Appendix B

GHG Inventory Methodology and Modeling

GHG Inventory

The Hayward community greenhouse gas (GHG) inventories (2005, 2010, 2015, 2017, 2018, and 2019) were prepared by Hayward City staff utilizing the same excel-based inventory tool used to assess GHG emissions for all 35 communities in the East Bay region. The inventory tool has the capability for each individual jurisdiction to modify data inputs to develop their own inventories. East Bay Energy Watch prepared the *East Bay Energy Watch Regional Greenhouse Gas Inventory Phase III Methodology Summary*[1] to detail the methodology utilized in the inventory tool including the activity data to use, where to obtain the activity data, where emission factors come from, and how annual emissions are calculated from the activity data and emission factors. In general, the methodology and calculated emissions using the East Bay tool align with the principles and methods outlined in the Local Governments for Sustainability USA (ICLEI) U.S. Community Protocol.

As a result of a GHG inventory data consistency and analysis review of the previous Hayward inventories, some methodologies were updated from those detailed in the *East Bay Energy Watch Regional Greenhouse Gas Inventory Phase III Methodology Summary.* Hayward staff prepared the *City of Hayward GHG Inventory Technical Memorandum*, attached to this Appendix, to detail the methodology changes by sector including the addition of AC Transit emissions to the inventory, updating transportation emission factors to using EMFAC2021, and updating the energy calculations to include California specific CH_4 and N_2O emission factors for electricity. Additionally, as part of the CAP, Hayward has decided to begin using Google EIE Model vehicle miles traveled (VMT) data for the on-road transportation sector. This decision was made as the travel demand model previously used to obtain VMT data for historic inventories, Metropolitan Transportation Commission (MTC), is anticipated to not be updated for future years so the data source may not be available. The use of different methodologies across GHG inventories and for forecasting GHG emissions from a sector limits the ability to discern changes related to GHG emissions trends versus changes due to methodology change. For consistency it is recommended that the same VMT data source be used for all inventories, forecasts, and for tracking progress against established emission targets.[2] As such, all Hayward inventories were updated to use VMT data based on the Google EIE Model. The methodology and results of the update to the on-road transportation sector using Google EIE VMT data are detailed in the *Vehicles Miles Traveled Data Source and Methodology Evaluation Memorandum*, attached as part of this Appendix.

Appendix C, GHG Forecast Methodology and Modeling, of the CAP further details updates made to the inventories and methodology or emission factor changes. Appendix C also provides a detailed summary of the updated 2019 GHG emissions inventory that was utilized for forecasting future emissions.

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[1] Easy Bay Energy Watch. 2020. East Bay Energy Watch Regional Greenhouse Gas Inventory Phase III Methodology Summary.

[2] The ICLEI Community Protocol recommends recalculation of previous inventories to ensure consistent comparisons of GHGs over time. Local Governments for Sustainability (ICLEI). 2019. U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Available: <https://icleiusa.org/us-community-protocol/>.

City of Hayward GHG Inventory Technical Memorandum

Adding AC Transit Calculation

The City of Hayward has the AC Transit system that operates multiple fixed bus routes within the City. Rincon recommended including the emissions from community use of the AC Transit bus system because MTC data does not include bus vehicle classes. Following ICLEI's Community Protocol Method *TR.4 Emissions from Transit*, Hayward staff attributed AC Transit emissions from the City of Hayward based on the City's geographic boundary, bus routes, and bus schedules.

Total transit emissions for AC Transit were first calculated using ICELI methods *TR.4.A Carbon Dioxide Emissions from Mobile Combustion* and *TR.4.B Methane and Nitrous Oxide Emissions from Mobile Combustion*. Operation information from the National Transit Database (NTD)[1] and gasoline and diesel emission factors from The Climate Registry[2] were used to calculate total MTCO2e for all AC Transit services.

Next, ICLEI method *TR.4.D Attribution of Fixed Route Transit* was used to determine the attribution from the City of Hayward. The AC Transit lines that operate in Hayward are listed on the City's Streets and Transportation webpage. GIS shapefiles of the transit routes in Hayward were used to determine the number of miles the buses travel within the City boundary. To avoid double counting, the route was measured in two segments: "Start in Hayward" and "End in Hayward". The schedule of each bus route was then used to calculate the annual vehicle revenue miles (VRM) travelled within Hayward based on mileage travelled during weekdays and weekends/holidays.

After calculating the total emissions from AC Transit with method TR.4.A and TR.4.B and determining the VRM attribution for the City of Hayward with method TR.4.D, the total fixed route emissions (MTCO2e) and average emissions factor (MTCO2e/mile) were calculated.

It should be noted that for inventory year 2005, Fuel Consumption (gal) and Miles Traveled by Fuel (NTD Fuel and Energy Data) were unavailable for both gasoline and diesel vehicles. Additionally, emission estimates should be used with caution because this method does not factor in the proportion of AC Transit users that live in Hayward.

Updating EMFAC 2017 to EMFAC 2021

Rincon noted in the GHG Inventory Review that the use of EMFAC2017 may overestimate GHG emissions from on-road vehicles because it does not accurately factor in the transition to electric vehicles.

