APPENDIX A

GHG Inventory and Forecast - Methodology and Calculations

Livermore Climate Action Plan Update

prepared for

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1 Introduction

California considers greenhouse gas emissions (GHG) emissions and the impacts of climate change to be a serious threat to the public health, environment, economic well-being, and natural resources of the state and has taken an aggressive stance to mitigate the impact of climate change at the state-level through the adoption of legislation and policies. Many cities and counties within California have developed local climate action plans and aligned goals to correspond with state emissions reduction targets. The two major state GHG emissions-related goals are established by Assembly Bill (AB) 32 and Senate Bill (SB) 32. AB 32 required state agencies reduce California GHG emissions to 1990 levels by 2020, whereas SB 32 requires a 40 percent reduction below 1990 levels by 2030. The goals set by AB 32 were achieved even earlier by the state in 2016,[1] and many California jurisdictions are completing updated GHG inventories to quantify progress toward their specific 2020 goals as well as develop targets to align with the requirements of SB 32. Additionally, Executive Order (EO) B-55-18, which was passed in 2018 by Governor Jerry Brown, establishes a goal for achieving carbon neutrality statewide by 2045. Executive Orders are only required by law for state agencies, but future climate legislation and goals are anticipated to be passed by the California legislature in the future[2].

This technical appendix to Livermore's Memorandum Detailing GHG Emissions Inventory, Forecast, and Provisional Targets for Livermore Climate Action Plan Update (2020) details the results of the GHG emissions inventories completed for Livermore (2005, 2010, 2015 and 2017) and forecasts of future GHG emissions (2020, 2025, 2030, 2035, 2040 and 2045). This technical appendix also quantifies the reduction impact that state regulations will have on Livermore's *business-as-usual forecast*[3] and presents the results in an *adjusted forecast.*[4]

This technical appendix covers GHG emissions inventories[5] prepared for 2010, 2015 and 2017 and updates made to the original 2005[6] baseline GHG inventory which was completed to fix discrepancies in the calculation methodologies and align the inventory with current standards. This allows for comparisons between all inventory years and provides accurate measurement of the City's progress towards the 2020 GHG reduction goals established in the first Livermore Climate Action Plan (CAP)[7] in 2012. All inventory years now use the most recent population, employment, and emissions factor data allowing for consistent and comparable methodologies across all inventory years and between Bay Area jurisdictions that are also using the GHG emissions inventories completed by East Bay Energy Watch (EBEW). These various inventories will assist in the

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[1] California Air Resources Board. California Greenhouse Gas Emissions Inventory. Available: https://ww3.arb.ca.gov/cc/inventory/inventory.htm. Accessed: April 14, 2020

[2] AB 2832 and SB 1362 were both introduced to the California state legislature in February 2020, which would codify the 2045 carbon neutrality target set out by Executive Order B-55-18 in 2018 into law.

[3] Forecasts emissions based on population and job growth, with no reduction measures from federal, state, or local governments.

[4] The adjusted forecast scenario incorporates expected federal, state, and local GHG reduction measures into the emissions forecast to develop a more accurate forecast of emissions through 2045.

[5] Note that all reference to inventories, forecasts, and targets in this memorandum are in reference to communitywide GHG emissions.

[6] The Updated 2005 GHG Emissions Inventory is an update of the previously prepared 2005 inventory that informed the first City CAP. This was done to use the most recent methodology, emissions factors, and data sources available, as well as for consistency between other inventory years. The original updated 2005 inventory was created by East Bay Energy Watch, and then updated by Rincon (for more information on these updates, refer to Section 2.3 of this Technical Appendix).

[7] City of Livermore. 2012. City of Livermore Climate Action Plan. Available*:* http://www.cityoflivermore.net/civicax/filebank/documents/9789/ Accessed: April 12, 2020.

preparation of the Livermore CAP Update by clearly tracking progress in specific GHG emissions sectors and to forecast future GHG emissions and develop a respective GHG target gap analyses that will assist in developing CAP Update policies structured to achieve Livermore's GHG emissions targets.

1.1 Regulatory Background

The state of California has adopted a variety of legislation and policies to mitigate and adapt to the effects of climate change. This includes legislation that sets clear targets for the state reducing GHG emissions which cause climate change, as well as directing state agencies such as the California Air Resources Board (CARB) to develop implementation plans for achieving these targets. The most relevant of the climate legislation passed in California are summarized below.

- **Executive Order S-3-05 (2005),** signed by former Governor Schwarzenegger in 2005, establishes statewide GHG emissions reduction goals to achieve long-term climate stabilization as follows: by 2020, reduce GHG emissions to 1990 levels and by 2050, reduce GHG emissions to 80 percent below 1990 levels. The 2050 goal was accelerated by the 2045 carbon neutral goal established by Executive Order (EO) B-55-18, as discussed below.[8]
- **Assembly Bill 32 (2006),** known as the Global Warming Solutions Act of 2006, requires California's GHG emissions be reduced to 1990 levels by the year 2020 (approximately a 15 percent reduction from 2005 to 2008 levels). The AB 32 Climate Change Scoping Plan, first published in 2008, identifies mandatory and voluntary measures to achieve the statewide 2020 emissions limit, and encourages local governments to reduce municipal and community GHG emissions proportionate with state goals.[9]
- **Climate Change Scoping Plan (2008),** the original California Climate Change Scoping Plan, includes measures to address GHG emissions reduction strategies related to energy efficiency, water use, and recycling and solid waste, among other measures. Many of the GHG reduction measures included in the Scoping Plan (e.g., Low Carbon Fuel Standard, Advanced Clean Car standards, and Cap-and-Trade) have been adopted and implemented since approval of the Scoping Plan.
- **Climate Change Scoping Plan Update (2013),** the first update to the California Climate Change Scoping Plan, defines CARB climate change priorities for the next five years and set the groundwork to reach post-2020 statewide GHG emissions reduction goals. The Scoping Plan Update highlighted California's progress toward meeting the 2020 GHG emissions goals defined in the original Scoping Plan. The Plan Update also evaluated how to align the state's longer-term GHG reduction strategies with other state policy priorities, including those for water, waste, natural resources, clean energy, transportation, and land use.
- **Executive Order B-30-15 (2015)**, establishes statewide GHG emissions reduction goals of reducing GHG emissions to 40 percent below 1990 levels by 2030.
- **Senate Bill 32 (2016),** signed by former Governor Brown in 2016, establishes a statewide mid-term GHG reduction goal of 40 percent below 1990 levels by 2030.

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[8] Executive Orders are binding only unto State agencies. Accordingly, EO S-03-05 will guide State agencies' efforts to control and regulate GHG emissions but will have no direct binding effect on local government or private actions.

[9] Specifically, the AB 32 Climate Change Scoping Plan states CARB, "encourages local governments to adopt a reduction goal for municipal operations emissions and move toward establishing similar goals for community emissions that parallel the State commitment to reduce GHG emissions by approximately 15 percent from current levels by 2020" (p. 27). "Current" as it pertains to the AB 32 Climate Change Scoping Plan is commonly understood as between 2005 and 2008.

- **Second Climate Change Scoping Plan (2017),** formally adopted by CARB in December 2017, updated the state Scoping Plan to include the GHG reduction goal of 40 percent below 1990 levels by 2030 set forth by SB 32. The Scoping Plan outlines the roadmap to achieve this goal and gives guidance on how to achieve substantial progress towards 2050 state goals.
- **Executive Order B-55-18 (2018),** signed by former Governor Brown in 2018, expanded upon EO S-3-05 by creating a statewide GHG goal of carbon neutrality by 2045. EO B-55-18 identifies CARB as the lead agency to develop a framework for implementation and progress tracking toward this goal in the next Climate Change Scoping Plan Update, which is expected in 2021 or 2022.

CEQA Guidelines Section 15183.5

The California Environmental Qualified Act (CEQA) has established specific requirements for climate action plans to qualify for project specific CEQA analysis streamlining. According to CEQA Guidelines Section 15183.5, project-specific environmental documents can tier from, or incorporate by reference, the existing programmatic review in a qualified GHG emissions reduction plan, which allows for project-level evaluation of GHG emissions through the comparison of the project's consistency with the GHG emissions reduction strategy included in the qualified GHG emissions reduction plan. To meet the requirements of CEQA Guidelines Section 15183.5, a qualified GHG emissions reduction plan must include the following:

1. Quantify existing and projected GHG emissions within the plan area;
2. Establish a level, based on substantial evidence, below which the contribution to GHG emissions from activities covered by the plan would not be cumulatively considerable;
3. Identify and analyze sector specific GHG emissions within the plan's geographic area;
4. Specify measures or a group of measures, including performance standards, that if implemented, would collectively achieve the specified emissions level;
5. Establish a tool or mechanism to monitor progress and to require amendment if the plan is not achieving specified levels; and
6. Be adopted in a public process following environmental review.

The state of California, via CARB, has issued several guidance documents concerning the establishment of GHG emissions reduction targets for local climate action plans to comply with legislated GHG emissions reductions goals and CEQA Guidelines Section 15183.5(b). In the first California *Climate Change Scoping Plan,*[10] CARB encouraged local governments to adopt a reduction target for community emissions paralleling the state commitment to reduce GHG emissions. In 2016, the state adopted SB 32 mandating a reduction of GHG emissions by 40 percent from 1990 levels by 2030 and in 2017 CARB published *California's 2017 Climate Change Scoping Plan* (hereafter referred to as the Scoping Plan Update) outlining the strategies the state will employ to reach these targets.[11] With the release of the Scoping Plan Update, CARB recognized the need to balance population growth with emissions reductions and in doing so, provided a new methodology for proving consistency with state GHG reduction goals through the use of per capita efficiency targets.

[10] California Air Resources Board. 2008. Climate Change Scoping Plan. Available: https://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf. Accessed: April 16, 2020

[11] California Air Resources Board. California's 2017 Climate Change Scoping Plan. Accessed at: https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf. Accessed: April 16, 2020

These targets are generated by dividing a jurisdiction's GHG emissions for each horizon year by the jurisdiction's total population for that target year and are discussed further in Section 5.

1.2 Greenhouse Gas Emissions Inventory Introduction

The Livermore GHG emissions inventories serve to detail progress towards Livermore's GHG emissions reduction targets. Each inventory provides the total community GHG emissions in carbon dioxide equivalents (CO_2e).[12] Data for 2005, 2010, 2015, and 2017 inventories was originally gathered by EBEW and then reviewed and updated by Rincon for consistency with the latest methodology available in the International Council for Local Environmental Initiative (ICLEI) U.S. Community Protocol[13] and California Supplement[14]. In order to maintain consistency across all years, the updated 2005 inventory will replace the existing 2005 baseline inventory used in Livermore's 2012 CAP. Changes to the 2005 inventory methodology include adding emissions from the water and wastewater inventory sectors and removal of the Bay Area Rapid Transit (BART) emissions, because the City of Livermore does not have direct control over BART and is unable to reduce these emissions and because reliable BART data was not available for the subsequent inventories.

Emissions for each inventory year were calculated using the principles and methods from these protocols. Emissions from nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2) are included in this assessment. Each GHG has a different capability of trapping heat in the atmosphere, known as its global warming potential (GWP), which is normalized relative to CO_2 and expressed as carbon dioxide equivalent, or CO_2e. The CO_2e values for these gases are derived from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change GWP values for consistency with the yearly CARB GHG inventory, as shown in Table 1.[15,16]

Table 1 Global Warming Potentials of Greenhouse Gases

Greenhouse Gas	Molecular Formula	Global Warming Potential (CO_2e)
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265

MT CO_2e: metric tons of carbon dioxide equivalent

[12] Carbon dioxide equivalent is a term for describing GHG emissions in a common unit, signifying for any GHG the amount of CO_2 that would have the equivalent global warming impact. The equivalent amount of CO_2 is calculated based on the GHG global warming potential value.

[13] ICLEI. 2012. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Available: <https://icleiusa.org/publications/us-community-protocol/>. Accessed: April 23, 2020.

[14] Association of Environmental Professionals. 2013. The California Supplement to the United States Communitywide GHG Protocol. Available: <https://califaep.org/docs/California_Supplement_to_the_National_Protocol.pdf>. Accessed: April 23, 2020.

[15] Intergovernmental Panel on Climate Change. 2014. Fifth Assessment Report: Climate Change. Direct Global Warming Potentials.

[16] All calculations use Intergovernmental Panel on Climate Change Fifth Assessment Report GWP values.

Greenhouse Gas Emissions Sectors

Each of the community inventories for the City of Livermore include estimated emissions for the following sectors:

- Energy (electricity, natural gas, direct access electricity)
- On-road Transportation (passenger, commercial)
- Off-road Transportation
- Waste (solid waste, alternative daily cover)
- Water
- Wastewater (direct, indirect)

Excluded Emissions

The following emissions sectors were excluded from Livermore's 2012 CAP baseline inventory for 2005 and are also excluded from the updated 2005, 2010, 2015, and 2017 inventories. Additional updates were also made to the 2005, 2010, and 2015 inventories in order to maintain consistent sources and emissions factors between all inventory years. These changes are summarized in Sections 2.2 and 2.3.

Consumption-based Emissions

GHG emissions from consumption of goods within the city are excluded from the inventory and forecast of future emissions. Consumptive based inventories for municipal jurisdiction are a relatively new the climate planning practice and standardized factors and methodologies are currently being developed. Without consistent methods, factors and established boundaries, the data provided from these inventories is limited and could negatively impact a jurisdictions ability to detail their progress with future GHG reductions.

Natural and Working Lands Emissions

GHG emissions from carbon sinks and sources in natural and working lands are not included in this inventory and forecast due to the lack the specific data necessary to estimate their contribution to the jurisdictions overall GHG emissions. CARB has included a state-level inventory of natural and working lands in the 2017 Scoping Plan Update[17] GHG inventory; however, at the time of this City of Livermore community-wide inventory, sufficient data was not available to conduct a jurisdiction-specific working lands inventory. CARB has developed the Natural and Working Lands Implementation Plan[18] and the Nature Conservancy and California Department of Conservation[19] have developed an inventory tool (TerraCount) which may be able to perform these inventories for Alameda County.

[17] California Air Resources Board. 2017. California's Climate Change Scoping Plan Update.

[18] California Air Resources Board. 2019. California 2030 Natural and Working Lands Climate Change Implementation Plan. Available: https://ww2.arb.ca.gov/sites/default/files/2019-06/draft-nwl-ip-040419.pdf. Accessed: April 12, 2020.

[19] California Department of Conservation. TerraCount Scenario Planning Tool. Accessed: https://maps.conservation.ca.gov/terracount/. Accessed: April 6, 2020.

