employees that may have formerly commuted by transit or carpool drove alone when commuting to their work location. For forecasting purposes, it was assumed that employee commute would continue to remain suppressed at similar levels to FY 2020 and FY 2021 for the next few years, consistent with trends assumed in MTC's PBA FY 2050 regional VMT forecasts, and then return to pre-COVID levels by FY 2030. However, to balance the recent work-from-home trends, the anticipated return to pre-COVID levels, and potential growth in VTA employee population, it was assumed that employee commute activity would remain at a constant level, representing the FY 2009-FY 2021 average, through FY 2050. As a result, employee commute VMT was assumed to be 3,688,803 VMT per year from FY 2030 through FY 2050. The historical trends and forecasts are shown in Table 34.

Table 34 Forecasted VTA Employee Commute Activity

Fiscal Year	Employee Commute VMT
2009	3,779,745
2010	3,705,668
2011	3,588,228
2012	3,599,069
2013	3,618,943
2014	3,754,450
2015	3,658,692
2016	4,041,725
2017	3,994,750
2018	4,067,020
2019	3,980,296
2020	3,628,510
2021	2,537,340
Forecasts	
2030	3,688,803
2035	3,688,803
2040	3,688,803
2045	3,688,803
2050	3,688,803

Source: Ascent Environmental in 2022.

Emissions Factors

For the forecasted emissions from employee commute, future GHG emission factors through FY 2050 were obtained from EMFAC2021, which was run for Santa Clara County for the three vehicle categories (LDA, LDT1, and LDT2). EMFAC2021 outputs were also adjusted to account for ACC2, which accelerates future penetration of ZEVs into the overall passenger vehicle market. Apart from the use of EMFAC2021, ACC2, and querying the emission factors for future years, the remaining methodology remains the same as in the inventory. Please refer to the 2020 VTA Sustainability Plan Technical Memorandum for the description of the original methods used to quantify emission factors used for the employee commute sector. The resulting emission factors are shown in Table 35. As these emissions factors are presented by calendar year, for modeling purposes, it was assumed that the emission factors for the same years were applied to fiscal years directly (e.g., CY 2020 emission factor used for FY 2020).

Table 35 Forecasted Employee Commute Emission Factors (g CO_2e/mi)

Vehicle Category	Fuel Type	FY 2030	FY 2035	FY 2040	FY 2045	FY 2050
LDA, LDT1, LDT2 Average	Gasoline	231	158	98	63	45

Note: CO_2e = carbon dioxide equivalents, g = gram, mi = mile, LDA = Passenger Cars; LDT1 = Light-Duty Trucks (GVWR* <= 3750 lbs.); LDT2 = Light-Heavy-Duty Trucks (GVWR 10001-14000 lbs.); FY = fiscal year

Source: Ascent Environmental in 2022.

WATER

Activity

Total water use forecasts were extrapolated linearly from historical trends in water consumption at VTA facilities. The distribution between non-potable and potable water use trends were evaluated separately. Between FY 2009 and FY 2021, VTA's overall water use has declined by 1.2 percent per year on average. At the same time, the percentage of potable water use has also decreased from 95 percent to 67 percent of total water consumption from FY 2009 to FY 2021, an average of a three percent annual reduction, while the percentage of non-potable use has also increased in proportion. These trends were applied to future total water forecasts, as shown in Table 36.

Table 36 Forecasted Water Use Activity by Source (gallons per year)

Fiscal Year	Potable	Non-Potable	Total
2009	54,321,484	2,883,910	57,205,394
2010	40,534,621	1,838,160	42,372,780
2011	36,246,886	2,337,373	38,584,259
2012	35,320,853	2,519,545	37,840,398
2013	39,695,829	3,401,841	43,097,670
2014	54,660,071	2,078,491	56,738,561
2015	48,139,825	4,737,427	52,877,252
2016	28,416,053	6,347,731	34,763,784
2017	25,534,268	7,836,806	33,371,075
2018	31,772,297	9,010,187	40,782,484
2019	32,691,249	15,691,916	48,383,165
2020	31,064,707	11,629,105	42,693,812
2021	26,347,823	12,745,214	39,093,036
Forecasts			
2030	19,339,261	16,057,032	35,396,293

Fiscal Year	Potable	Non-Potable	Total
2035	19,581,593	13,054,396	32,635,989
2040	17,925,411	11,950,274	29,875,685
2045	16,269,228	10,846,152	27,115,381
2050	14,613,046	9,742,031	24,355,076

Source: Ascent Environmental in 2022.

Emissions Factors

Emissions resulting from water use were based on water energy intensity factors assumed in the inventory and future estimated PG&E emission factors are shown in Table 31.

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ATTACHMENT 1
VMT PROCESS TECHNICAL MEMO

The following is the VMT processing technical memo prepared by MTC.