Following Rincon's recommendation, Hayward staff updated EMFAC tabs for all nine inventory years with EMFAC's Model Version 2021 v1.0.1. No changes were made to the methodology in the Regional Greenhouse Gas Inventory Phase III Methodological Summary. With the incorporation of the updated EMFAC data, the table on page 16-17 should now read (for Alameda County):

[1] Annual Metrics data (https://www.transit.dot.gov/ntd/data-product/2018-metrics) and annual Fuel and Energy data (https://www.transit.dot.gov/ntd/data-product/2018-fuel-and-energy)

[2] Assumed that for gasoline, DR uses EPA tier 2 vans, and both MB and CB are EPA Tier 2 buses. For Diesel, DR and all buses are Advanced.

YEAR	ALAMEDA COUNTY MTCO2E/VMT			CONTRA COSTA COUNTY MTCO2E/VMT		
	LIGHT DUTY	HEAVY DUTY	COMBINED	LIGHT DUTY	HEAVY DUTY	COMBINED
2005	0.000401	0.001464	0.000514	N/A	N/A	N/A
2010	0.000393	0.001449	0.000499	N/A	N/A	N/A
2015	0.000361	0.001422	0.000457	N/A	N/A	N/A
2017	0.000346	0.001395	0.000447	N/A	N/A	N/A
2018	0.000339	0.001386	0.000438	N/A	N/A	N/A
2019	0.000333	0.001383	0.000432	N/A	N/A	N/A
2020	0.000326	0.001391	0.000436	N/A	N/A	N/A
2021	0.00032	0.001359	0.000418	N/A	N/A	N/A
2022	0.000313	0.001342	0.00041	N/A	N/A	N/A

Updating eGRID/Energy Calculations

In Rincon's GHG inventory assessment, Rincon noticed that the Methodological Summary and inventory workbook indicates that CH4 and N2O emission factor is regionally specific to California. However, the CH4 and N2O emission factors using in the GHG calculations, reported on the Energy calculations tab, are not consistent with California specific CH4 and N2O emission factors as calculated on the eGRID tabs in the inventory workbook.

To address this inconsistency, Hayward staff updated the Energy Calculations tab, row 199 and 200, with CH4 and N2O emissions factors calculated on the eGRID tab.

Since there was no eGRID2019 tab, 2019 emissions factors were pulled from the EPA's website. Table 3 from eGRID2019 Summary Tables was used for the emissions factors within the spreadsheet. Data source: https://www.epa.gov/sites/default/files/2021-02/documents/egrid2019_summary_tables.pdf

The spreadsheet now follows the methodology provided by the Methodological Summary. However, with the updates in emission factors, the table on page 6 should now be as follows:

Electricity Emissions	2005	2010	2015	2017	2018	2019
Carbon dioxide (lbs CO2/kWh)	0.489	0.445	0.405	0.210	0.206	0.206
Methane (lbs CH4/MWh)	0.0306	0.0308	0.0311	0.0233	0.0271	0.0270
Nitrous oxide (lbs N2O/MWh)	0.0045	0.0044	0.0038	0.0029	0.0034	0.0030
Combined (MTCO2e/kWh)	0.000223	0.000203	0.000185	0.000096	0.000094	0.000094

Updating Water/Wastewater

No changes were made to the methodology described in the Methodological Summary. Hayward staff obtained water and wastewater data and input the data into the spreadsheet and emissions were calculated as described in the Methodological Summary.

Rincon Consultants, Inc.

Environmental Scientists *Planners* *Engineers*

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Date: June 21, 2022

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Project: **Hayward Climate Action Plan Update**

Re: Vehicle Miles Traveled Data Source and Methodologies Evaluation Memorandum

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Rincon Consultants, Inc. (Rincon) has conducted an evaluation of four different data sources for purposes of estimating Hayward vehicle miles traveled (VMT) for use in estimated greenhouse gas (GHG) emissions related to the transportation sector. The goal of the analysis was to determine the most appropriate VMT data source for inclusion in the Hayward greenhouse gas (GHG) emissions inventory and forecast that would provide accurate and comparable VMT data over time and be consistent with methodologies defined by the ICLEI U.S. Community Protocol. [1] Specifically, this effort included a review of the VMT data and methodologies used by Metropolitan Transportation Commission (MTC), traffic engineers using the Alameda County Transportation Commission (ACTC) travel model, Google Environmental Insights Explorer (Google EIE), and California Air Resources Board (CARB) EMission FACtor (EMFAC) 2021 online database to determine the existing and forecasted VMT associated with on-road transportation within the community of Hayward. This evaluation utilizing

[1] Local Governments for Sustainability (ICLEI). 2019. U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Available: <https://icleiusa.org/us-community-protocol/>. Accessed May 20, 2022.

criteria agreed upon by the city resulted in the identification of Google EIE VMT data as the preferred option for purposes of updating past GHG emissions inventories, updating the existing GHG emissions inventory, conducting future GHG emissions inventories, and estimating future GHG emissions. Because the VMT data set from Google EIE VMT is based on location-based GPS data that is continuously tracked, VMT data from Google EIE is more accurate than modeled data from a transportation demand model.[2] Additionally, Google EIE VMT data is advantageous as it is reflective of local conditions in a community and is able to capture change year over year, unlike traditional transportation demand models, such as the MTC, ACTC, and EMFAC models, that are forecasted based on a series of historic base assumptions and anticipated land use and population changes that may not be actualized. This increased sensitivity to local changes will allow Hayward to better monitor the efficacy of its VMT reduction measures as well as limit the risk of over or underestimating changes in VMT that are an artifact of modeling assumptions.