Agricultural Emissions

Emissions from agricultural activities are not included in this inventory as the Community Protocol and California Supplement[20] both note agricultural activity is not a required component of Community Protocol inventories and should be included only if relevant to the community conducting the inventory. Agricultural emissions are generally inventoried at a County scale, and data is difficult to allocate to local municipal jurisdictions. Regulations exist to encourage urban agriculture within the City boundaries. Many of the emissions from these activities (e.g. energy) are covered under other sectors included in this inventory and no major commercial-scale livestock activity is noted within the city boundaries.

High GWP Emissions

High GWP emissions, including chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs) used as substitutes for ozone-depleting substances are not included in this inventory as it is not a required component of the Community Protocol and the California Supplement notes these emissions are not generally included in California inventories, including in Livermore. Furthermore, many of these emissions are from industrial manufacturing sources and are already accounted for in the California Cap-and-Trade program.

[20] Association of Environmental Professionals. 2013. The California Supplement to the United States Community-Wide Greenhouse Gas (GHG) Emissions Protocol. Available: https://califaep.org/docs/California_Supplement_to_the_National_Protocol.pdf. Accessed: April 8, 2020.

2 Previous GHG Emissions Inventories

2.1 1990 Reference-Year Inventory

The state of California uses 1990 as a reference year to remain consistent with AB 32 and SB 32, which codified the state's 2020 and 2030 GHG emissions targets by directing CARB to reduce statewide emissions to 1990 levels by 2020 and 40 percent below 1990 levels by 2030. The City of Livermore's initial inventory was conducted for the year 2005. The state indicated in the first Climate Change Scoping Plan in 2008 that local governments wishing to remain consistent with state targets could use a 15 percent reduction from 2005-2009 levels as a proxy for a 1990 baseline.[21] The updated 1990 proxy baseline used for target setting by the City of Livermore is 610,604 MT CO_2e.[22]

2.2 2005 Baseline Inventory

In 2008, Livermore collaborated with ICLEI to develop a 2005 community GHG emissions inventory. The 2005 inventory quantified community emissions and forecast business-as-usual (BAU) conditions to 2020 based on expected population, employment, and growth. It included emissions from the residential energy, commercial/industrial energy, on-road transportation (using data from the Metropolitan Transportation Commission (MTC) for VMT data), and waste sectors. This inventory was used to inform the development of the City's General Plan Climate Change Element, which includes a goal to reduce GHG emissions by 15% below 2008 levels by 2020.

In 2010, ICF International updated this 2005 inventory to include additional sectors (referred to here as the 2012 CAP baseline inventory), developed an estimate of 2008 emissions based on the 2005 inventory, and updated the 2020 forecast using current socioeconomic factors. The 2012 CAP baseline inventory added emissions from water consumption and wastewater treatment and utilized the Alameda County CMA Travel Demand Model (now known as Alameda CTC) for VMT estimates. These changes led to an overall 40% decrease in GHG emissions for the 2005 baseline inventory year compared to the original 2005 inventory completed by ICLEI.

The 2012 CAP baseline inventory was updated again by Rincon as part of this current 2020 inventory and forecast effort for the CAP Update, using the most recent methodology, data, and emissions factors. As part of the CAP Update, GHG inventories for 2010, 2015, and 2017 that were originally developed by East Bay Energy Watch in 2019 were also updated by Rincon (see Section 2.3 below for more details on changes made by Rincon to these inventories).

Table 2 compares changes in emissions by sector between the original 2012 CAP baseline inventory and the updated CAP Update 2005 inventory. Overall, emissions in the updated CAP 2005 inventory increased by 5 percent, mainly due to an increase in emissions from the off-road transportation sector.

[21] Due to lack of 1990 inventory data for local governments, page 27 of the 2008 Climate Change Scoping Plan identifies 15 percent below "current" (2005-2008) levels by 2020 as consistent with the State goals of 1990 levels by 2020, allowing local governments to back-cast to develop 1990 baselines for future GHG reduction targets.

[22] Calculated using updated 2005 CAP 2.0 inventory created by EBEW and completed by Rincon.

Table 2 GHG Emissions Comparison Between the 2012 CAP Baseline Inventory and the CAP Update 2005 Inventory

Sector	2012 CAP Baseline GHG Emissions (MT CO_2e)[23]	CAP Update Updated 2005 GHG Emissions (MT CO_2e)	Percent Change
Residential Energy[1]	121,572	120,961	-0.50%
Nonresidential Energy[1]	104,183	95,643	-8.20%
Direct Access Electricity	N/A[2]	15,192	+100%
On-road Transportation	147,327	353,319	+139.82%
Off-road Transportation	N/A[2]	88,179	+100%
Solid Waste Disposal	32,783	38,495	-17.42%
Water and Wastewater	6,072	6,567	-8.15%
Municipal Operations	7.095	N/A[3]	-100%
Total	**411,937**	**718,358**	**+74.39%**

kWh: kilowatt hours; mgy: million gallons per year; N/A: not applicable; MT CO_2e: metric tons of carbon dioxide equivalent; VMT: vehicle miles traveled

[1] The electricity and gas sectors were not separated in the 2005 CAP inventory.

[2] Direct access electricity data not separated from nonresidential electricity in inventory. Off-road emissions not included.

[3] Municipal operations are a subset of community emissions in the updated 2005 CAP Update inventory and were not calculated separately.

2.3 Summary of 2005, 2010, 2015, and 2017 East Bay Energy Watch Inventories

In 2019, East Bay Energy Watch (EBEW) developed GHG inventories for jurisdictions across the Bay Area. GHG inventories for 2005, 2010, 2015, and 2017 were established for the City of Livermore as part of this effort (referred to from here as the EBEW inventories). Although the EBEW inventories use slightly different methodologies than the 2005 inventory, due to the availability of data, the consistency of the new methodology between all inventory years and between other local jurisdictions, and the use of the most recent emissions factors and data sources, the City has adopted the EBEW inventories and will incorporate updated versions into the CAP process.

Several updates were performed by Rincon as part of the current effort to adjust the EBEW inventories to create a consistent methodology across the 2005, 2010, 2015, and 2017 inventories. These included adding natural gas emissions from the industrial sector in 2015 and 2017 (due to the data being unavailable from PG&E reporting due to CPUC energy data access rules[24]), adding activity and emissions data for both water and wastewater sectors into the inventories, and updating off-road transportation sector emissions calculations to utilize the most recently available data.

The following section outlines the changes made to the EBEW inventories for consistency with the ICLEI U.S. Community Protocol[25] and inventory years.

23 Original 2005 CAP 1.0 inventory here refers to the 2012 CAP 1.0 inventory, which had previously been updated from ICLEI's 2005 inventory (completed in 2008 for use in Livermore's 2012 CAP 1.0).

24 California Public Utilities Commission Decision (D.14-05-016) establishes the Data Request and Response Process, a protocol for investor owned utilities to follow when providing customer usage data to eligible third-party requesters.

25 ICLEI. 2013. U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions, Version 1.1.

Natural Gas

When examining the available PG&E natural gas data for Livermore (obtained via PG&E's Green Communities portal) it was determined that an unknown, large natural gas facility came online in Livermore between 2011 and 2012 and triggered the CPUC 15-15 rule[26] starting in 2014. This prevented PG&E from reporting industrial natural gas emissions in 2015 and 2017 as a part of the data request for Livermore's energy data, which was listed as 'Fail-Dropped'. In other years, industrial natural gas emissions were included with commercial emissions.

To allow for accurate comparison and better consistency of energy sector emissions between all four EBEW inventory years, however, the calculated activity data from Lawrence Livermore National Lab (LLNL) was added into the nonresidential natural gas sector for 2015 and 2017 to account for industrial natural gas emissions. CARB reports Cap-and-Trade emissions data to the public as a part of California's Regulations for the Mandatory Reporting of Greenhouse Gases[27], which covers all entities that emit over 10,000 MT CO_2e in a given year. Rincon examined this data for large facilities in Livermore to determine the source of the large increase in natural gas usage. By comparing Cap-and-Trade data to the available PG&E data, it was determined that LLNL, which began reporting as a part of the Cap-and-Trade program in 2012, was largely responsible for the new natural gas usage. This was confirmed by calculating the activity data for LLNL's emissions, using the calculated emissions factor for PG&E natural gas[28], which matched the increase in natural gas usage shown in Livermore's PG&E data for 2012 and 2013.

Other industrial emissions were not added into the inventories, as they are under the purview of the CARB Cap-and-Trade Program for emissions reductions and are, therefore, already accounted for in the 2017 Scoping Plan Update. The California Supplement does not recommend including these sources unless they are under the direct jurisdictional control of the reporting agency.[29]

Direct Access Electricity

Direct Access is an option that allows eligible customers to purchase their electricity directly from third party Electric Service Providers. Direct access electricity[30] was not reported by PG&E for the 2017 reporting year due to the CPUC's data access rules, specifically what is known as the 15-15 rule. It was determined by examining the available PG&E data for Livermore (obtained via PG&E's Green Communities portal) that direct access electricity users triggered the 15-15 rule in 2017. This prevented PG&E from reporting 2017 direct access electricity activity data as part of the data request for Livermore's energy data. In all other years, including the 2005, 2010, and 2015 inventory years, this direct access electricity data was reported.

To allow for accurate comparison of energy sector emissions between inventory years, direct access electricity usage and emissions were estimated for 2017. This was done by using the average ratio

[26] The 15/15 rule states no data can be provided if there are less than 15 users in any sector or if one user makes up more than 15 percent of the total usage. This applies to natural gas and electricity consumption.

[27] Cap-and-Trade emissions data obtained from the California Air Resource Board's Mandatory Reporting of Greenhouse Gas (MRR) data portal. Available: https://ww2.arb.ca.gov/mrr-data. Accessed May 7, 2020.

[28] Emissions factor for natural gas = .00531051, as calculated and used in the 2017 baseline inventory and GHG forecast for CAP 2.0. See Section 3.1 for more details on energy emissions factors.

[29] Association of Environmental Professionals. 2013. The California Supplement to the United States Community-Wide Greenhouse Gas (GHG) Protocol. Page 10.

[30] Direct access electricity is retail electric service where customers purchase electricity from a competitive provider called an Electric Service Provider (ESP), instead of from a regulated electric utility. An ESP is a non-utility entity that offers electric service to customers within the service territory of an electric utility. The utility delivers electricity that the customer purchases from the ESP to the customer over its distribution system.

of direct access electricity usage to commercial electricity based off 2015 and 2016, the closest available years with data. Direct access electricity usage was estimated in this way for 2017 also to provide direct access electricity emissions across all four inventory years.

Water and Wastewater

The EBEW inventories did not include data or emissions from water or wastewater, which are standard sectors in the ICLEI U.S. Community Protocol. Activity data for these sectors was obtained from the City in April 2020 for 2005, 2010, 2015, and 2017, and added into the inventories for all years. Water data was provided in millions of gallons supplied by CalWater and Livermore Municipal Water, and emissions were calculated by determining the amount of electricity used as a part of processing and distribution[31], and multiplying by PG&E emissions factors for electricity. Wastewater data was provided in millions of gallons from the Livermore Water Reclamation Plant, and emissions were calculated using the following ICLEI Community Protocol methods (determined based on facility information gathered by Rincon): WW.2, WW.8, and WW.12. For more detail on these calculations, see Section 3.3.

BART

The EBEW inventories originally included emissions from Bay Area Rapid Transit (BART). It was decided by Rincon and City staff to ultimately remove these emissions from the four EBEW inventory years (2005, 2010, 2015, and 2017). This was due to a lack of emissions data available for years after 2013, which prevented emissions from being accurately calculated and forecasted. Additionally, all four inventory years originally used the same emissions factor, calculated based off of 2013 data, leading to inaccurate estimation of emissions. The City of Livermore ultimately does not have control over reducing these emissions, and BART already has its own GHG emissions reduction goals in place over the next decade. These emissions also represented a small percentage of Livermore's overall emissions (0.22% in 2017). For these reasons, these emissions were ultimately removed.

Off-road Transportation

The EBEW inventories originally calculated GHG emissions from off-road equipment using the CARB OFFROAD2007 model. In late 2021, CARB released OFFROAD2021 as a replacement for previous off-road inventory models, which included more up-to-date off-road equipment inventories and activity estimates.[32] Rincon updated the 2005, 2010, 2015, and 2017 inventories to use off-road transportation activity data from the CARB OFFROAD2021 model database.

[31] Electricity usage was determined via methods outlined in the California Energy Commission's Refining Estimates of Water-related Energy Use in California, 2006. https://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF.

[32] CARB. 2021. Mobile Source Emissions Inventory – Modeling Tools. https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/msei-modeling-tools.

Summary of GHG Inventory Data by Year

A summary of emissions for the 2005, 2010, 2015, and 2017 GHG inventories by sector for Livermore can be found below in Table 3, as well as back-casted emissions for 1990.

Table 3 Livermore GHG Inventories Emissions Summary

Sector	1990[1] (MT CO_2e)	2005 (MT CO_2e)	2010 (MT CO_2e)	2015 (MT CO_2e)	2017 (MT CO_2e)
Residential Electricity	42,349	49,822	44,872	37,602	19,775
Residential Gas	60,468	71,139	72,206	61,334	65,896
Nonresidential Electricity	55,991	65,872	55,902	52,865	27,836
Nonresidential Gas	25,305	29,771	29,075	52,236	57,462
Direct Access Electricity	12,913	15,192	8,075	9,734	6,545
On-Road Transportation	300,322	353,320	312,355	325,691	314,154
Off-Road Transportation	10,246	12,055	14,061	17,394	18,002
Waste	32,721	38,495	24,315	20,859	23,052
Wastewater	1,604	1,887	1,809	1,661	1,366
Water	3,978	4,680	3,860	2,400	1,479
Total Emissions	**545,898**	**642,233**	**566,530**	**581,776**	**535,567**
Emissions per capita	9.62	8.23	7.00	6.72	5.92

$MTCO_2e$: metric tons of carbon dioxide equivalent

[1] All 1990 inventory data calculated as a 15 percent reduction from CAP 2.0 2005 inventory levels per California Air Resources Board Scoping Plan. The original 2012 CAP used this same methodology for calculating 1990 emissions, although a 2008 inventory was developed as a baseline.

[2] Includes emissions from direct access electricity.

[3] Nonresidential natural gas emissions adjusted to include estimated emissions from industrial sources, which were not reported by PG&E due to CPUC privacy rules.

The updated activity data, emissions factors, and total emissions for the 2005, 2010, 2015, and 2017 inventories for Livermore are summarized below in Table 4, Table 5, Table 6, and Table 7. All of the inventory years utilize the same methodology, except for changes made to the original EBEW inventories by Rincon to specific inventory years (as identified in this section).