1 OD TRIP MATRIX AVAILABILITY

Since the project team decided that the VMT by speed bins are not needed, MTC recommended that we use the OD trip matrix to estimate the VMT, instead of using individual and joint residence micro trip table previously.

Through the BOX, MTC provided 20 trip matrix for each year, separated by four categories as below:

- household travel demand (main/trips@token_period@.tpp)
- external travel demand for the 9-county region (nonres/tripsIx@token_period@.tpp)
- commercial travel demand (nonres/tripsTrk@token_period@.tpp)
- air passenger travel demand (nonres/tripsAirPax@token_period@.tpp)

Specifically, the matrix for year 2050 are listed below in Figure1-1 and Figure1-2:

› Base › Year2050 › main

Name	Date modified	Type	Size
tripsAM.tpp	8/31/2022 11:35 AM	TPP File	5,906 KB
tripsEV.tpp	8/31/2022 11:34 AM	TPP File	4,629 KB
tripsMD.tpp	8/31/2022 11:34 AM	TPP File	4,729 KB
tripsPM.tpp	8/31/2022 11:24 AM	TPP File	5,631 KB
tripsEA.tpp	8/31/2022 11:22 AM	TPP File	1,687 KB

Figure 1-1 Files of Trip Matrix of Main Residence Model

› Base › Year2050 › nonres

Name	Date modified	Type	Size
tripsAirPaxAM.tpp	8/31/2022 11:39 AM	TPP File	277 KB
tripsAirPaxEA.tpp	8/31/2022 11:38 AM	TPP File	249 KB
tripsAirPaxEV.tpp	8/31/2022 11:38 AM	TPP File	284 KB
tripsAirPaxMD.tpp	8/31/2022 11:38 AM	TPP File	291 KB
tripsAirPaxPM.tpp	8/31/2022 11:38 AM	TPP File	280 KB
tripsIXAM.tpp	8/31/2022 11:39 AM	TPP File	404 KB
tripsIXEA.tpp	8/31/2022 11:39 AM	TPP File	297 KB
tripsIXEV.tpp	8/31/2022 11:39 AM	TPP File	412 KB
tripsIXMD.tpp	8/31/2022 11:39 AM	TPP File	422 KB
tripsIXPM.tpp	8/31/2022 11:39 AM	TPP File	406 KB
tripstrkAM.tpp	8/31/2022 11:37 AM	TPP File	4,516 KB
tripstrkEA.tpp	8/31/2022 11:37 AM	TPP File	4,289 KB
tripstrkEV.tpp	8/31/2022 11:37 AM	TPP File	4,814 KB
tripstrkMD.tpp	8/31/2022 11:37 AM	TPP File	7,504 KB
tripstrkPM.tpp	8/31/2022 11:37 AM	TPP File	5,809 KB

Figure 1-2 Files of Trip Matrix of Non-residence Modes

2 SKIM MATRIX AVAILABILITY

Also, MTC provided 5 files of skims matrix for each TOD (time of day), for each year. The skims files for year 2050 are listed below.

› Base › Year2050 › skims

Name	Date modified	Type	Size
HWYSKMAM.tpp	9/12/2022 2:18 PM	TPP File	74,262 KB
HWYSKMEA.tpp	9/12/2022 2:17 PM	TPP File	74,099 KB
HWYSKMEV.tpp	9/12/2022 2:18 PM	TPP File	74,217 KB
HWYSKMMD.tpp	9/12/2022 2:17 PM	TPP File	74,640 KB
HWYSKMPM.tpp	9/12/2022 2:17 PM	TPP File	74,637 KB

Specifically, each skim file contains 21 tables that include distances, times, tolls and others by mode. Of the 21 tables, six tables are distance related, which are used to calculate the VMT by mode. They are listed below.

skim_table_num	skim_table_name
2	DISTDA
5	TOLLDISTDA
9	DISTS2
12	TOLLDISTS2
16	DISTS3
19	TOLLDISTS3

Figure 2-1 List of Tables of Distance Skims

3 CLARIFICATION ON TRIP MATRIX: PERSON TRIPS VS VEHICLE TRIPS

As MTC instructed, of all OD trip matrix tables, only the main model provides person trips, while the rest of model presents vehicle trips. See the details below.

- household travel demand (main/trips@token_period@.tpp): **person** trips
- external travel demand (nonres/tripsIx@token_period@.tpp): **vehicle** trips
- commercial travel demand (nonres/tripsTrk@token_period@.tpp): **vehicle** trips
- air passenger travel demand (nonres/tripsAirPax@token_period@.tpp)L: **vehicle** trips

4 MAIN MODEL – MODES OF TRIPS, MATCHED SKIMS, AND OCCUPANCY ASSUMPTION

The modes availability in each OD trip matrix varies depending on the type of model, and different skims are matched accordingly. The details are listed in Figure 4-1 below.