VMT Data Source Review Purpose

The City of Hayward is in the process of updating its Climate Action Plan (CAP). As part of this effort, GHG emissions associated with on-road transportation are calculated based on community VMT for inclusion in the community GHG inventories (i.e., 2005, 2010. 2015, 2017, 2018, and 2019) and for forecasting GHG emissions in future years (i.e., 2025, 2030, 2035, 2040, and 2045). For the previously developed inventories (i.e., 2005, 2010, 2015, 2017, 2018, and 2019), VMT data was obtained for the community from the MTC Traffic demand model. However, Rincon understands the MTC may not be updating the traffic model for future years limiting the ability to obtain future VMT projections beyond 2040. Therefore, Hayward is considering the use of alternative VMT data sources, including the ACTC Countywide Transportation Demand Model, EMFAC 2021 Model, and Google EIE Model, to update the GHG inventories.

As detailed in the *Hayward GHG Inventory Data Consistency and Analysis Approach Review Memorandum* dated November 5, 2021, the use of different methodologies across GHG inventories and for forecasting GHG emissions from a sector limits the ability to discern changes related to GHG emissions trends versus changes due to methodology change. For consistency it is recommended that the same VMT data source be used for all inventories, forecasts, and for tracking progress against established emission targets.[3] Prior to use of a new VMT data source in the forecast and updating of the inventories, Rincon evaluated four different VMT data sources available for the Hayward community including MTC provided data, modeled VMT data provided by traffic engineers using the ACTC travel model, VMT data obtained from the EMFAC 2021 online database, and Google EIE VMT data.

This memorandum provides the following:

- Background review of the methodology used by each data source to calculate VMT for the Hayward community and evaluation of the limitations that exist with use for each data source;
- Comparison of the annual VMT data for the Hayward community obtained from each data source for the years 2018 and 2019;
- Determination of the data source to be utilized for Hayward GHG inventories and forecasts; and

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[2] Local Governments for Sustainability (ICLEI). (2021, May 11). 4 Ways Google EIE Transformed Transportation Data Collection. Available: < https://icleiusa.org/4-ways-google-eie-transformed-transportation-data-collection/#:~:text=EIE%20aggregates%20trip%20data%20from%20Google%20Maps%2C%20processed,EIE%20calculates%20the%20total%20CO%202%20equivalents%20emissions.>. Accessed June 1, 2022

3 The ICLEI Community Protocol (cited in footnote 1) recommends recalculation of previous inventories to ensure consistent comparisons of GHGs over time.

- Results of final updates to on-road transportation sector GHG emissions.

Activity data and associated emissions detailed within this memorandum include activities under the jurisdictional control or significant influence of the City of Hayward, as recommended by the Association of Environmental Professionals (AEP) in preparing Community Protocol and CEQA-compliant GHG inventories.[4]

Methodology Review and Evaluation of VMT Data Sources

This section includes 1) a review of the various models to determine on-road VMT attributed to the Hayward community; and, 2) an evaluation of the limitations and/or advantages associated with each model.

MTC Travel Demand Model

Background Review

Haywards previous GHG emissions baselines were modeled using the MTC data for years 2005 and 2015, while future years were modeled for years 2020, 2030, 2035, and 2040. MTC uses an activity-based travel demand model that generates simulations based on "agents" or the activities carried out by the households and people, that reside in the Bay Area to determine VMT for communities under typical conditions (i.e., weekday, normal weather). VMT changes are based on the land use assumptions that have been input into the model or transportation projects that would influence the *agents* trip. The MTC model is based on previous and prospective populations, households and land use developments in the nine-county Bay Area and accounts for interregional travel amongst those nine counties. The MTC model uses an origin-destination method, the recommended VMT estimation approach,[5] to assign light-duty VMT to individual communities. Under this method, the model separates out trips that begin and end in the community, trips that begin in the community but end elsewhere (or vice-versa), and trips that do not begin or end in the community (although they may pass through). 100% of the VMT is applied to the trips that originate and end within a jurisdiction and 50% of VMT is applied to trips that originate or end within a specific jurisdiction. MTC's data outputs label this data as "Entirely within," "Partially in," and "Entirely outside," respectively.

MTC uses the transportation demand model to calculate light-duty VMT for each community, while MTC provides heavy-duty VMT obtained from a regional dataset using a "Longitudinal Employer-Household Dynamics" (LEHD) method. Countywide heavy-duty VMT that occurs within the county's limits is assigned to the county regardless of where a trip begins or ends (this is typically referred to as the geographic boundary or in-boundary method for estimating VMT). Countywide heavy-duty VMT is allocated to individual jurisdictions in the county based on the number of jobs in a specific economic sector that generates heavy-duty vehicle trips such as agriculture, forestry, mining, utilities, construction, manufacturing, wholesale trade, retail trade and transportation/ warehousing. Jobs numbers by sectors were obtained from the US Census.