Table 4 Livermore 2005 GHG Inventory Data

	Activity Data	Emissions Factors	Emissions ($MT\ CO_2e$)
Residential Electricity (kWh)	223,251,790	0.000223	49,822
Residential Gas (therms)	13,395,923	0.00531	71,139
Nonresidential Electricity (kWh)	295,174,279	0.000223	65,872
Nonresidential Gas (therms)	5,606,070	0.00531	29,771
Direct Access Electricity (kWh)	39,378,526	0.000386	15,192
Passenger On-road Transportation (VMT)	548,153,828	0.000399	218,684
Commercial On-Road Transportation (VMT)	91,610,896	0.00147	134,636
Off-Road – Diesel (Gallons)	600,655	0.0103	6,212
Off-Road – Gasoline (Gallons)	338,135	0.00905	3,062
Off-Road – NG/LPG (Gallons)	477,673	0.00582	2,780
BART (Passenger Miles)	Removed	Removed	Removed
Solid Waste (tons)	119,384	0.293	35,008
Alternative Daily Cover Waste (tons)	14,193	0.246	3,487
Wastewater (mgy)	2,640	0.000223	1,887
Water (mgy)	5,879	0.000223	4,680
Total			**642,233**

kWh: kilowatt hours; mgy: million gallons per year; N/A: not applicable; MT CO_2e: metric tons of carbon dioxide equivalent; VMT: vehicle miles traveled; NG: natural gas; LPG: liquefied petroleum gas

Table 5 Livermore 2010 GHG Inventory Data

	Activity Data	Emissions Factors	Emissions (MT CO_2e)
Residential Electricity (kWh)	221,110,304	0.000203	44,872
Residential Gas (therms)	13,596,747	0.00531	72,206
Nonresidential Electricity (kWh)	275,465,613	0.000203	55,902
Nonresidential Gas (therms)	5,475,062	0.00531	29,075
Direct Access Electricity (kWh)	28,367,259	0.000285	8,075
Passenger On-road Transportation (VMT)	493,823,032	0.000391	193,056
Commercial On-Road Transportation (VMT)	80,288,169	0.00149	119,299
Off-Road – Diesel (Gallons)	777,146	0.0103	8,038
Off-Road – Gasoline (Gallons)	344,849	0.00905	3,123
Off-Road – NG/LPG (Gallons)	498,303	0.00582	2,900
BART (Passenger Miles)	Removed	Removed	Removed
Solid Waste (tons)	65,600	0.296	19,430
Alternative Daily Cover Waste (tons)	19,881	0.246	4,885
Wastewater (mgy)	2,586	0.000203	1,809
Water (mgy)	5,324	0.000203	3,860
Total			**566,528**

kWh: kilowatt hours; mgy: million gallons per year; N/A: not applicable; MT CO_2e: metric tons of carbon dioxide equivalent; VMT: vehicle miles traveled; NG: natural gas; LPG: liquefied petroleum gas

Table 6 Livermore 2015 GHG Inventory Data

	Activity Data	Emissions Factors	Emissions ($MT\ CO_2e$)
Residential Electricity (kWh)	203,689,656	0.000185	37,602
Residential Gas (therms)	11,549,521	0.00531	61,334
Nonresidential Electricity (kWh)	286,367,883	0.000185	52,865
Nonresidential Gas (therms)[1]	9,836,396	0.00531	52,236
Direct Access Electricity (kWh)	32,760,434	0.000297	9,734
Passenger On-road Transportation (VMT)	534,438,400	0.000355	189,523
Commercial On-Road Transportation (VMT)	95,769,686	0.00142	136,168
Off-Road – Diesel (Gallons)	1,061,791	0.0103	10,982
Off-Road – Gasoline (Gallons)	362,052	0.00905	3,278
Off-Road – NG/LPG (Gallons)	538,354	0.00582	3,134
BART (Passenger Miles)	Removed	Removed	Removed
Solid Waste (tons)	65,091	0.286	18,619
Alternative Daily Cover Waste (tons)	9,118	0.246	2,240
Wastewater (mgy)	2,179	0.000185	1,661
Water (mgy)	3,708	0.000185	2,400
Total			**581,777**

kWh: kilowatt hours; mgy: million gallons per year; N/A: not applicable; MT CO_2e: metric tons of carbon dioxide equivalent; VMT: vehicle miles traveled; NG: natural gas; LPG: liquefied petroleum gas

[1] Data for 2015 industrial natural gas was unavailable due to the CPUC's 15-15 privacy rule. Emissions from industrial natural gas for 2015 were estimated using reported emissions from the Livermore Lawrence National Laboratory as a part of California's Cap-and-Trade program.

Table 7 Livermore 2017 GHG Inventory Data

	Activity Data	Emissions Factors	Emissions ($MT\ CO_2e$)
Residential Electricity (kWh)	205,232,521	0.000096	19,775
Residential Gas (therms)	12,408,537	0.00531	65,896
Nonresidential Electricity (kWh)	288,894,815	0.000096	27,836
Nonresidential Gas (therms) [1]	10,820,445	0.00531	57,462
Adjusted Direct Access Electricity (kWh)[2]	32,283,926	0.000203	6,545
Passenger On-road Transportation (VMT)	538,932,050	0.000338	181,900
Commercial On-Road Transportation (VMT)	96,824,903	0.001422	132,254
Off-Road – Diesel (Gallons)	1,104,596	0.0103	11,425
Off-Road – Gasoline (Gallons)	371,061	0.00905	3,360
Off-Road – NG/LPG (Gallons)	552,683	0.00582	3,217
BART (Passenger Miles)	Removed	Removed	Removed
Solid Waste (tons)	73,437	0.286	21,006
Alternative Daily Cover Waste (tons)	8329	0.246	2046
Wastewater (mgy)	2,132	0.000096	1,366
Water (mgy)	4,378	0.000096	1,479
Total			**535,566**

kWh: kilowatt hours; mgy: million gallons per year; N/A: not applicable; $MT\ CO_2e$: metric tons of carbon dioxide equivalent; VMT: vehicle miles traveled

[1] Data for 2017 industrial natural gas was unavailable due to the CPUC's 15-15 privacy rule. Emissions from industrial natural gas for 2017 were estimated using reported emissions from the Livermore Lawrence National Laboratory as a part of California's Cap-and-Trade program.

[2] Data for 2017 direct access electricity was unavailable due to the CPUC's 15-15 privacy rule. Emissions from direct access electricity for 2017 were estimated using the average ratio of direct access electricity to commercial electricity between 2015 and 2016.

3 2017 GHG Emissions Inventory

The methodologies, data sources, calculations, and results associated with the Livermore community-wide 2017 GHG emissions inventory update are included in this section. This section focuses on the 2017 inventory since it is the most recent inventory, but the methodologies used for the 2017 inventory were also utilized for the 2005, 2010, and 2015 inventories. The 2017 Livermore GHG emissions inventory serves as the inventory to inform development of future GHG emissions forecasts that will assist the City in setting GHG emissions targets that are consistent with state-level goals and the Livermore General Plan 2003-2025.

The 2017 GHG inventory is structured based on emissions sectors. The ICLEI Community Protocol recommends local governments examine their emissions in the context of the sector responsible for those emissions. Many local governments will find a sector-based analysis more directly relevant to policy making and project management, as it assists in formulating sector-specific reduction measures for climate action planning. The reporting sectors are made up of multiple subsectors to allow for easier identification of sources and targeting of reduction policies.

The 2017 inventory reports all Basic Emissions Generating Activities[33] required by the Community Protocol[34] by the following main sectors:

- Energy (electricity and natural gas)
- Transportation
- Water and Wastewater
- Solid Waste

The data used to complete this inventory and forecast came from multiple sources, as summarized in Table 8. Data for the 2017 water and wastewater sector calculations were provided by the City via personal communication with Tricia Pontau.

[33] Required emissions generating activities include: use of electricity by the community, use of fuel in residential and commercial stationary combustion equipment, on-road passenger and freight motor vehicle travel, use of energy in potable water and wastewater treatment and distribution, and generation of solid waste by the community.

[34] ICLEI. 2012. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Section 2.2.

Table 8 Inventory and Forecast Data Sources

Sector	Activity Data	Unit	Source
Inventory			
Energy	Electricity Consumption Natural Gas Consumption	kWh Therms	Pacific Gas and Electric; CARB Mandatory GHG Reporting (Cap-and-Trade)
On-road Transportation	Annual Mileage	VMT	Metropolitan Transportation Commission Vehicle Miles Traveled Data Portal; EMFAC2017 Model
Off-road Transportation	Annual Fuel Consumption	Gallons	OFFROAD2021 Model
Water	Water Pumping Electricity Usage	AF kWh	Tricia Pontau; Livermore Municipal Water; California Water Service
Wastewater	Electricity Consumption, Water Treated	kWh MGD	Tricia Pontau; Community Protocol Estimates; Livermore Water Reclamation Plant
Solid Waste	N/A	N/A	CalRecycle; California Air Resources Board Landfill Emissions Tool Version 1.3
Forecast Growth Indicators			
Population	Residents	Persons	California Department of Finance E4 and E5 demographic datasets; Association of Bay Area Governments Plan Bay Area Projections 2040
Commerce	Jobs	Number of Jobs	California Department of Finance E4 and E5 demographic datasets; U.S. Census OnTheMap tool; Association of Bay Area Governments Plan Bay Area Projections 2040
Transportation	Annual Mileage, Emissions	N/A	EMFAC2017 Model; Metropolitan Transportation Commission Vehicle Miles Traveled Data Portal
Off-road Transportation	Annual Fuel Consumption	Gallons	OFFROAD2021 Model
Building Efficiency	Title 24 Efficiency Increases	Percent	California Energy Commission
Electricity Emissions	Renewable Portfolio Standard	Percent	Renewable Portfolio Standard; Senate Bill 100

kWh; kilowatt hours; VMT: vehicle miles traveled; AF: acre-foot; MGD: million gallons per day; N/A: not applicable;

GHG Inventory data was originally gathered by EBEW and then reviewed and updated by Rincon for consistency with the latest methodology available in the Community Protocol[35] and California Supplement[36]. The updated 2005 GHG Inventory added emissions from the water and wastewater inventory sectors and removed the Bay Area Rapid Transit (BART) emissions, because the City of Livermore does not have direct control over BART and is unable to reduce these emissions and because BART data was not available for the subsequent inventories. Information regarding updates to the original EBEW 2005, 2010, 2015, and 2017 inventories is in Section 2.3 and information relating to the emissions forecast are located in Section 4 of this technical appendix.

[35] ICLEI. 2012. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Available: <https://icleiusa.org/publications/us-community-protocol/>. Accessed: April 23, 2020.

[36] Association of Environmental Professionals. 2013. The California Supplement to the United States Communitywide GHG Protocol. Available: <https://califaep.org/docs/California_Supplement_to_the_National_Protocol.pdf>. Accessed: April 23, 2020.

3.1 Energy Emissions

The energy sector includes GHG emissions resulting from the consumption of electricity and natural gas. Both energy sources are used in residential and nonresidential (commercial and industrial) buildings and for other power needs throughout the City of Livermore. The following subsections describe the data sources, emissions factors and calculation methodologies associated with electricity and natural gas.

Overall, residential energy emissions were about equal to non-residential (commercial and industrial) in their contribution to energy emissions in 2017, at approximately 50.11 percent and 49.89 percent respectively, as shown in Figure 1. It should be noted that, due to data availability issues in reporting years after 2013, large industrial gas data was not provided by PG&E and was instead estimated for 2015 and 2017 to allow for more accurate comparisons between inventory. Direct access electricity usage was also estimated for 2017 as data from PG&E was not available. Additional information on why this change was made as well as the methodologies used to estimate 2017 commercial gas data are provided in Section 2.3.

Electricity

Emissions resulting from electricity consumption were estimated by multiplying annual electricity consumed by an emissions factor representing the average emissions associated with generation of one megawatt hour (MWh) of electricity. Electricity is supplied to the City by PG&E. In its 2017 report to the verification body, The Climate Registry, PG&E reported an electricity carbon intensity factor of 210 pounds CO_2e per MWh.[37] PG&E also reported to the California Energy Commission, an average of 33 percent renewable energy in its portfolio in 2017.[38] From 2005, residential electricity use decreased by 18,019 MWh while nonresidential electricity decreased by 6,279 MWh for a total net decrease of 24,298 MWh. Therefore, the 83,275 MT CO_2e reduction in GHG emissions from electricity between 2005 and 2017 was due to a decrease in electricity usage and an approximately 57 percent reduction in the PG&E electricity emissions factor.

In 2017, a total 47,611 $MTCO_2e$ was generated within the community due to residential and commercial electricity use. Table 7 show the breakdown of emissions from electricity by both category (residential, nonresidential) and by source.

Direct access electricity was also calculated using the same methodology, but with a calculated emissions factor of 0.203 MT CO_2e/MWh. This is equivalent to the California state grid (CAMX) average carbon intensity of electricity (reported by the California Energy Commission), as direct access electricity is not provided by PG&E.[39] Direct access electricity data was not provided by PG&E due to CPUC privacy regulations, and so was estimated based off the average of 2015 and 2016 direct access activity data. Direct access electricity accounted for 32,284 MWh of electricity use in 2017, which resulted in 6,545 MT CO_2e of emissions.

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[37] The Climate Registry. 2019 Default Emissions Factors. Available: https://www.theclimateregistry.org/wp-content/uploads/2019/05/The-Climate-Registry-2019-Default-Emission-Factor-Document.pdf. Accessed: April 15, 2020

[38] California Energy Commission. Sacramento Municipal Utility District 2016 Power Content Label. Available: https://ww2.energy.ca.gov/pcl/labels/2017_labels/PG_and_E_2017_PCL.pdf Accessed April 15, 2020

[39] California Energy Commission. Total System Electric Generation. Available: https://ww2.energy.ca.gov/almanac/electricity_data/system_power/2017_total_system_power.html. Accessed: May 7, 2020.