The main model is the only one displaying in person trips, which needs to be converted into vehicle trips before multiplying with skims. The Occupancy assumption are listed in the same figure. Specifically, the 3.25 persons/vehicle for sr3 and s3_av is suggested by MTC. The 3.83 persons/vehicle for s3_tnc is the weighted average from MTC Model Calibration and Validation Report.

Moreover, through discussions with MTC, please note the important clarifications:

- The DA, SR2, SR3 modes (modes 1-6) in the trip tables are trips made in human-driven vehicles.
- The "AV modes" refer to household owned AVs.
- Trips included in the TNC modes are mutually exclusive from those counted in the household-owned AV modes.

With this clarification, we can simply sum up VMT of each mode in the main model and are sure we're not double-counting trips/VMT.

In addition, as MTC suggested, we applied the TOLLDISTS2 skim for 'da_tnc' mode due to considering the additional TNC driver in the vehicle; similarly, we applied the TOLLDISTS3 skim for s2_tnc and s3_tnc due to considering the TNC driver in the vehicle.

table_number	mode_name	skims_matched	Occupancy(person/ vehicle)
1	da	DISTDA	1
2	datoll	TOLLDISTDA	1
3	sr2	DISTS2	2
4	sr2toll	TOLLDISTS2	2
5	sr3	DISTS3	3.25
6	sr3toll	TOLLDISTS3	3.25
7	walk	not used	
8	bike	not used	
9	walk_loc_walk	not used	
10	walk_lrf_walk	not used	
11	walk_exp_walk	not used	
12	walk_hvy_walk	not used	
13	walk_com_walk	not used	
14	drv_loc_walk	not used	
15	drv_lrf_walk	not used	
16	drv_exp_walk	not used	
17	drv_hvy_walk	not used	
18	drv_com_walk	not used	
19	walk_loc_drv	not used	
20	walk_lrf_drv	not used	
21	walk_exp_drv	not used	
22	walk_hvy_drv	not used	
23	walk_com_drv	not used	
24	da_tnc	TOLLDISTS2	1
25	s2_tnc	TOLLDISTS3	2
26	s3_tnc	TOLLDISTS3	3.83
27	da_av	DISTDA	1
28	s2_av	DISTS2	2
29	s3_av	DISTS3	3.25

Figure 4-1 List of Trip Modes, Skims, and Occupancy of Main Model

5 AIRPORT MODEL: MODES OF TRIPS AND MATCHED SKIMS

In the airport model, there are only six modes available. The trip modes and the matched skims are displayed in Figure5-1.

Please note that mode choice of air passengers is conducted in the air passenger model separately, which is different from the mode choice in the main model. In another words, TM 1.5 does not assume any usage of TNC or household AVs for airport passengers.

table_number	mode_name	skims_matched
1	da	DISTDA
2	sr2	DISTS2
3	sr3	DISTS3
4	datoll	TOLLDISTDA
5	sr2toll	TOLLDISTS2
6	sr3toll	TOLLDISTS3

Figure 5-1 List of Trip Modes and Skims Matched for Airport Model

6 EXTERNAL MODEL: MODES OF TRIPS AND MATCHED SKIMS

In the external model, there are only six modes available. The trip modes and the matched skims are displayed in Figure 6-1.

table_number	mode_name	skims_matched
1	da	DISTDA
2	sr2	DISTS2
3	sr3	DISTS3
4	datoll	TOLLDISTDA
5	sr2toll	TOLLDISTS2
6	sr3toll	TOLLDISTS3

Figure 6-1 List of Trip Modes and Skims Matched for External Model

7 COMMERCIAL MODEL: MODES OF TRIPS AND MATCHED SKIMS

In truck model, there are eight modes available. The trip modes and the matched skims are displayed in Figure 7-1.

tab_number	tab_name	notes	skimsUsed
1	vsTruck	verySmallTruck	DISTDA
2	sTruck	smallTruck	DISTDA
3	mTruck	mediumTruck	DISTDA
4	cTruck	CombinedTruck	DISTDA
5	vsTollTruck	verySmallTruckToll	TOLLDISTDA
6	sTollTruck	smallTruckToll	TOLLDISTDA
7	mTollTruck	mediumTruckToll	TOLLDISTDA
8	cTollTruck	CombinedTruckToll	TOLLDISTDA

Figure 7-1 List of Trip Modes and Skims Matched for Commercial Model

8 TRIP-BASED VMT VS. LINK-BASED VMT

The link-based VMT is not required by the project. However, we still calculated it for purpose to verify with the trip-based result.

As displayed in figure 8-1 below, at the whole regional level, the total of trip-based VMT is close to the link-based VMT within 3% range.

Year	linkBasedVmt	tripBasedVmt	gaps
2015	140,389,348	142,469,457	1.5%
2035	156,470,654	159,904,897	2.2%
2050	173,949,337	179,380,232	3.1%

Figure 8-1 Compare trip-based VMT with link-based VMT, at regional level

ATTACHMENT 2
COMMUNITYWIDE TRANSPORTATION CALCULATIONS

This attachment will be provided online.