[4] Association of Environmental Professionals. 2013. The California Supplement to the United States CommunityWide Greenhouse Gas (GHG) Protocol. Available < https://califaep.org/docs/California_Supplement_to_the_National_Protocol.pdf>. Accessed May 20, 2022

[5] Regional Targets Advisory Committee (RTAC). 2009. Recommendations of the Regional Targets Advisory Committee (RTAC) Pursuant to Senate Bill 375: A Report to California Air Resources Board. Available < https://www.fresnocog.org/wp-content/uploads/files/SB375/finalreport.pdf>. Accessed June 22, 2022

The method that MTC uses to model VMT omits motorcycles from light-duty VMT totals, as well as motor homes and all types of buses from heavy-duty VMT totals. To provide a more complete inventory, past Hayward inventories would estimate VMT from these vehicle types using CARB's most recent EMFAC model. The EMFAC-reported VMT for all light-duty vehicles and all heavy-duty vehicles for the county is summed and divided by the VMT from all over vehicle types to determine the ratio of motorcycle VMT and bus VMT to VMT from other vehicle types. The light-duty VMT for Hayward as reported by MTC is divided by the countywide percent of VMT from motorcycles to "add back in" the amount of light-duty VMT not captured in the MTC model. Similarly, the heavy-duty VMT for Hayward is divided by the countywide percent of VMT from motorhomes and buses to "add back in" the amount of heavy-duty VMT not captured in the MTC estimations.[6]

Evaluation

The MTC travel demand model relies on previous years of data including surveys of transportation patterns, land uses, and several other factors that may be dated given current conditions and recent situations that have altered traffic patterns (e.g., COVID-19). Future road networks and land use changes are based on the Plan Bay Area 2040. As such future travel demand is based on existing or modeled patterns and not able to capture year over year changes that could occur due to local changes. Additionally, because the model is developed using regional data and for regional traffic planning, it is limited in terms of the accuracy it can provide for a specific jurisdiction. The complete VMT data set includes the use of multiple data sources to estimate VMT for the community, including use of a travel demand model following origin-destination methodology for passenger vehicles and a regional data set for commercial vehicles based on a geographic boundary methodology for heavy-duty vehicles. Additionally, the MTC method for modeling omits certain vehicle types from VMT totals requiring off model calculations to estimate VMT from those omitted vehicle types occurring in Hayward. The use of differing methodologies with different base assumptions limits the accuracy of the final data set to be used in the inventory. Finally, the MTC model horizon year is 2040 and MTC has indicated that the model is not planned to be updated for future horizon years, limiting is usefulness in the future once the horizon year has been surpassed and may inadvertently introduce future emission changes that don't represent the actual conditions found in the city.

ACTC Countywide Transportation Demand Model

Background Review

As part of the Hayward Housing Element and General Plan Amendments being prepared in parallel with the Hayward CAP Update, transportation engineers Kittelson & Associates modeled VMT in Hayward using the latest version (July 2018) of the ACTC Countywide Transportation Demand Model, an activity-based travel demand model that is a variant of the MTC model that was developed for jurisdiction-level usage. The current version of the ACTC model includes land use assumptions and transportation investments associated with the Sustainability Communities Strategy from the Plan Bay Area 2040 and is consistent with the assumptions of the MTC's regional travel demand model. The ACTC model includes output spanning the years 2010 through 2040. The model includes the nine Bay Area counties, same as the MTC model, as well as San Joaquin County. Compared to the MTC model, the ACTC model has a refined Transportation Analysis Zone (TAZ) system in Alameda County and the adjacent TAZ sections in Santa Clara and Contra Costa Counties and uses local development information and census block level

[6] East Bay Energy Watch. 2020. Regional Greenhouse Gas Inventory Phase III Methodological Summary.

information for these TAZ sections.[7] No differences exist at the census tract level outside of Alameda County for the other MTC counties. In addition to the trip purposes modeled by MTC, the ACTC model also includes additional purposes in the travel demand model like light, medium, and heavy-duty internal and interregional truck trips to capture commercial trips as part of the travel demand model and has added additional mode choice options to include transit buses. The ACTC model also uses an origin-destination method to assign VMT to individual communities (i.e., 100 percent of daily trips completely within the jurisdiction, 50 percent of Partially In trips, and 0 percent of outside trips were allocated to Hayward).

The ACTC model VMT data is generally consistent with the MTC model, however, it differs in a few ways. The ACTC model captures interregional travel between San Joaquin County and Hayward which are not captured with the MTC model while commercial vehicle VMT are modeled with the ACTC model rather than using a regional data set like the MTC model. Therefore, while the ACTC model produced travel demand forecasts that are generally consistent with the travel demand forecasts that the MTC model produces, VMT reported from the ACTC model are 7 percent higher than VMT values reported from the MTC model due to the inclusion of the San Joaquin County in the ACTC, there is more refined demographic data for Alameda County compared with the MTC regional model, and ACTC includes of commercial VMT in the model.