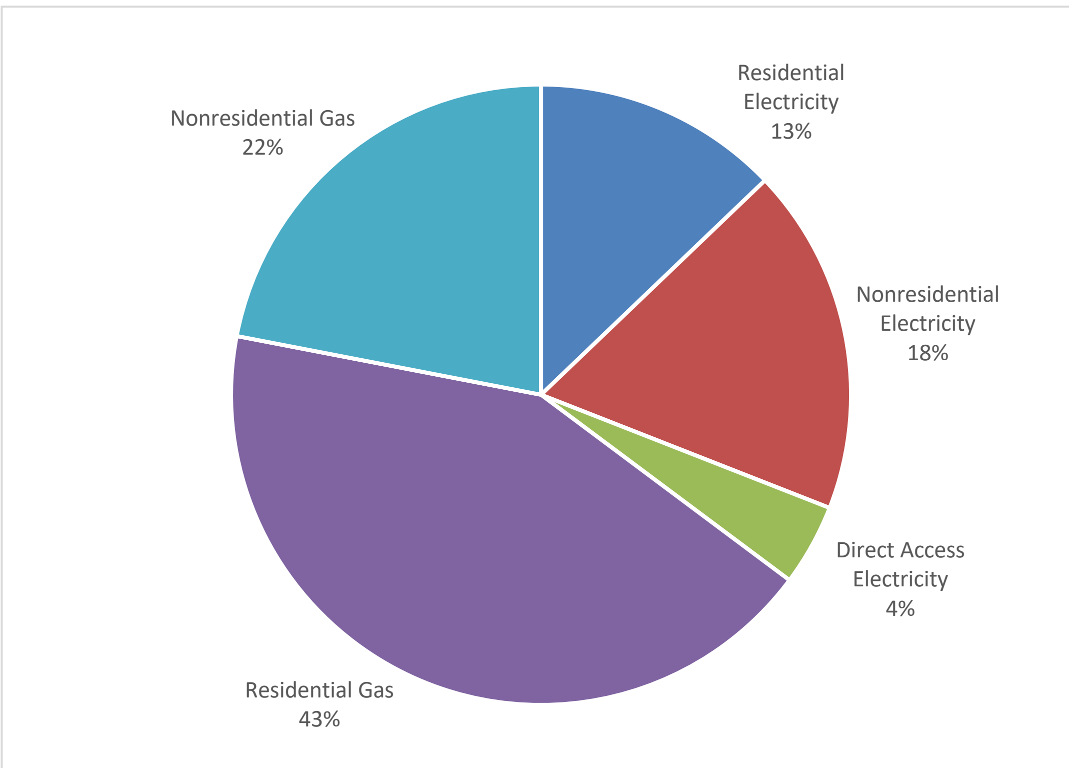
Natural Gas

In order to calculate emissions from natural gas consumption, the total therms consumed is multiplied by the PG&E reported emissions factor of .00531 MT CO_2/therm. Due to CPUC privacy regulations, data regarding the therms of natural gas consumed in 2017 was not provided by PG&E. Emissions were instead estimated based on the most recently available data for this category, which was 2013. [40]

Residential natural gas usage decreased from 13.4 million therms in 2005 to 12.4 million therms in 2017, and nonresidential natural gas usage increased from 5.6 million therms to 10.8 million therms Overall, this resulted in a 5,243 MT CO_2e reduction in emissions from the natural gas sector in 2005 compared to 2017.

In 2017, the residential and nonresidential sectors consumed a total of 23,228,982 therms of natural gas, which, based on the emissions factor of 0.00531 MT CO_2/therms, generated 123,358 MTCO_2e. A complete breakdown of natural gas use by category and sector is provided in Table 9.

Figure 1 Energy Emissions by Category for Year 2017



[40] Emissions were added based on reported emissions from the Lawrence Livermore Laboratory to CARB as a part of California's Cap-and-Trade program. For more information on this calculation and adjustment, see Section 2.3.

Table 9 Energy Emissions by Category for Year 2017

Source	Activity Data	Emissions Factor	Total Emissions ($MTCO_2e$)
Residential			**85,671**
Natural Gas	12,408537 therms	0.00531 MT CO_2e/therms	65,896
Electricity	205,233 MWh	0.09635 MT CO_2e/MWh	19,775
Nonresidential			**85,298**
Natural Gas[1]	10,820,445 therms	0.00531 MT CO_2e/therms	57,462
Electricity	288,895 MWh	0.09635 MT CO_2e/MWh	27,836
Direct Access Electricity			**6,545**
Natural Gas	32,284 MWh	0.2027 MT CO_2e/MWh	6,545
Total			**177,514**

MWh: megawatt hours; MT CO_2e: metric tons of carbon dioxide equivalent

[1] Large industrial natural gas has been estimated for 2017 due to CPUC privacy rules.

3.2 Transportation Emissions

On-Road

Transportation modeling for VMT attributed to the City of Livermore was obtained using the Bay Area Metropolitan Transportation Commission (MTC) VMT data model. The emissions associated with on-road transportation were then calculated by multiplying the estimated daily VMT and the average vehicle emissions rate established by CARB EMFAC2017 modeling for vehicles within the region. The MTC model does not directly provide VMT projections for 2017, so VMT was estimated by interpolating for years between 2015 and 2020 (for which VMT data is directly available from the MTC model).

The MTC VMT modeling results allocate the total VMT derived from the activity-based model to the City of Livermore using the Origin-Destination (O-D) method. The O-D VMT method is the preferred method recommended by the U.S Community Protocol in on-road methodology TR.1 and TR.2 to estimate miles traveled based on trip start and end locations. Under these recommendations, all trips that start and end within the City are attributed to the City. Additionally, one half of the trips that start internally and end externally and vice versa are attributed to the City, and no “pass through” trips are accounted for.

Due to the MTC model not being able to provide VMT for unincorporated county areas, data was used from the Highway Performance Monitoring System,[41] which is published annually by Caltrans. This data provides VMT counts on local roads for each jurisdiction, as well as County-level VMT for all other roads (state highways, roads on land under state or federal jurisdiction such as military bases or state parks, etc.). This data includes all vehicle types and is allocated using the geographic boundary method.

[41] Caltrans. 2019. Highway Performance Monitoring System. Available: https://dot.ca.gov/programs/research-innovation-system-information/highway-performance-monitoring-system. Accessed: May 25, 2020

Commercial VMT for heavy-duty vehicles is also provided by MTC, but separately from light-duty vehicles VMT.[42] Commercial VMT includes heavy-duty freight trucks, motor homes, public and private buses, and other commercial vehicles. Commercial VMT was assigned to individual communities by MTC using a method called "Longitudinal Employer-Household Dynamics" (LEHD). Under this method, MTC first models the county-wide VMT of heavy-duty vehicles using an approach called a geographical boundary method. In this method, all the heavy-duty VMT that occurs within a county's geographic limits is assigned to that county, regardless of where the trip begins or ends. MTC next looks at the number of jobs in specific economic sectors that generate heavy-duty vehicle trips (such as agriculture, construction, retail trade, and manufacturing) for the entire county and for each jurisdiction in the county. The US Census provides the number of jobs in these sectors through its online OnTheMap tool.[43] MTC sums the number of jobs in these sectors, and uses the percent of each community's share of jobs in these sectors, relative to the number of Alameda County jobs in the sectors, to allocate heavy-duty VMT. In 2017, Livermore was attributed 7.52 percent of commercial VMT in Alameda County, which was 3,553,565.

In 2017 on-road transportation attributed to the City of Livermore resulted in 314,154 MT CO_2e. This resulted in a 39,165 MT CO_2e reduction compared to 2005. During this time VMT decreased by 0.6 percent or 4 million miles traveled, and the emissions reductions in this sector were driven by an increase in average vehicle efficiency and adoption of electric vehicles. These changes drove the 12 percent decrease in average vehicles emissions per mile.

A summary of the VMT results can be found in Table 10.

Table 10 Estimated On-Road Transportation Emissions for 2017

Source	Activity Data (VMT)[2]	Emissions Factor (MT CO_2e per VMT)	Total Emissions (MTCO_2e)
Internal-Internal Daily VMT	319,968	0.000445	142
½ Internal-External Daily VMT	608,864	0.000445	271
½ External-Internal Daily VMT	615,276	0.000445	274
Total Passenger Daily VMT	1,544,108	0.000338	522
Total Adjusted Passenger Daily VMT[3]	1,553,118	0.000338	525
Total Commercial Daily VMT	267,057	0.001366	365
Total Adjusted Commercial Daily VMT[3]	279,034	0.001366	381
Yearly Passenger VMT[1]	**538,932,050**	**0.000338**	**181,900**
Yearly Commercial VMT[1]	**96,824,903**	**0.001366**	**132,254**
Yearly VMT[1]	**635,756,952**	**0.000852**	**314,154**

MT CO_2e: metric tons of carbon dioxide equivalent; VMT: vehicle miles traveled

[1] Weekday to annual conversion of 347 is used per CARB guidance on VMT modeling

2 The origin-destination methodology for VMT calculation attributes 100 percent of internal to internal daily trips, 50 percent of internal-external and external-internal daily trips and excludes all pass-through trips. This sum is then multiplied by 347 to get an annual VMT number.

[3] Motorcycle, motor homes, and bus VMT not included in original data, and were estimated based on average prevalence of these vehicles in Alameda County, which is approximately 1 percent.

42 East Bay Energy Watch. 2019. Regional Greenhouse Gas Inventory Methodological Summary. Available: https://static1.squarespace.com/static/53fe4fcfe4b070b8a2eb623b/t/5c36664b21c67c309508c0ff/1547069004776/EBEW-RegionalGHGTool-Methodological-Summary.pdf. Accessed: May 25, 2020.

43 United States Census Bureau. 2018. OnTheMap Version 6. Available: https://onthemap.ces.census.gov/. Accessed: April 2020.

Transportation emissions are generated by the community of Livermore through on-road transportation, including passenger, commercial, and heavy machinery. Emissions factors are established using the latest CARB and EPA-approved emissions modeling software, 2017 State EMissions FACtors (EMFAC) Model. Carbon dioxide, nitrous oxide, and methane emissions from engine combustion are multiplied by their GWP to determine CO_2e per VMT. Emissions for both passenger and commercial vehicles were established using the EMFAC2017 GHG module and weighted by VMT to establish an average emissions factor per VMT for the City. Emissions from electricity used by charging of electric vehicles are captured under the electricity sector. In 2017, the average emissions factor for cars on the road in the County of Alameda was 0.000435 $MTCO_2e$ per VMT as calculated using the EMFAC2017 model.[44] Technical details on the EMFAC2017 modeling tool can be found on the EMFAC Mobile Source Emissions Inventory Technical Support Documentation Portal.[45]

Off-Road

Off-road emissions were calculated using the California Air Resources Board's OFFROAD2021 modeling tool.[46] Some categories of off-road equipment are included in the datasets, but were not present in the Alameda County OFFROAD2021 output, and so were not included[47]. These categories are commercial harbor craft, locomotives, and forestry equipment.. OFFROAD2021 output for Alameda County fuel consumption is shown below in Table 11. This data was supplemented by various demographic, land use, and infrastructure data. Population and household data are from the California Department of Finance's E5 dataset and jobs data comes from the U.S. Census. The Metropolitan Transportation Commission supplied land use data, and the California Department of Conservation provided necessary data on oil wells. EBEW also used data on road miles in each community, which was obtained from Caltrans.

Since the off-road emissions data is available at a County level, a portion of emissions had to be allocated to the City of Livermore. These allocation methods were developed by EBEW and modified by Rincon for each category, which look at how much of a certain activity or indicator occurs in each community as a percent of how much of that activity or indicator occurs county-wide. These allocations by equipment category are shown below in Table 12. Total emissions from off-road transportation in 2017 was 58,852 MT CO_2e, shown in Table 13.

[44] California Air Resources Board. 2017. EMFAC2017. Base year 2017, County of Alameda model run. Available: https://www.arb.ca.gov/emfac/ Accessed: April 5, 2020

[45] California Air Resources Board. EMFAC Software and Technical Support Documentation. Available: https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/road-documentation/msei-modeling-tools-emfac Accessed: April 5, 2020.

[46] California Air Resources Board. 2021. OFFROAD2021 version 1.0.2 Emissions Inventory. Available: https://arb.ca.gov/emfac/. Accessed: April 1, 2022.

[47] East Bay Energy Watch. January 2019. Regional Greenhouse Gas Inventory Methodological Summary. Available: https://static1.squarespace.com/static/53fe4fcfe4b070b8a2eb623b/t/5c36664b21c67c309508c0ff/1547069004776/EBEW-RegionalGHGTool-Methodological-Summary.pdf. Accessed: June 1, 2020.

Table 11 Estimated Off-Road Activity Data for Alameda County 2017

Source	Diesel	Gasoline	Natural Gas/LPG
Agricultural Equipment	391,247	0	0
Airport Ground Support Equipment	197,062	968,520	113,373
Cargo Handling Equipment	3,867,750	338,177	65,565
Construction and Mining Equipment	6,020,196	239,270	0
Industrial Equipment	985,121	2,803,920	5,052,615
Lawn and Garden Equipment	56	2,936	0
Light Commercial Equipment	446,969	794,877	630,231
Ocean Going Vessels	12,631,094,402	0	0
Oil Drilling	8,108	0	0
Other Portable Equipment	5,690,698	0	0
Pleasure Craft	0	23,333	0
Recreational Equipment	0	404,075	0
Transport Refrigeration Units	4,607,216	0	0
Total	**12,653,308,824**	**5,575,110**	**5,861,784**

Notes: LPG: liquefied petroleum gas
All data is presented in gallons per year.

Since the off-road emissions data is available at a County level, a portion of emissions had to be allocated to the City of Livermore. These allocation methods were developed by EBEW and modified by Rincon for each category, which look at how much of a certain activity or indicator occurs in each community as a percent of how much of that activity or indicator occurs county-wide. These allocations by equipment category are shown below in Table 12.

Table 12 Allocation Method for Off-Road Equipment Categories

Source	Allocation Method
Agricultural Equipment	Percent of agricultural acres
Airport Ground Support Equipment	Excluded – No airport facilities in Livermore
Cargo Handling Equipment	Excluded – No port facilities in Livermore
Construction and Mining Equipment	Percent of service population[2]
Industrial Equipment	Percent of industrial acres
Lawn and Garden Equipment	Percent of service population[2]
Light Commercial Equipment	Percent of jobs
Ocean Going Vessels	Excluded – No port facilities in Livermore
Oil Drilling	Percent of active wells
Other Portable Equipment	Percent of service population[2]
Pleasure Craft	Excluded – No docking facilities in Livermore
Recreational Equipment	Percent of population

Transport Refrigeration Units	Percent of service population[2]

[1] EBEW allocated all airport ground support equipment emissions to Oakland because it is the only included community with commercial airport operations. Although charter service and general aviation is available at airports in Concord, unincorporated Contra Costa, Hayward, and Livermore, activity and emissions at these facilities is considered insignificant.

[2] Service population is the sum of residents plus jobs, or people who live in the community plus people who work in the community. Someone who both lives and works in the community is counted as two people under this method.

After applying the above attribution metrics to the fuel consumption outputs from OFFROAD2021 Alameda County, GHG emission factors were applied to the fuel totals to obtain total GHG emissions. The GHG emission factors used were 0.0103, 0.00905, and 0.00582 MT CO_2e per gallon of fuel; for diesel, gasoline, and natural gas/liquefied petroleum gas, respectively. Total emissions from off-road transportation in 2017 was 58,852 MT CO_2e, shown in Table 13.

Table 13 Estimated Off-Road Transportation Emissions for 2017

Source	Fuel Consumption (Gallons)	GHG Emissions (MT CO_2e)
Diesel	1,104,596	11,425
Gasoline	371,061	3,360
Natural Gas/Liquefied Petroleum Gas	552,683	3,217
Total	**2,028,314**	**18,002**

Notes: MT CO_2e: metrics tons of carbon dioxide equivalent

3.3 Water and Wastewater Emissions

Water

Water is supplied to Livermore by Livermore Municipal Water and the California Water Service (CalWater), primarily sourced from the State Water Project in the Central Valley. The Livermore Municipal Water receives treated water from Zone 7 Water Agency and serves about one-third of the City, while central and southern parts of the City are served by CalWater. Water supplied to the community contributes emissions through the use of energy to extract, convey, treat, and deliver water. The amount of energy required for community water usage was calculated using embodied energy data emissions factors based on the processes used, taken from the California Energy Commission's 2007 Refining Estimates of Water-Related Energy Use in California report. It was determined that in 2017 Livermore Municipal Water provided water at an average of 3,808 kWh per million gallons, while CalWater provides water at an average of 3,305 kWh per million gallons. This resulted in Livermore Municipal Water using 6,608 MWh and CalWater using 8,736 MWh to provide the City water in 2017. A breakdown of all water emissions by source are shown below in Table 14.

PG&E is the electricity provider for the City; therefore, PG&E's energy emissions factor of 210 pounds CO_2e/MWh was applied to the calculated electricity used for water consumption in the city. Energy consumption related to water use in the city of Livermore resulted in the generation of approximately 1,479 $MTCO_2e$ in 2017, or 52 percent of total water and wastewater emissions. In 2005, the City used 5,879 million gallons of water. In 2017, Livermore used 4,378 million gallons of water, or about 26 percent less overall. Emissions overall decreased by 3,200 MT CO_2e, due to this decrease in water usage as well as the reduction in PG&E's electricity emissions factor.

Wastewater

The wastewater generated by community residents and businesses creates GHG emissions during the treatment processes, including process, stationary, and fugitive emissions. The sources and magnitude of emissions depend on the type of wastewater treatment plant and the treatment processes utilized.

Wastewater generated in the City of Livermore is collected in local sewer lines which ultimately discharge into the Livermore Water Reclamation Plant managed by Water Resources Division of the Livermore Public Works Department. The wastewater treatment plant treated 2132 million gallons of sewage from Livermore in 2017, according to data obtained from the City. Emissions were calculated using Community Protocol Methodology WW.2, WW.8, and WW.12 based on processes used at the treatment facility (Figure 2). In 2017, a total of 3.32 MT N_2O and 1.88 MT CH_4 were emitted from the effluent discharge, process and stationary sources at the treatment plant. The wastewater treatment plant also used 3,671,304 kWh of electricity in 2017, which resulted in emissions of 354 MT CO2e. As shown in Table 14 the total process emissions and electricity usage for Livermore wastewater treatment and disposal resulted in emissions of 1,366 MT CO_2e per year, or 48 percent of the water and wastewater emissions.

Table 14 Water and Wastewater Emissions for Year 2017

Source	Activity Data	Kilowatts per Million Gallons[1]	Kilowatt Hours	Emissions Factor (MT CO_2e/ MWh)	Total Emissions (MT CO_2e)
Water Use					
Livermore Municipal Water	1,735 MG	3,808	6,608,374	0.09635	637
California Water Service	2,643 MG	3,305	8,736,088	0.09635	842
Total					**1,479**
Wastewater Generation					
Livermore Water Reclamation Plant[2]	2,132 MG	1,722	3,671,304	0.09635	354
Process Nitrous Oxide Emissions	0.3034 MT N_2O	–	–	1 N_2O to 265 CO_2e	80
Stationary Methane Emissions	1.88 MT CH_4	–	–	1 CH_4 to 28 CO_2e	53
Effluent Discharge	3.32 MT N_2O	–	–	1 N_2O to 265 CO_2e	879
Total					**1,366**

MWh: megawatt hours; MT: metric tons; CO_2e: carbon dioxide equivalent; CH_4: methane; N_2O: nitrous oxide

[1] Calculated based off of the data regarding the processes used for water and wastewater generation. Water factors included: average depth of groundwater wells (160 ft), and sources of water (surface water, groundwater, state water project, recycled water). Wastewater factors included: type of wastewater treatment technology (activated sludge and digesters), use of pumps to dispose of wastewater, wastewater discharge into the San Francisco Bay, and number of septic tanks in Livermore (144 in 2017)

[2] Indirect emissions from electricity use during the wastewater generation process.

Figure 2 Wastewater Methodology

Box WW.2.(alt) **Example Calculation of N_2O Emissions from Combustion when only Population Served by System is Known**

A centralized wastewater facility serves a city with a population of 100,000 people. No other data is available. Based on this scenario the N_2O emissions from the combustion of digester biogas can be calculated as follows

Description		Value
N_2O emissions	= Total N_2O emitted by combustion ($mtCO_2e$)	Result
P	= Population served by anaerobic digester	100,000
Digester gas	= Measured standard cubic feet of digester gas produced per person per day (std ft^3/person/day)	1.0
fCH_4	= Fraction of CH_4 in biogas	0.65
BTU_{CH4}	= Default BTU content of CH_4, higher heating value (BTU/ft^3)	1028
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{N2O}	= N_2O emission factor (kg N_2O/MMBTU)	6.3×10^{-4} kg N_2O per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[11]

Sample Calculation:

Annual N_2O *emissions* $= (100{,}000 \times 1 \times 0.65 \times 1028 \times 10^{-6} \times (6.3 \times 10^{-4}) \times 365.25 \times 10^{-3}) \times 310$

$= 4.8\ mtCO_2e$

Equation WW.8 **N_2O Process Emissions from Wastewater Treatment Plants (or aeration basin) without nitrification or denitrification**

Annual N_2O *emissions* $= ((P \times F_{ind\text{-}com}) \times EF \times 10^{-6}) \times GWP$

Where:

Description		Value
Annual N_2O emissions	= Total annual N_2O emitted by WWTP processes ($mtCO_2e$)	Result
P	= Population served by the WWTP	User input
$F_{ind\text{-}com}$	= Factor for high nitrogen loading of industrial or commercial discharge	1.25
$F_{ind\text{-}com}$	= Factor for insignificant industrial or commercial discharge	1
$EF_{w/o\ nit/denit}$	= Emissions factor for a WWTP without nitrification or denitrification(g N_2O/ person / year)	3.2
10^{-6}	= Conversion from g to mt (mt/g)	10^{-6}
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[25]

Source: *As listed in LGO protocol Equation 10.7 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1890-2007, Chapter 8, 8-13 (2009)*

Equation WW.12.(alt) **N_2O Emission from Effluent Conversion when only Population Served by Wastewater Treatment Plant is Known**		
Annual N_2O emissions = $((P \times F_{ind\text{-}com}) \times$ (Total N load - N uptake x BOD5 load) $\times$ EF effluent $\times$ 44/28 $\times$ (1 – Fplant nit/denite) $\times$ 365.25 $\times 10^{-3}) \times$ GWP		
Where:		
Description		Value
N_2O emissions	= Total annual N_2O emitted by effluent (mtCO2e)	Result
P	= Population	User input
$F_{ind\text{-}com}$	= Factor for industrial or commercial discharge	1.25 (if applicable)
Total N-Load	= Average total nitrogen per day (kg N/person/day)	0.026[34]
N uptake	= Nitrogen uptake for cell growth in *aerobic* systems (kg N/kg BOD_5)	0.05
OR		
N uptake	= Nitrogen uptake for cell growth in *anaerobic or lagoon* systems(kg N/kg BOD_5)	0.005
BOD_5	= Amount of BOD_5 produced per person per day (kg BOD_5/person/day)	0.090
EF	= Emission factor (kg N_2O-N/kg sewage-N discharged)	0.005 for river or stream discharge, 0.0025 for direct ocean discharge[35]
44/28	= Molecular weight ratio of N_2O to N_2	1.57
F*plant nit/denit*	= Fraction of nitrogen removed from the WWTP with nitrification/denitrification	0.7
OR		
F*plant*	= Fraction of nitrogen removed from the WWTP without nitrification/denitrification	0.0
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[36]
Source: *As listed in LGO protocol Equation 10.10 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chapter 8, 8-13 (2009); except Grady, C.P. L., Jr., G. T. Daigger, and H. C. Lim, Biological Wastewater Treatment p. 108-109, 644 2nd Edition (1999)*		

3.4 Solid Waste Emissions

GHG emissions result from management and decay of organic material solid waste. Community waste was calculated by determining lifetime methane emissions from solid waste generated by the community in the year of the inventory, using Community Protocol method SW.4[48]. This

[48] ICLEI. 2012. US Community Protocol. Available: https://icleiusa.org/publications/us-community-protocol/. Accessed: April 24, 2020.

methodology attributes 100 percent of lifetime GHG emissions from the tonnage reported in the inventory year.

Waste from the City of Livermore went to 20 landfills in 2017 according to waste data obtained from CalRecycle. Data for the inventory was split between instate solid waste and alternative daily cover waste, 73,437 tons and 8,329 tons respectively. Small quantities of 'transform' and 'AIC' waste data from two landfill sites were not included in the inventory (Covanta Stanislaus, Inc. and Fink Road Landfill), because only reported in-state waste and alternative daily cover waste were included in the inventory. Activity data for the waste sector of the GHG inventory is shown below in Table 15 by landfill destination.

Table 15 Summary of Solid Waste Activity Data by Landfill for Year 2017

Source	Solid Waste (tons)	ADC Waste (tons)
Landfills	–	–
Altamont Landfill & Resource Recovery	9,047	699
Azusa Land Reclamation Co. Landfill	13	0
Corinda Los Trancos Landfill (Ox Mtn)	26	0
Fink Road Landfill	362	0
Foothill Sanitary Landfill	93	0
Forward Landfill, Inc.	861	0
Keller Canyon Landfill	383	88
Kirby Canyon Recycl. & Disp. Facility	1	0
L and D Landfill	0	1
Monterey Peninsula Landfill	191	0
Newby Island Sanitary Landfill	113	0
North County Landfill & Recycling Center	3	0
Potrero Hills Landfill	204	0
Recology Hay Road	686	0
Redwood Landfill	3	1
Sacramento County Landfill (Kiefer)	1	0
Vasco Road Sanitary Landfill	61,443	7,535
Yolo County Central Landfill	1	0
Zanker Material Processing Facility	6	4
Total Tons of Waste Disposal	**73,437**	**8,329**

Communities are required to estimate the emissions resulting from waste disposed by the community (SW.4.1)[39], regardless of whether the receiving landfill(s) are located inside or outside of the community boundary. Community Protocol Method SW.4.1[39] is summarized in Figure 3, utilizing mass of waste being disposed, organic content of waste, methane capture ability of the landfill, oxidation rate, and methane GWP. The 2017 emissions factor for generated solid waste and ADC waste in Livermore was derived from the California Air Resources Board California Landfill Emissions Tool Version 1.3, shown in Table 16 and Table 17, respectively.

Figure 3 Waste Generation Methodology

Equation SW.4.1 Methane Emissions

$$CH_4\ Emissions = GWP_{CH4} * (1 - CE) * (1 - OX) * M * \sum_i P_i * EF_i$$

Where:

Term	Description	Value
CH_4 emissions	= Community generated waste emissions from waste M ($mtCO_2e$)	Result
GWP_{CH4}	= CH_4 global warming potential	
M	= Total mass of waste entering landfill (wet short ton)	User Input
P_i	= Mass fraction of waste component i	User Input
EF_i	= Emission factor for material i ($mtCH_4$/wet short ton)	Table SW.5
CE	= Default LFG Collection Efficiency	No Collection, 0 Collection, 0.75
OX	= Oxidation rate	0.10

Source: As developed by ICLEI staff and Solid Waste Technical Advisory Committee. Emissions factors from U.S. EPA Municipal Solid Waste Publication (2008) available at http://www.epa.gov/epawaste/nonhaz/municipal/pubs/msw2008data.pdf

In 2017, Livermore produced 73,437 tons of solid waste and 8,329 of ADC waste.[49] A CO_2e emissions factor for mixed-waste of 0.286 MT CO_2e/ton was established and multiplied by the total solid waste disposed of from the community to calculate emissions from waste generated in 2017 of 21,006 MT CO_2e. For ADC waste, a CO_2e emissions factor of 0.246 MT CO_2e/ton was established and multiplied by the total ADC waste disposed of from the community to calculate emissions from waste generated in 2017 of 2046 MT CO_2e. These emissions factors include the expected lifetime emissions associated with the specified tonnage of waste sent to landfill. The emissions factors were developed using SW 4.1 as well as the relative waste stream percentages of different organic materials as shown in Table 16 and Table 17 to establish a methane emissions factor. From 2005 to 2017 GHG emissions from community waste decreased by 15,442 MT of CO_2e. This was due to a combination of factors including a reduced solid waste emissions factor as well as an overall reduction in waste generation of 51,812 tons. Total waste emissions for 2017 are summarized in Table 18.

[49] CalRecycle. 2017. Local Government Information Center. Available: https://www.calrecycle.ca.gov/LGCentral/MyLoGIC/. Accessed: April 18, 2020.