Evaluation

Similar to the MTC model limitations, the ACTC model relies on previous years of data including surveys of transportation patterns, land uses, and several other factors that may be dated given current conditions and recent situations that have altered traffic patterns (e.g., COVID-19). Future road networks and land use changes are based on the Plan Bay Area 2040. As such future travel demand is based on existing or modeled patterns and not able to capture year over year changes that could occur due to local changes. Additionally, like the MTC model, the horizon year for the model is 2040. This limits the accuracy and utility of this model for years beyond the horizon year. The ACTC model is advantageous for GHG modeling to the MTC model as VMT data generated by the ACTC model includes light-duty and heavy-duty vehicle trips (i.e., passenger and commercial trips) using the same travel demand model and origin-destination boundary approach, improving consistency of the data set compared with the MTC model that uses two different data sets to obtain passenger and commercial VMT data. Additionally, the ACTC model has more refined demographic data for Alameda County in which Hayward is located, making this model potentially a more accurate representation of VMT in Hayward than the MTC model.

EMFAC 2021Model

Background Review

EMFAC 2021 is the latest emission inventory model that CARB developed to assess emissions from on-road motor vehicles including cars, trucks, and buses in California. It's based on the statewide and regional vehicle activities and includes recently adopted regulations like the Advanced Clean Trucks, Innovative Clean Transit, and Heavy-Duty Omnibus regulations. The model utilizes Department of Motor Vehicle (DMV) registration data, International Registration Plan data, National Transit Database data, and vehicle data from the California Highway Patrol and major ports for vehicle characterizations in a

7 ACTC. 2018. Alameda Countywide Travel Demand Model Plan Day Area 2040 Update. Available < https://www.alamedactc.org/wp-content/uploads/2018/12/Key_Features_of_the_Model_Jul2018-1.pdf> Accessed June 2022.

county or region. Activity data are incorporated into the model from several sources including National Household Travel Surveys, 2018 California Vehicle Inventory and Use Survey and Geotab Telematics Data, and Portable Activity Measurement Systems from 200-Vehicle Project. The model estimates future light-duty VMT and new vehicle sales based on the latest available socio-economic data from UCLA Anderson Forecast, California Department of Finance, California Board of Equalization, California Energy Commission, and Federal Reserve Bank of St. Louis. VMT of light-duty vehicles at the statewide level is forecasted using multivariate regression analysis based on previous time-series data from 2003-2019. Heavy-duty VMT future trends are based on the forecasted VMT per county from the California Statewide Freight Forecasting Model. EMFAC 2021 also forecasts the penetration of zero-emission vehicles (ZEV) based on the projected ZEV market share under the most likely compliance scenario with California's ZEV mandate. Default VMT data is estimated based on previous fuel sales and is tied to a specific county, sub-county or region where vehicles are registered rather than assigned to a community using an origin-destination method.

Evaluation

The EMFAC model generates data only as granular as the county level limiting accuracy for a city within Alameda County and does not utilize the origin-destination methodology recommended by the ICLEI U.S. Community Protocol.[8] Similar to the ACTC and MTC model limitations, the EMFAC model relies on previous years of data and other factors that may be dated given current conditions and recent situations that have altered VMT. As such future VMT is based on existing or modeled patterns and not able to capture year over year changes that could occur due to local changes. Additionally, the EMFAC model was developed for emission inventorying, so the VMT activity data is an estimate based on fuel sales, vehicle sales, and vehicle registration records and does not incorporate or account for impacts on VMT due to land use development changes. As such, VMT activity data from EMFAC 2021 is limited in its accuracy for municipal and for projecting VMT changes over time. However, EMFAC 2021 is particularly useful for developing an emission factor by vehicle category given the emissions inventory data and incorporated regulations impacting emissions, as well as provides useful information surrounding the anticipated future penetration of ZEVs into the vehicle mix of a region or County.

Google EIE Model

Background Review

Google EIE uses Google GIS data sources included in cell phones and modeling capabilities to produce estimates of activity data and emissions for various sectors to aid agencies in climate action planning. The modeled estimates are based on actual measurements of activity and current infrastructure paired with machine learning techniques and scaling factors. Collected activity and infrastructure data is the same as the underlying information used for Google Maps where the data is anonymous, aggregated and combined with other data sources to create useful VMT estimates in Google EIE. For the transportation sector, Google EIE accounts for all trips by all vehicle types that start or ends within the City boundary using anonymized and aggregated Location History data. The data accounts for movement on all major road classifications ranging from interstates to local roads. Annual vehicle trips by mode and vehicle distances are estimated using population and occupancy factors scaling techniques similar to transportation demand models. Region-specific assumptions obtained from Climate Action for Urban Sustainability tool are used to determine vehicle fleet mix and average fuel efficiency of vehicles

[8] ICLEI. 2019. U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Available: <https://icleiusa.org/us-community-protocol/>. Accessed May 20, 2022.

in the region.[9] Provided Google EIE VMT data for Hayward includes light-duty and heavy-duty automobiles VMT and buses (excluding public transit) VMT. Additionally, Google EIE provides data regarding on-foot miles traveled and miles traveled by subways. Hayward utilized ridership data obtained from Bay Area Rapid Transit (BART) to calculate emissions associated with Hayward community use of BART. Hayward does not have another rail or subway system beyond BART and therefore, subway mileage data from Google EIE was not used in the Hayward inventory or forecast. Data for VMT follows the origin-destination method where 100 percent of in-boundary trips and 50 percent of outbound and inbound trips are attributed to the community of Hayward, while pass through trips are excluded from the VMT data set.

Evaluation

Google EIE data captures VMT data in real-time and is advantageous to transportation demand modeled data as it is able to accurately portray changes in VMT year over year that may be related to circumstances like COVID-19 or implementation of local policies and land use developments. Google EIE data is limited in previous data only dating as far back as 2018. As such, for to update GHG inventories older than 2018, a conversion or scaling factor would be applied to previous MTC inventory data to provide estimates comparable to Google EIE. Additionally, Google EIE does not distinguish between light-duty and heavy-duty vehicles in the automobile class of VMT and does not include public transit buses as part of the bus class of VMT. As such, the automobile class VMT would need to be allocated to passenger or commercial vehicles based on another data source, such as EMFAC, and public transit bus VMT would need to be evaluated separately for the inventory.

Comparison of VMT Data

This section includes a comparison of the VMT data sources for Hayward from the four different models. VMT data from each of the four data sources was compared during 2018 and 2019, which are years that data was available and considered “typical”[10]. VMT data was compared against MTC data, as MTC data is the data source originally used for the Hayward GHG emissions inventories (i.e., 2005, 2010. 2015, 2017, 2018, and 2019) and the Hayward 2009 CAP. Table 1 provides a summary of the comparison.

[9]Google. (n.d). *Methodology.* Google Insights Explorer. Available: <https://insights.sustainability.google/methodology>. Accessed May 20, 2022.
[10] Due to impacts on VMT and traffic patterns caused by COVID-19 in 2020, the 2020-year data was not evaluated as it is not reflective of “typical “ conditions.

Table 1 Comparison of VMT Data Sources for Hayward for 2018 and 2019

	MTC[1]	ACTC[2]	EMFAC 2021[3,4]	Google EIE[5]
2018				
Total VMT	1,088,220,072	1,164,159,045	1,349,979,145	973,250,000
Passenger Vehicles	915,174,796	1,003,996,271	1,234,860,955	890,131,191
Commercial Vehicles	165,116,268	152,338,752	109,413,100	78,868,809
Buses Vehicles	7,929,007	7,824,021	5,705,090	4,250,000
Average % deviation from MTC total VMT[6]	N/A	7%	24%	-11%
2019				
Total VMT	1,095,372,659	1,169,822,223	1,356,385,315	942,650,000
Passenger Vehicles	921,045,495	1,008,627,852	1,240,475,294	860,511,102
Commercial Vehicles	166,473,724	153,450,839	110,263,061	76,488,898
Buses Vehicles	7,853,439	7,743,533	5,646,959	5,650,000
Average % deviation from MTC total VMT[6]	N/A	7%	24%	-14%

Notes: Values in this table may not add up to totals due to rounding.
VMT = vehicle miles traveled; MTC = Metropolitan Transportation Commission; ACTC = Alameda County Transportation Commission; EMFAC = EMission FACtor (EMFAC) 2021; Google EIE = Google Environmental Insights Explorer

1. MTC data includes passenger and commercial vehicles with any omitted vehicle types added back in using EMFAC data proportions. Bus VMT is estimated as a percent proportion of commercial MTC data using EMFAC countywide percent proportion for Alameda County.

2. ACTC data includes passenger and commercial data where bus vehicle types are included in the commercial vehicle total. Bus VMT is estimated as a percent proportion of commercial MTC data using EMFAC countywide percent proportion for Alameda County.

3. Vehicle types from EMFAC 2021 are categories as passenger, commercial or buses as follows: Passenger (LDA, LDT1, LDT2, MCY, MDV, MH); Commercial (LHDT1, LHDT2, MHDT, HHDT); Buses (OBUS, SBUS, UBUS).

4. EMFAC 2021 data is countywide therefore to estimate VMT for Hayward, passenger vehicle VMT were scaled to Hayward based on the percent proportion of Hayward's population compared with the countywide population; commercial vehicle and bus VMT were scaled to Hayward based on the percent proportion of Hayward's service population compared with the countywide service population

5. Google EIE data reports VMT for two categories: 1) "automobiles" which include passenger and commercial vehicles and 2) "buses" which encompass all buses (e.g., school buses, private charter buses) except public transit like AC Transit. Automobile VMT is allocated to passenger or commercial vehicle VMT using the EMFAC Countywide proportion of passenger and commercial vehicle VMT for Alameda County.

6. Total VMT from each of the four data sources was compared back to MTC total VMT as MTC data is the data source originally used for Hayward inventories and the Hayward 2009 Climate Action Plan.

As shown in Table 1, VMT data sourced from the ACTC model is most similar to the MTC VMT data. This is anticipated given that both models use the same base assumptions and encompass the nine Bay area counties. ACTC VMT is approximately 7% greater than MTC likely due to the inclusion of interregional trips between Hayward and San Joaquin County, a county not included in the MTC model. EMFAC2021 VMT data deviates the furthest from the MTC model at approximately 24% greater VMT. This is likely a by-product of EMFAC2021 VMT data being an estimate based on fuel consumption at a Countywide level leading to overestimation of VMT when scaled to jurisdiction level for Hayward. Google EIE VMT data is approximately 11% and 14 % less than MTC modeled data for 2018 and 2019 respectively. However, Google EIE data is considered to be more reflective of annual jurisdiction VMT as data is based on data collected annually rather than MTC VMT data that is modeled based on a 2005 and 2015 baseline conditions forecasted forward where local condition changes or policies occurring in a year would not be captured.