Table 16 California Default Solid Waste Characterization[1]

Waste Type	WIPFRAC	TDOC	DANF	ANDOC	Weighted MT CO_2e/ton
Newspaper	1.44%	47.09%	15.05%	0.12%	0.279029616
Office Paper	0.73%	38.54%	87.03%	0.62%	1.320583313
Corrugated Boxes	3.13%	44.84%	44.25%	0.95%	0.781203158
Coated Paper	12.10%	33.03%	24.31%	0.72%	0.316139414
Food	18.12%	14.83%	86.52%	1.99%	0.505176074
Grass	1.84%	13.30%	47.36%	0.12%	0.247998153
Leaves	3.52%	29.13%	7.30%	0.07%	0.083723708
Branches	3.27%	44.24%	23.14%	0.20%	0.403054324
Lumber	11.91%	43.00%	23.26%	1.45%	0.393788725
Textiles	5.85%	24.00%	50.00%	0.66%	0.472461427
Diapers	4.29%	24.00%	50.00%	0.52%	0.472461427
Construction/Demolition	2.31%	4.00%	50.00%	0.11%	0.078743571
Medical Waste	0.11%	15.00%	50.00%	0.00%	0.295288392
Sludge/Manure	0.57%	5.00%	50.00%	0.00%	0.098429464
MSW Total				**7.52%**	**0.28604673**

[1] The static values here are from the California Landfill Emissions Tool Version 1.3

Table 17 Alternative Daily Cover Waste Characterization[1]

Waste Type	WIPFRAC	TDOC	DANF	ANDOC	Weighted MT CO_2e/ton
Newspaper	0.00%	47.09%	15.05%	0.12%	0.003580198
Office Paper	0.00%	38.54%	87.03%	0.62%	0.00861393
Corrugated Boxes	0.00%	44.84%	44.25%	0.95%	0.021806282
Coated Paper	0.00%	33.03%	24.31%	0.72%	0.034152408
Food	0.00%	14.83%	86.52%	1.99%	0.081728001
Grass	50.00%	13.30%	47.36%	0.12%	0.004081975
Leaves	25.00%	29.13%	7.30%	0.07%	0.002627254
Branches	25.00%	44.24%	23.14%	0.20%	0.011770174
Lumber	0.00%	43.00%	23.26%	1.45%	0.041876495
Textiles	0.00%	24.00%	50.00%	0.66%	0.024668962
Diapers	0.00%	24.00%	50.00%	0.52%	0.018088588
Construction/Demolition	0.00%	4.00%	50.00%	0.11%	0.001622068
Medical Waste	0.00%	15.00%	50.00%	0.00%	0.000298201
Sludge/Manure	0.00%	5.00%	50.00%	0.00%	0.000497751
MSW Total				**7.25%**	**0.245693584**

[1] The static values here are from the California Landfill Emissions Tool Version 1.3

Table 18 Summary of Solid Waste Activity Data for Year 2017

Source	Tons	Emissions Factor ($MT\ CO_2e$/ton)	Total Emissions ($MT\ CO_2e$)
Solid Waste	73,437	0.286	21,006
ADC Waste	8,329	0.246	2,046
Total Waste Emissions	–	–	**23,052**

MT CO2e: metric tons of carbon dioxide equivalent

3.5 2017 GHG Emissions Inventory Results Summary

Overall the City of Livermore's GHG emissions were estimated to be 535,566 MT CO_2e in 2017. The on-road transportation sector (passenger and commercial vehicles) was the largest emissions sector with 59 percent of total baseline inventory emissions, followed by natural gas use in the energy sector at 23 percent. Off-road transportation emissions were estimated to be 4 percent of emissions, and waste accounted for 4 percent. The smallest emissions sector was water and wastewater, which combine to account for less than 1 percent of total 2017 emissions for the City of Livermore. Emissions are summarized in Table 19 and Figure 4.

Table 19 2017 GHG Inventory

Sector	Activity Data	Emissions Factors	Units	MT CO_2e
Residential Electricity (kWh)	205,232,521	0.00009635	MT CO_2e/kWh	19,775
Nonresidential Electricity (kWh)	288,894,815	0.00009635	MT CO_2e/kWh	27,836
Direct Access Electricity[5] (kWh)	32,283,926	0.0002027	MT CO_2e/kWh	6,545
Residential Gas (therms)	12,408,537	0.00531	MT CO_2e/therms	65,896
Adjusted Nonresidential Gas (therms)	10,820,445[1]	0.00531	MT/CO_2e/therms	57,462[1]
Passenger On-Road Transportation (VMT)	538,932,050	0.000338	MT CO_2e/mile	181,900
Commercial On-Road Transportation (VMT)	96,824,903	0.001366	MT CO_2e/mile	132,254
Off-Road – Diesel (Gallons)	1,104,596	0.0103	MT CO_2e/gallon	11,425
Off-Road – Gasoline (Gallons)	371,061	0.00905	MT CO_2e/gallon	3,360
Off-Road – NG/LPG (Gallons)	552,683	0.00582	MT CO_2e/gallon	3,217
Waste (tons)[6]	81,766	0.2860	MT CO_2e/ton	23,052
Wastewater (kWh)	N/A[4]	N/A[4]	MT CO_2e/kWh	1,366
Water (kWh)	15,344,462	0.00009635	MT CO_2e/kWh	1,479
Total Emissions				**535,566**

MWh: megawatt hours; kWh: kilowatt hours; CO_2e: carbon dioxide equivalent; MT: metric tons; VMT: vehicle miles traveled; ADC: Alternative Daily Cover

[1] No natural gas usage was reported by PG&E for large industrial users after 2013 due to California Public Utilities Commission privacy rules. Natural gas emissions reported by the Lawrence Livermore National Laboratory to the California Air Resources Board as a part of the Cap-and-Trade program were added to allow for accurate comparison of emissions from nonresidential gas in previous inventory years. Data reported as a part of the Cap-and-Trade program can be found here: https://ww2.arb.ca.gov/mrr-data

[2] Off-road emissions calculated as a proportion of total emissions in Alameda County based on changes in population and does not have activity data.

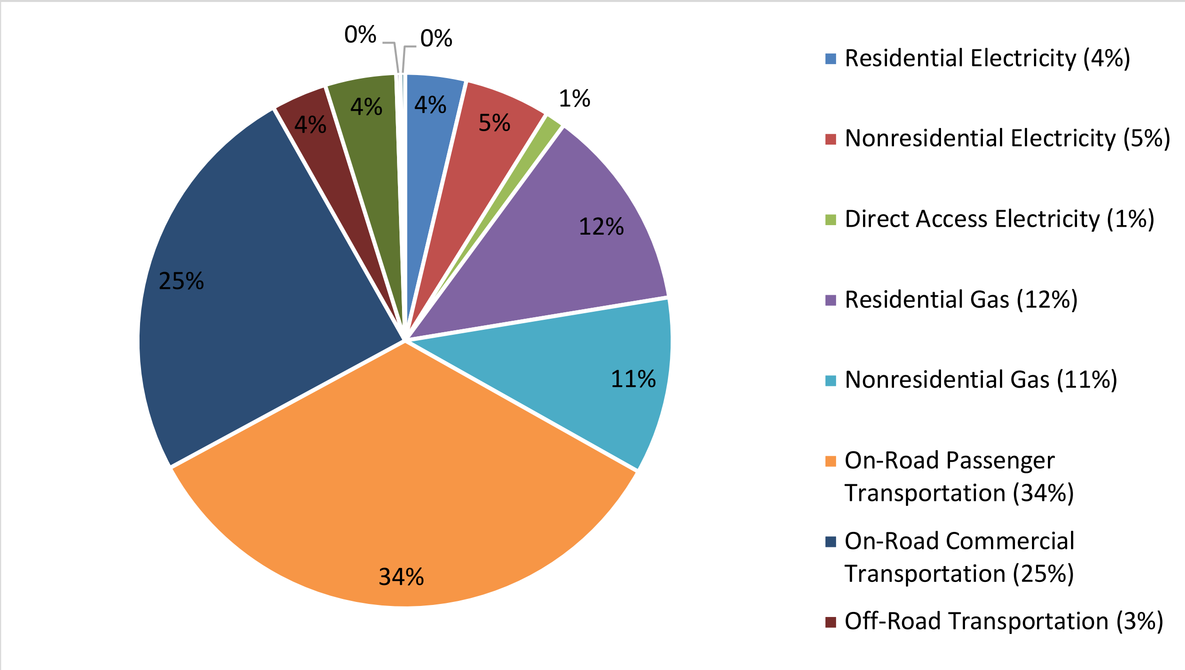
[3] Off-road emissions calculated as a proportion of total emissions in Alameda County based on Livermore's percentage of population and jobs within the County, as well as the effective change in service population, which was defined as on the sum of new population and jobs in Livermore divided by the total sum of new jobs and population in Alameda County for each inventory year.

[4] Wastewater is a combination of stationery and process emissions, further detail is Section 3.3.

[5] Direct access service is retail electric service where customers purchase electricity from a competitive provider called an Electric Service Provider instead of from a regulated electric utility. An Electric Service Provider is a non-utility entity that offers electric service to customers within the service territory of an electric utility.

[6] Includes 8329 tons of Alternative Daily Cover Waste for which a different emissions factor was used (.246 $MTCO_2e$/ton). This emissions factor was calculated using data from the CARB California Landfill Emissions Tool Version 1.3.

Figure 4 2017 City of Livermore Community Emissions by Sector



Between 2005 and 2017, Livermore was able to reduce total GHG emissions by 17 percent from 2005 to 2017, or 106,667 $MTCO_2e$, and experienced a population increase of approximately 16 percent which led to a per-capita emissions reduction of 38 percent. The 17 percent decrease in total GHG emissions from 2005 levels meets the 2020 AB 32 goal of reducing emissions by 15 percent (1990 levels), as well as the 2020 emissions reduction target set forth by Livermore's 2012 CAP. Table 20 summarizes GHG emissions changes in Livermore from 2005 to 2017, and Table 21 summarizes changes in activity data.

Between 2005 and 2017, Livermore reduced GHG emissions in every sector except for nonresidential gas and off-road transportation, which may have increased due to growth in development of the commercial and industrial sectors within the City. Major GHG emissions reductions were achieved in the waste sector and wastewater sectors, although these sectors make up smaller proportions of Livermore's overall emissions as shown in Figure 4. It is worth noting that large GHG emissions reductions from electricity usage were driven largely by PG&E's electricity fuel mix, which saw a significant decrease in carbon intensity[50] from 2005 to 2017. Although there was an increase in commercial vehicle miles traveled (VMT), GHG emissions associated with the commercial on-road transportation sector declined because of the increased fuel efficiency of vehicles as detailed in Table 20 and Table 21.

[50] Carbon intensity is the amount of carbon by weight emitted per unit of energy consumed. For example, as the percentage of renewable energy sources used to produce electricity increases, the carbon intensity of that electricity decreases.

Table 20 Summary of Livermore GHG Emissions Changes from 2005 to 2017

GHG Emissions Sources	2005 (MT CO_2e)	2017 (MT CO_2e)	Percent Change
Residential Electricity	49,822	19,775	-60%
Nonresidential Electricity	65,872	27,836	-58%
Direct Access Electricity	15,192	6,545[2]	-57%
Residential Gas	71,139	65,896	-7%
Nonresidential Gas	29,771	57,462[1]	+93%
Solid Waste	35,008	21,006	-40%
Alternative Daily Cover Waste	3,487	2,046	-41%
Water	4,680	1,479	-68%
Wastewater	1,839	1,366	-28%
On-Road Passenger Transportation	218,684	181,900	-17%
On-Road Commercial Transportation	134,636	132,254	-2%
Off-Road Transportation	88,179	58,852	+49%
Total Emissions	**642,233**	**535,566**	**-17%**
Emissions Per Capita	**9.62**	**5.92**	**-38%**

MT CO_2e: metric tons of carbon dioxide equivalent

[1] PG&E did not report data for industrial natural gas usage in Livermore for 2015 and 2017 due to the CPUC's 15-15 privacy rule. Industrial natural gas usage was estimated for these years using the reported GHG emissions from the Livermore Lawrence National Laboratory for those years as a part of California's Cap-and-Trade program. (see Section 2.3 for more details on this calculation).

[2] PG&E did not report data for direct access electricity usage in Livermore for 2017 due to the CPUC's 15-15 privacy rule and was estimated using the average of 2015 and 2016 data as they were the closest available years (see Section 2.3 for more details on this calculation).

Table 21 Summary of Livermore Activity Data and Emissions Factor Changes from 2005 to 2017

Raw Activity Data	2005 Activity Data	2017 Activity Data	Percent Change
Population	78,019	90,454	+16%
Residential Electricity (kWh)	223,251,790	205,232,521	-8%
Residential Gas (therms)	13,395,923	12,408,537	-7%
Nonresidential Electricity (kWh)	295,174,279	288,894,815	-2%
Adjusted Nonresidential Gas (therms)	5,606,070	10,820,445[1]	+93%
Direct Access Electricity (kWh)	39,378,526	32,283,926[2]	-18%
Wastewater (kWh)	4,546,080	3,671,304	-19%
Water (kWh)	20,975,856	15,344,462	-27%
Solid Waste (tons)	119,384	73,437	-38%
Alternative Daily Cover Waste (tons)	14,193	8,329	-41%
Passenger VMT	548,153,828	538,438,400	-2%
Commercial VMT	91,610,896	95,769,686	+5%
Passenger VMT Emissions Factor (MT CO_2e/VMT)	0.000399	0.000338	-15%
Commercial VMT Emissions Factor (MT CO_2e/VMT)	0.001470	0.001366	-7%
Off-Road D**iesel (gallons)**	600,655	1,104,596	+84%
Off-Road Gasoline (gallons)	338,135	371,061	+10%
Off-Road NG/LPG (gallons)	477,673	552,683	+16%
PG&E Elec Factor (MT CO_2e/MWh)	0.000223	0.000096	-57%

MT CO_2e: Metric tons of carbon dioxide equivalent; kWh: Thousand watt hours; MWh: Million watt hours; ADC: Alternative Daily Cover; NG: natural gas; LPG: liquefied petroleum gas

[1] Includes activity data from Lawrence Livermore National Laboratory, calculated using reported emissions to CARB as a part of the Cap-and-Trade Mandatory GHG Reporting program and the natural gas emissions factor of 0.00531.

[2] Activity data for 2017 direct access electricity unavailable from PG&E due to CPUC privacy rules and was estimated for consistency with other inventory years based on an average of 2015 and 2016 direct access electricity data.

4 Future GHG Emissions Forecasts

A GHG emissions inventory sets a reference point for a single year. However, annual emissions change over time due to factors such as population and job growth as well as new technologies and policies. A GHG emissions forecast accounts for projected growth and presents an estimate of GHG emissions in future years. Calculating the difference between the GHG emissions forecast and the GHG emissions reduction targets set by a jurisdiction determines the GHG emissions reduction gap that needs to be closed through the jurisdiction's climate action plan policies. This section calculates an emissions forecast for the City of Livermore through a 2045 in a *business-as*-usual (BAU) scenario, and then quantifies the reduction impact that state regulations will have on the City of Livermore GHG emissions forecast and presents the results in an *adjusted scenario* forecast. The *adjusted scenario* incorporates the impact of state regulations which would reduce the City of Livermore's GHG emissions to provide a more accurate picture of future emissions growth and the responsibility of the City and community for GHG reductions once state regulations to reduce GHG emissions have been implemented.

Several indicator growth rates were developed and applied to the various emissions sectors to forecast emissions as shown in Table 22. The growth rates were applied to the most recent inventory year (2017) data to obtain projected activity data (e.g., energy use, waste production). Growth rates were developed from the Association of Bay Area Government's Plan Bay Area Projections 2040, EMFAC Modeling, OFFROAD2021 modeling, Livermore 2025 General Plan demographic projections methodology, and California Department of Finance demographic estimates for the City of Livermore and Alameda County. As the Applicable state and federal regulatory requirements, including Corporate Average Fuel Economy standards, Advanced Clean Car Standards, Renewable Portfolio Standard, and Title 24 efficiencies were then incorporated to accurately reflect expected reductions from state programs.

Plan Bay Area Projections 2040 has demographic projections starting with 2010 and was the primary source for forecast projections.[51] In comparison with demographic data from the California Department of Finance E4 and E5 datasets[52] (which are updated year-to-year based on census data and jurisdictional data on population changes). However, Plan Bay Area Projections 2040 underestimates population and job growth in Livermore for 2015. This was due to the use of "modeled" rather than "observed" data used in the projections.[53] Therefore, subsequent forecast years are lower than those provided by Department of Finance. For this reason, these demographic projections were corrected to better reflect real-world population changes that occurred in Livermore up until 2017, using the calculated percent difference between the Plan Bay Area Projections 2040 and the Department of Finance data in 2015 and 2020. The result is a set of adjusted population and job projections through 2045 that reflect the greater increase in growth experienced by the City of Livermore between 2015 and 2020.