VMT Data Determination

This section includes a final determination of the data source to be utilized for Hayward GHG emissions inventories and forecast. Due to the base assumptions used in a travel demand model like MTC or ACTC that are based on land use developments, trip purposes, and human behavior under typical conditions, the VMT data from such models likely overestimate VMT traveled by the Hayward community, and accuracy diminishes the further the modeled year is from the baseline year. This would be especially true for years following the COVID-19 pandemic where base assumptions surrounding trip purposes and human behavior are no longer reflective of current conditions. As EMFAC 2021 uses fuel use data and vehicle registration data to estimate VMT at the county level, EMFAC 2021 VMT data does not accurately reflect local conditions of a jurisdiction. As such, while EMFAC 2021 is useful for providing emission factors or information on future market trends for vehicle types (i.e., EV, ZEV penetration), EMFAC 2021 overestimates the VMT associated with a community such as Hayward and is limited in accuracy.

Google EIE VMT data, though not available for years earlier than 2018 or for future years, is reflective of local conditions in a community, provides the greatest level of accuracy of VMT data, and is able to capture change year over year, as it captures actual travel data within the subject year[11] rather than relying on the application of base assumptions. This method of VMT capture provides value to Hayward in that policies or actions taken locally (such as expanded transit or pedestrian infrastructure) or other conditions (like COVID-19) that impact VMT would be reflected in the annual community VMT data. This increased sensitivity to local changes will allow Hayward to better monitor the efficacy of its VMT reduction measures as well as limit the risk of over or underestimating changes in VMT that are an artifact of modeling assumptions.

Therefore, based on the review of the four data sources available for VMT for Hayward, the limitations of each data source, and the ease of access for annual data, Hayward has opted to use Google EIE VMT data to update previous and existing GHG inventories as well as for future GHG inventories.

Resulting On-road Transportation Sector GHG Inventory Updates

This section describes the methodology and results of the updated GHG inventories resulting from the use of Google EIE VMT data. It is important that the methodology and data sources utilized for the GHG inventories and forecasts are consistent, as this limits the risk of GHG emission changes observed to be an artifact of methodology or model changes. In order to address the risk associated with transitioning to a different VMT data source that uses a different estimation methodology, the City of Hayward updated all previous GHG emissions inventories (2005, 2010, 2015, 2017, 2018, and 2019) to be based on Google EIE VMT data.

Google EIE began collecting VMT data in 2018 and does not have VMT values earlier than 2018. As such, the City updated the 2018 and 2019 inventories using available Google EIE data. Google EIE provides data for on-road transportation in two categories: 1) “automobiles” which include passenger and commercial vehicles and 2) “buses” which encompass all buses (e.g., school buses, private charter buses) except public transit like AC Transit. Emissions associated with AC Transit is calculated separately for the inventory using data obtained from the National Transit Database and is further detailed in the

[11] Location History data is gathered locally and continuously measured via people’s phones. The data used for transportation behavior is the same underlying information as made available in Google Maps where information such as traffic are updated continuously.

Hayward Future GHG Emissions Forecast and Gap Analysis Memorandum dated April 5, 2022. VMT from the bus category of Google EIE data make up approximately 0.5 percent of total (i.e., automobile + bus category) Google EIE VMT data for Hayward. This is comparable to EMFAC 2021 Countywide VMT data for corresponding years (2018 and 2019) where vehicle types categorized as buses made up 0.4 percent of total VMT. Because Google EIE VMT data for automobiles is not broken out by passenger and commercial vehicles, it was assumed that the distribution between passenger and commercial vehicles in Alameda County, as determined by EMFAC 2021, are representative of Hayward. Therefore, Google EIE automobile VMT was allocated to Hayward passenger and commercial vehicle categories based on the EMFAC 2021 data for the County, where in both 2018 and 2019 approximately 92 percent of all "automobiles", excluding bus vehicle types, were passenger vehicles and 8 percent were commercial vehicles.

For GHG inventories earlier than 2018 where Google EIE data is not available, the previous GHG inventories on-road transportation sector needed to be adjusted to remain comparable to future years where Google EIE would be the data source for VMT. As shown in Table 1, total annual VMT data obtained from Google EIE for Hayward for 2018 and 2019 was found to be approximately 11 percent and 14 percent lower than the modeled 2018 and 2019 MTC data, respectively, utilized in the previous GHG inventories. As such, Google EIE VMT data from the two comparable inventory years (2018 and 2019)[12] was on average approximately 12 percent lower than modeled MTC data for the same years. To make the previous GHG inventories (i.e., 2005, 2010, 2015, and 2017) comparable to the revised 2018 and 2019 GHG inventories, the previous annual MTC total VMT data from 2005, 2010, 2015, and 2017 was scaled down by 12 percent. The adjusted total VMT data by year was then attributed to passenger, commercial, and bus vehicle categories based on the percent distribution between passenger vehicles, commercial vehicles, and buses determined for Alameda County using EMFAC 2021.[13] On-road transportation emissions were calculated using the adjusted VMT data and emissions factors by vehicle category (i.e., passenger, commercial, and bus) derived from EMFAC 2021 on-road model. A summary of the Hayward previous and updated on-road VMT and associated emissions for each inventory year is provided in Table 2. On-road transportation emissions were forecasted based on 2019 data year. Reference the *Hayward Future GHG Emissions Forecast and Gap Analysis Memorandum* dated April 5, 2022 for details regarding methodology for forecasting Hayward activity data and associated GHG emissions.

Table 2 Hayward Previous and Updated On-Road VMT and Associated GHG Emissions

On-Road Total Annual VMT	2005	2010	2015	2017	2018	2019
Previous On-Road Total Annual VMT[1]	1,126,343,501	1,023,970,690	1,075,958,492	1,091,342,210	1,088,176,092	1,095,363,045
Previous On-Road Total CO_2e Emissions (MT)	630,735	576,052	577,103	568,684	550,025	547,339
Google EIE data[2]	n.d.	n.d.	n.d.	n.d.	973,250,000	942,650,000
Updated On-Road Total Annual VMT[2,3]	988,348,823	898,518,280	944,136,765	957,635,737	973,250,000	942,650,000
% Passenger Vehicles[4,5]	90.3%	90.9%	91.7%	91.2%	91.4%	91.2%

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13 Vehicle types from EMFAC 2021 are categories as passenger, commercial or buses as follows: Passenger (LDA, LDT1, LDT2, MCY, MDV, MH); Commercial (LHDT1, LHDT2, MHDT, HHDT); Buses (OBUS, SBUS, UBUS). See EMFAC 2021 technical documentation for vehicle classification definitions.

% Commercial Vehicles[4,5]	9.3%	8.7%	7.9%	8.4%	8.2%	8.2%
% Buses Vehicles[3,4,5]	0.4%	0.4%	0.4%	0.4%	0.4%	0.6%
Passenger EF (MT CO_2e/VMT)[6]	0.00042	0.00041	0.00038	0.00036	0.00035	0.00035
Commercial EF (MT CO_2e/VMT)[6]	0.00148	0.00146	0.00147	0.00144	0.00144	0.00144
Bus EF (MT CO_2e/VMT)[6]	0.00171	0.00175	0.00155	0.00150	0.00149	0.00147
Updated On-Road Total CO_2e Emissions(MT)[7]	520,768	458,988	441,751	437,514	436,005	417,862

Notes: Values in this table may not add up to totals due to rounding.
VMT = vehicle miles traveled; CO_2e = carbon dioxide equivalent; n.d. = no data available

1. VMT data in previous inventories obtained from MTC. The method that MTC uses to model VMT omits certain types of vehicles, including motorcycles, motor homes and all types of buses. Previous inventories estimated VMT from these vehicle types to ensure a more complete inventory, using data from the California Air Resources Board's EMFAC model. VMT from these omitted vehicle types were added back into the MTC VMT total.
2. VMT data for 2018 and 2019 were obtained from Google EIE where total VMT includes the Google EIE vehicle category "automobile", that encompasses passenger and commercial vehicles, and "buses" that includes all buses except AC Transit.
3. Because Google EIE data is only available for 2018 and 2019, MTC data for earlier inventory years (2005, 2010, 2015, and 2017) was calculated by scaling down original MTC modeled data for those inventory years by the average difference between Google EIE 2018 and 2019 data and 2018 and 2019 MTC data (i.e., Google EIE VMT data was ~12% lower than annual MTC VMT data for the corresponding year).
4. Percent distribution between passenger, commercial, and bus VMT was obtained from EMFAC 2021 for Alameda County for inventory years 2005, 2010, 2015, and 2017. For 2018 and 2019, the percent distribution of total VMT that was buses was obtained directly from Google EIE, whereas the remaining VMT was allocated to either passenger or commercial VMT based on the percent distribution between passenger and commercial vehicles obtained from EMFA C2021 for Alameda County.
5. Vehicle types from EMFAC 2021 are categories as passenger, commercial or buses as follows: Passenger (LDA, LDT1, LDT2, MCY, MDV, MH); Commercial (LHDT1, LHDT2, MHDT, HHDT); Buses (OBUS, SBUS, UBUS)
6. City-level data is not available from EMFA C2021 however it is assumed that county-level emission factors and vehicle class distribution is representative of the City.
7. VMT by vehicle class was determined by multiplying total adjusted VMT by % distribution by vehicle class. Emission factors by vehicle class were applied to the VMT by vehicle class and summed to calculate the updated on-road emissions total for all inventories.

Table 2 provides the updated VMT for each historic inventory year (i.e., 2005, 2010. 2015, 2017, 2018, and 2019) using Google EIE data for 2018 and 2019, and by applying the scaling factor to the original MTC VMT data for years that Google EIE data was not available (i.e., 2005, 2010. 2015, and 2017). Additionally, the table presents the updated GHG emissions for the on-road transportation sector. The original 2019 inventory VMT data resulted in GHG emission from on-road transportation comprising of 67% of Hayward's community GHG emissions, whereas with the updated VMT data for 2019 using Google EIE, on-road emissions comprised of 61% of Haywards community GHG emissions. This change is associated with the previous VMT data sourced from the MTC model likely overestimating VMT activity data for Hayward. The document *Hayward Future GHG Emissions Forecast and Gap Analysis Memorandum* dated April 5, 2022, includes additional details regarding the updated inventories for Hayward including activity data and associated GHG emissions as well as details the methodology for forecasting emissions from all sectors including the on-road transportation sector using Google EIE VMT data.

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