[51] Association of Bay Area Governments; Metropolitan Transportation Commission. 2018. Plan Bay Area Projections 2040. Available: http://projections.planbayarea.org/. Accessed April 22, 2020.

[52] California Department of Finance. 2020. Available: http://www.dof.ca.gov/Forecasting/Demographics/Estimates/. Accessed: April 22, 2020.

[53] http://mtcmedia.s3.amazonaws.com/files/Projections_2040-ABAG-MTC-web.pdf

4.1 Business-as-Usual Forecast Scenario

The City of Livermore business-as-usual scenario forecast provides an estimate of how GHG emissions would change in the forecast years if consumption trends continue as in 2017, absent any new regulations which would reduce local emissions. Several indicator growth rates were developed from 2017 activity levels and applied to the various emissions sectors to project future year emissions. Table 22 contains a list of growth factors used to develop the business-as-usual scenario forecast. The BAU growth factors were then multiplied by the population or service person growth rates to develop the BAU emissions forecast.

Table 22 Business-as-Usual Growth Factors

Sector	Activity Data
Emissions per capita (MT CO2e/capita)	6.4
Residential electricity per capita (kWh/capita)	2,268.9
Commercial electricity use per job (kWh/employment)	6,002.0
Residential gas per capita (therm/capita)	137.2
Commercial gas use per job (therm/job)	224.8
Solid Waste per service person (tons/SP)	0.53
ADC Waste per service person (tons/SP)	0.06
Wastewater Process GHG per service population (MT CO_2e/SP)	0.01
CO_2e per ton solid waste (MT CO_2e/ton)	0.29
CO_2e per ton ADC waste (MT CO_2e/ton)	0.25
Water electricity per service person (kWh/SP)	110.7
Wastewater electricity per service person (kWh/SP)	26.5
Total VMT per service person (VMT/SP)	4,587.4

kWh: kilowatt hour; SP: service person (sum of population and employment) MT CO_2e: metric tons of carbon dioxide equivalent; VMT: vehicle miles traveled

Under the BAU forecast scenario, the City of Livermore's GHG emissions are projected to continue increasing through 2045. This increase is led primarily by a strong commercial and residential development trend. After the current General Plan horizon year of 2025, major increases in in emissions are largely attributed to the increased population and vehicular traffic from the greater Alameda County Area traveling into the city. By 2045, the City is expected to produce 99,286 MT CO_2e more under the business-as-usual projections, an increase of 19 percent over 2017 emissions. Per capita emissions are projected to go down, however, from 5.92 in 2017 to 4.92 in 2045. The BAU forecast is summarized below in Table 23.

Table 23 Business-as-usual Forecast by Sector

	2017 ($MT CO_2e$)	2020 ($MT CO_2e$)	2025 ($MT CO_2e$)	2030 ($MT CO_2e$)	2035 ($MT CO_2e$)	2040 ($MT CO_2e$)	2045 ($MT CO_2e$)
Population	90,454	91,474	96,699	105,967	113,218	120,925	129,158
Jobs	48,133	48,340	48,686	49,372	50,649	51,499	52,364
Residential Electricity	19,775	19,998	21,140	23,167	24,752	26,437	28,237
Nonresidential Electricity	27,836	27,956	28,156	28,553	29,291	29,783	30,283
Direct Access Electricity	6,545	6,618	6,996	7,667	8,192	8,749	9,345
Residential Gas	65,896	66,639	70,445	77,197	82,479	88,094	94,091
Nonresidential Gas	57,462	57,709	58,123	58,941	60,465	61,481	62,513
Waste	23,052	23,256	24,183	25,839	27,257	28,681	30,194
Water	1,479	1,492	1,551	1,657	1,748	1,840	1,937
Wastewater	1,366	1,378	1,433	1,531	1,615	1,699	1,789
On-Road Passenger Transportation	181,900	184,250	191,175	198,101	201,095	204,090	207,084
On-Road Commercial Transportation	132,254	132,641	134,445	136,248	138,355	140,462	142,568
Off-Road Transportation	18,002	18,951	20,532	22,114	23,680	25,245	26,811
Total Emissions	**535,566**	**540,888**	**558,181**	**581,014**	**598,930**	**616,560**	**634,852**
Emissions Per Capita	**5.92**	**5.91**	**5.77**	**5.48**	**5.29**	**5.10**	**4.92**

$MT CO_2e$: metric tons of carbon dioxide equivalent

4.2 Adjusted Forecast Scenario

Adjustments Due to State Legislation

The adjusted scenario estimates future City of Livermore emissions including adopted GHG reduction strategies currently being implemented at the state and federal level. The 2017 Scoping Plan Update identified several existing state programs and targets, or known commitments required by statute which can be assumed to achieve GHG reductions without City action, such as increased fuel efficiency standards of mobile vehicles. The following known commitments are factored into the adjusted scenario projection and a summary of the programs can be found in Table 24.

Table 24 Summary of Legislative Reductions

Legislation	2020 (MT CO_2e)	2025 (MT CO_2e)	2030 (MT CO_2e)	2035 (MT CO_2e)	2040 (MT CO_2e)	2045 (MT CO_2e)
Senate Bill 100	6,003	16,514	28,314	41,250	55,159	70,265
Title 24	82	1,157	3,080	4,776	6,448	2,281
Transportation (Pavley, etc.)	21,344	62,120	94,871	114,488	125,512	131,342
Total	**27,429**	**79,790**	**125,265**	**160,514**	**187,119**	**203,887**

MT CO_2e: metric tons of carbon dioxide equivalent

State programs will lead to an estimated reduction of approximately 203,887 MT CO_2e in GHG emissions by 2045 in Livermore. The increasing decarbonization of the electricity supply due to SB 100 and the Renewable Portfolio Standard (RPS) will lead to GHG emissions reductions in Livermore and avoid over 70,265 MT CO_2e by 2045. The transportation sector will experience the largest GHG reductions, with over 131,342 MT CO_2e reduced by 2045 through state and federal fuel efficiency and tailpipe emissions standards. A description of the GHG reduction policies for each sector are included below.

Transportation Legislation

The CARB EMFAC2017 transportation modeling program incorporates legislative requirements and regulations including Advanced Clean Cars program (Low Emissions Vehicles III, Zero Emissions Vehicles program, etc.), and Phase 2 federal GHG Standards. Signed into law in 2002, AB 1493 (Pavley Standards) required vehicle manufactures to reduce GHG emissions from new passenger vehicles and light trucks from 2009 through 2016, with a target of 30 percent reductions by 2016, while simultaneously improving fuel efficiency and reducing motorists' costs.[54]

Prior to 2012, mobile emissions regulations were implemented on a case-by-case basis for GHG and criteria pollutant emissions separately. In January 2012, CARB approved a new emissions-control program (the Advanced Clean Cars program) combining the control of smog, soot causing pollutants, and GHG emissions into a single coordinated package of requirements for passenger cars and light trucks model years 2017 through 2025. The Advanced Clean Cars program coordinates the goals of the Low Emissions Vehicles, Zero Emissions Vehicles, and Clean Fuels Outlet programs. However, in 2019 the federal government issued a final action entitled the One National Program on Federal Preemption of State Fuel Economy Standards Rule, which finalized Part I of the Safer, Affordable, Fuel-Efficient (SAFE) Vehicles Rule and stated that federal law preempts state and local tailpipe GHG emissions standards as well as zero emissions vehicle mandates. While still in flux, under the SAFE Rule discussed above, fuel economy and GHG emissions standards for new vehicles may not improve beyond model year 2020. According to CARB, the federal rollback proposal of the remaining Advanced Clean Cars Program standards would increase global warming emissions by 14 million metric tons per year by 2025.[55]

[54] California Air Resources Board. 2013. Clean Car Standards – Pavley, Assembly Bill 1493.

[55] California Air Resources Board. 2018. California moves to ensure vehicles meet existing state greenhouse gas emissions standards. Available: https://ww2.arb.ca.gov/news/california-moves-ensure-vehicles-meet-existing-state-greenhouse-gas-emissions-standards-0. Accessed: April 17, 2020.

Reductions in GHG emissions from the above referenced standards were calculated using the CARB EMFAC2017 model for Alameda County. The EMFAC2017 model integrates the estimated reductions into the mobile source emissions portion of the model.[56]

Note: As of the time of this writing, the federal Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule Part 2 has been posted in the Federal Register but will not take effect until June 29, 2020. This new rule rolls back California fuel efficiency standards for on-road passenger vehicles, so that cars and trucks will now only achieve a 40.4 mpg industry average by 2026 compared to the 46.7 mpg projected requirement under the previous California Advanced Clean Car Program/federal Corporate Average Fuel Economy (CAFE) standards. No methodology currently exists for extracting or altering the on-road passenger vehicles fuel efficiency standard aspect of the Emissions Factors (EMFAC) model[57] used to calculate forecasted vehicle GHG emissions. In addition, the California Climate Change Scoping Plan does not yet address or provide guidance related to this pending change in fuel efficiency standards with regard to GHG emissions determination. Furthermore, California is currently challenging this new rule in the court system. Therefore, the Livermore adjusted forecasts have not been modified to reflect the new SAFE Rule Part 2.

Title 24

Although it was not originally intended to reduce GHG emissions, California Code of Regulations Title 24, Part 6: California's Energy Efficiency Standards for Residential and Nonresidential Buildings, was adopted in 1978 in response to a legislative mandate to reduce California's energy consumption, which in turn reduces fossil fuel consumption and associated GHG emissions. The standards are updated triennially to allow consideration and possible incorporation of new energy-efficient technologies and methods. Starting in 2020, new residential developments will include on-site solar generation and near-zero net energy use. For projects implemented after January 1, 2020, the California Energy Commission estimates the 2019 standards will reduce consumption by seven percent for residential buildings and 30 percent for commercial buildings, relative to the 2016 standards. These percentage savings relate to heating, cooling, lighting, and water heating only and do not include other appliances, outdoor lighting not attached to buildings, plug loads, or other energy uses. The calculations and GHG emissions forecast assume all growth in the residential and commercial/industrial sectors is from new construction.

The 2017 Scoping Plan Update calls for the continuation of ongoing triennial updates to Title 24 which will yield regular increases in the mandatory energy and water savings for new construction. Future updates to Title 24 standards for residential and non-residential alterations past 2023 are not taken into consideration due to lack of data and certainty about the magnitude of energy savings realized with each subsequent update.

Renewables Portfolio Standard & Senate Bill 100

Established in 2002 under SB 1078, enhanced in 2015 by SB 350, and accelerated in 2018 under SB 100, California's Renewable Portfolio Standard (RPS) is one of the most ambitious renewable energy

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[56] Additional details are provided in the EMFAC2017 Technical Documentation, July 2018. Available: https://www.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf. Accessed: April 15, 2020. The Low Carbon Fuel Standard (LCFS) regulation is excluded from EMFAC2017 because most of the emissions benefits due to the LCFS come from the production cycle (upstream emissions) of the fuel rather than the combustion cycle (tailpipe). As a result, LCFS is assumed to not have a significant impact on CO_2 emissions from EMFAC's tailpipe emissions estimates.

[57] The EMFAC model is developed and used by CARB to assess emissions from on-road vehicles including cars, trucks, and buses in California and to support CARB regulatory and planning efforts to meet Federal Highway Administration transportation planning requirements.

standards in the country. The RPS program requires investor-owned utilities, publicly owned utilities, electric service providers, and community choice aggregators to increase procurement from eligible renewable energy resources to 50 percent of total procurement by 2026 and 60 percent of total procurement by 2030. The RPS program further requires these entities to increase procurement from GHG-free sources to 100 percent of total procurement by 2045.

PG&E provides electricity in Livermore and is subject to the RPS requirements. PG&E forecast emissions factors include reductions based on compliance with RPS requirements through 2045. In 2017, PG&E reported an emissions factor of 210 pounds CO_2e per MWh.

Direct access electricity accounted for 6.1 percent of total electricity usage in 2017, which is provided by third party electricity providers instead of traditional energy utilities. Emissions factors for the carbon intensity of direct access electricity was assumed to be equal to the state average, calculated to equal .203 MT CO_2e/MWh in 2017. RPS requirements were used to adjust this emissions factor for forecasted emissions through 2045.

Assembly Bill 939 & Assembly Bill 341

In 2011, AB 341 set the target of 75 percent recycling, composting, or source reduction of solid waste by 2020 calling for the California Department of Resources Recycling and Recovery (also known as CalRecycle) to take a statewide approach to decreasing California's reliance on landfills. This target was an update to the former target of 50 percent waste diversion set by AB 939.

Actions beyond the projected waste diversion target of 5.9 pounds per person per day set under AB 939 for the City of Livermore will be quantified and credited to the City during the Climate Action Plan measure development process. As of 2017, Livermore is meeting both the 5.9 pounds per person per day and 9.5 pounds per job per day diversion targets set by CalRecycle under AB 341.

Senate Bill 1383

SB 1383 established a methane emissions reduction target for short-lived climate pollutants in various sectors of the economy, including waste. Specifically, SB 1383 establishes targets to achieve a 50 percent reduction in the level of the statewide disposal of organic waste from the 2014 level by 2020 and a 75 percent reduction by 2025.[58] Additionally, SB 1383 requires a 20 percent reduction in "current" edible food disposal by 2025. Although SB 1383 has been signed into law, compliance at the jurisdiction-level has proven to be difficult. For example, Santa Clara County suggests the 75 percent reduction in organics is not likely achievable under the current structure; standardized bin colors are impractical; and the general requirement is too prescriptive.[59] As such, SB 1383 is not included as part of the adjusted forecast. Instead measures addressing compliance with SB 1383 will be addressed through newly identified GHG reduction measures included in the Climate Action Plan.

Adjusted Forecast Results

The adjusted scenario is based on the same information as the business-as-usual scenario but also includes the legislative actions and associated emissions reductions occurring at the state and federal levels. These actions include regulatory requirements to increase vehicle fuel efficiency or standards to reduce the carbon intensity of electricity. The difference between the emissions

[58] CalRecycle. April 16, 2019. Short-Lived Climate Pollutants (SLCP): Organic Waste Methane Emissions Reductions (General Information). Available: https://www.calrecycle.ca.gov/climate/slcp. Accessed: April 16, 2020

[59] Santa Clara County. June 20, 2018. SB 1383 Rulemaking Overview. Available: https://www.sccgov.org/sites/rwr/rwrc/Documents/SB%201383%20PowerPoint.pdf. Accessed: April 16, 2020

projected in the adjusted scenario and the GHG reduction targets established for each horizon year is the amount of GHG reductions which are the responsibility of the City. This "gap analysis" provides the City with the total GHG emissions reduction required as well as information on the emissions sectors and sources which have the most GHG reduction opportunities.

The electricity and water/wastewater sectors all experience a strong downward trend, approaching near-zero in 2045 due to extremely stringent RPS from SB 100. Natural gas emissions are expected to continue an upward trajectory until the 2045 due to strong population growth projections in the city. This trend is partially offset due to the increasingly stringent efficiency requirements for new homes in the upcoming Title 24 code cycles. Commercial growth will also lead commercial natural gas emissions on a similar trajectory. Transportation emissions are expected to decrease significantly in the next 10 to 15 years due to existing fuel efficiency requirements and fleet turnover rates. As most current regulations expire in 2025 or 2030, emissions standards will experience diminishing returns while VMT continues to increase, leading to lower rates of emissions reduction in the transportation sector.

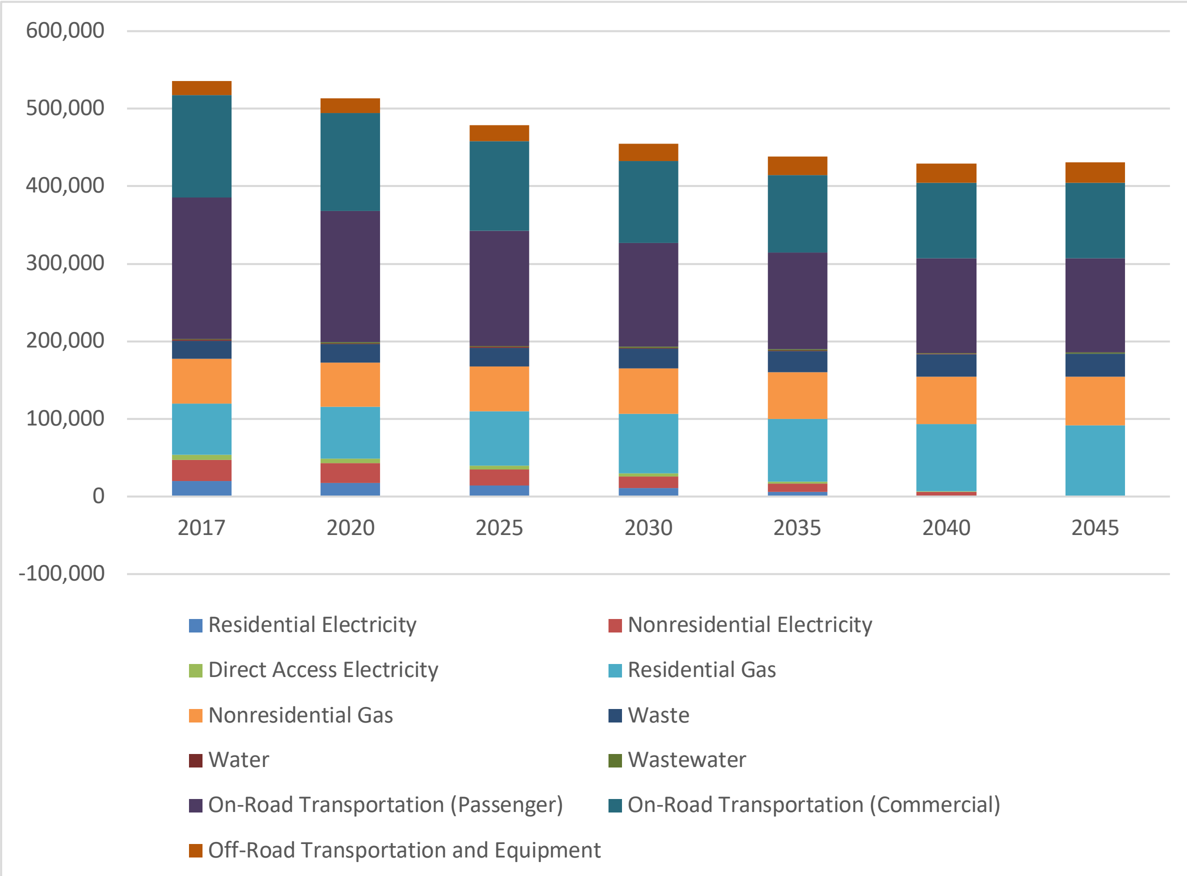
A summary of Livermore's projected emissions by sector and year through 2045 can be found in Figure 5 and Table 25. Further details on the growth rates and emissions for each sector can be found in the corresponding discussion sections.

Table 25 Adjusted Forecast Summary by Sector by Year

	2017 (MT CO_2e)	2020 (MT CO_2e)	2025 (MT CO_2e)	2030 (MT CO_2e)	2035 (MT CO_2e)	2040 (MT CO_2e)	2045 (MT CO_2e)
Population	90,454	91,474	96,699	105,967	113,218	120,925	129,158
Jobs	48,133	48,340	48,686	49,372	50,649	51,499	52,364
Residential Electricity	19,775	17,816	14,455	10,692	6,281	1,269	0
Nonresidential Electricity	27,836	24,949	20,040	15,105	10,049	4,758	0
Direct Access Electricity	6,545	5,944	4,996	3,997	2,597	996	0
Residential Gas	65,896	66,621	70,161	76,440	81,353	86,575	92,152
Nonresidential Gas	57,462	57,703	58,088	58,849	60,267	61,211	62,171
Waste	23,052	23,256	24,183	25,839	27,257	28,681	30,194
Water	1,479	1,332	1,108	888	624	328	0
Wastewater	1,366	1,340	1,327	1,347	1,346	1,338	1,326
On-Road Passenger Transportation	181,900	169,242	148,578	133,987	125,081	121,771	121,487
On-Road Commercial Transportation	132,254	126,305	114,922	105,492	99,881	97,268	96,823
Off-Road Transportation	18,002	18,951	20,532	22,114	23,680	25,245	26,811
Total Emissions	**535,566**	**513,465**	**478,628**	**455,776**	**440,625**	**433,262**	**430,965**
Emissions Per Capita	**5.92**	**5.61**	**4.95**	**4.30**	**3.89**	**3.58**	**3.34**

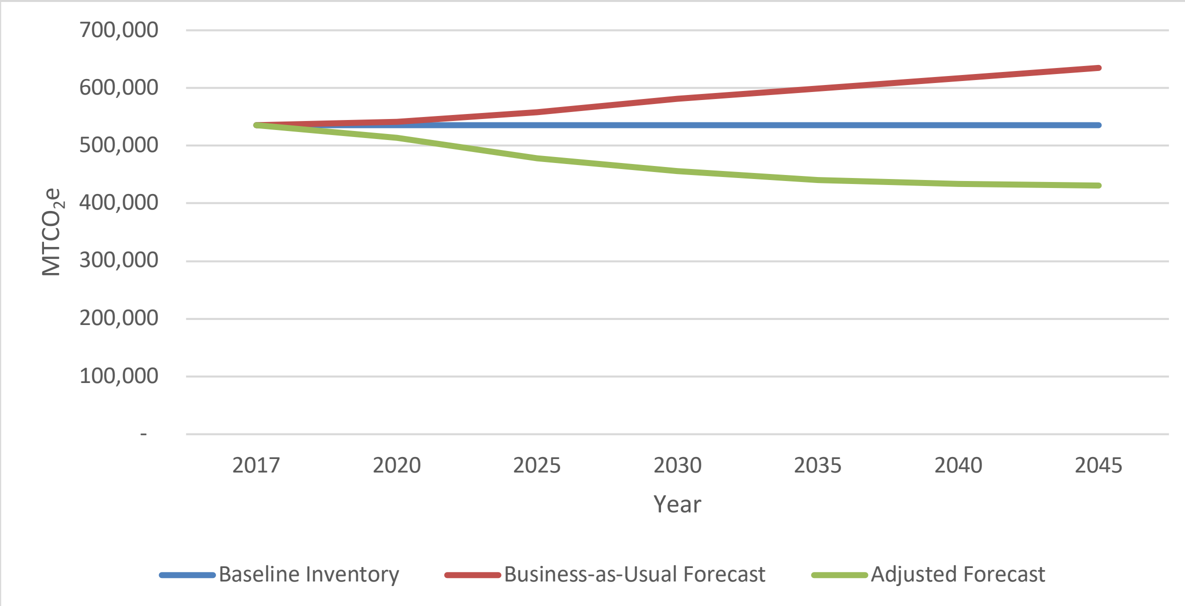
MT CO_2e: metric tons of carbon dioxide equivalent

Figure 5 Adjusted GHG Emissions Forecast Results by Sector and Forecast Year



As shown in Figure 6, without legislative reductions, Livermore's emissions would increase proportionally with population and economic growth. In reality, several existing legislative reductions would limit the Livermore's emissions growth, causing projected emissions to decrease. This scenario is depicted by the Adjusted Forecast. The legislative reductions for each sector and scaling methods used to project emissions are discussed in detail below.

Figure 6 BAU Scenario and Adjusted Scenario Forecast



Electricity Emissions

Between 2017 and 2045, electricity emissions for residential and nonresidential buildings in the City of Livermore are assumed to decrease from 51,735 MT CO_2e to 0 MT CO_2e in 2045 despite steady growth in Livermore's population and employment levels due to the adoption of SB 100 and the renewable portfolio standard

Emissions from future electricity use were forecasted by projecting anticipated growth in residential and commercial sectors and multiplying by expected electricity emissions factors. Anticipated growth in the residential sector was projected as a function of population growth within the city while commercial sector electricity use was projected as a function of employment projections. Legislative adjustments included in the electricity sector forecast include RPS of 60 percent by 2030 and 100 percent GHG-free by 2045. Additionally, Title 24 building code efficiency increases for the 2019 code cycle were applied to all new growth within the city. The methodologies for the electricity sector which were forecasted in the adjusted scenario are summarized in Table 26 and Table 27.

Table 26 Electricity Sector Adjusted Scenario Forecast Methodology

Source Category	Forecasted Activity Data (Scaling Factor)	Emissions Factor	Applied Legislative Reductions
Residential Electricity	Population growth in Livermore	Assumes an electricity mix of 44 percent, 60 percent, and 100 percent GHG-free by 2025, 2030, and 2045, respectively, for PG&E emissions factors per RPS requirements.	Title 24 standards for new construction in 2019 (53 percent residential, 30 percent commercial), RPS requirements
Commercial & Industrial Electricity	Employment growth in Livermore		

RPS: Renewable Portfolio Standard; GHG: greenhouse gas; PG&E: Pacific Gas and Electric

Table 27 Electricity Adjusted Scenario Forecast Results by Forecast Year

Activity Data	2020	2025	2030	2035	2040	2045
Residential Electricity						
Population	91,474	96,699	105,967	113,218	120,925	129,158
BAU total kWh	207,546,359	219,401,455	240,429,720	256,881,190	274,369,398	293,048,186
BAU per capita kWh	2,268.92	2,268.92	2,268.92	2,268.92	2,268.92	2,268.92
Adjusted kWh (Title 24)	207,136,052	212,707,947	222,591,232	230,323,423	238,542,881	247,321,911
Adjusted per capita kWh (Title 24)	2,264.46	2,264.46	2,264.46	2,264.46	2,264.46	2,264.46
Adjusted emissions factor (MT CO_2e/MWH)	0.0860312	0.0688249	0.0516187	0.0344125	0.0172062	0
MT CO_2e	**17,816**	**14,527**	**10,692**	**6,281**	**1,269**	**0**
Nonresidential Electricity						
Employment	48,340	48,686	49,372	50,649	51,499	52,364
BAU total kWh	290,135,098	292,216,547	296,328,536	303,994,718	309,098,544	314,288,060
BAU per job kWh	6,002.01	6,002.01	6,002.01	6,002.01	6,002.01	6,002.01
Adjusted kWh (Title 24)	290,010,745	291,467,760	294,346,152	299,712,479	303,285,158	306,917,819
Adjusted per job kWh	5,999.44	5,999.44	5,999.44	5,999.44	5,999.44	5,999.44
Adjusted emissions factor (MT CO_2e/MWh)	0.08603	0.06882	0.05162	0.03441	0.01721	0
MT CO_2e	**24,949**	**20,040**	**15,105**	**10,049**	**4,758**	**0**
Direct Access Electricity						
Population	91,474	96,699	105,967	113,218	120,925	129,158
BAU total kWh	32,647,902	34,512,758	37,820,591	40,408,476	43,159,443	46,097,694
BAU per capita kWh	357	357	357	357	357	357
Adjusted kWh (Title 24)	32,611,369	33,916,768	36,232,251	38,043,770	39,969,447	42,026,223
Adjusted per capita kWh	357	357	357	357	357	357
Adjusted emissions factor (MT CO_2e/MWh)	0.1823	0.1483	0.1142	0.07614	0.03807	0
MT CO_2e	**5,944**	**4,996**	**3,997**	**2,597**	**996**	**0**

MT CO_2e: metric ton of carbon dioxide equivalent; kWh: kilowatt hour; MWh: megawatt hour; BAU: business-as-usual

Natural Gas Emissions

Emissions from projected natural gas use were forecast using a similar methodology to the electricity sector. Anticipated natural gas use was projected for the residential and commercial sectors separately using population change and employment increase as growth indicators respectively. These results were multiplied by a natural gas emissions factor of 0.00531 MT CO_2e per therms of natural gas.[60] Unlike electricity, the natural gas emissions factor is based on the quality of the gas and remains relatively constant over time. As there are no legislative requirements related to renewable natural gas at this time, this analysis did not consider any shift to renewable gas which may become more common over time and the use of which may affect future natural gas emissions

[60] The Climate Registry. 2019 Default Emissions Factors. Accessed: https://www.theclimateregistry.org/wp-content/uploads/2019/05/The-Climate-Registry-2019-Default-Emission-Factor-Document.pdf. Accessed: April 15, 2020

factors. The methodologies and data used to calculate natural gas emissions over time are summarized in Table 28 and Table 29.

Legislative adjustments applied for the natural gas sector include efficiency increases from Title 24 building code updates for new construction after the 2019 code cycle begins. Specific efficiency increases for new buildings over the previous triennial cycle are discussed in Section 4.3.

Table 28 Natural Gas Adjusted Scenario Forecast Methodology

Source Category	Forecasted Activity Data (Scaling Factor)	Emissions Factor	Applied Legislative Reductions
Residential Natural Gas	Population growth in Livermore	0.00531 MT CO_2e/therms[1]	Title 24 standards for efficiency in new construction in 2019 (7 percent residential, 30 percent commercial over 2016 Title 24)
Commercial & District Natural Gas	Employment growth in Livermore		

MT CO_2e: metric ton of carbon dioxide equivalent

[1] Reported directly by PG&E for 2017 in their data delivery forms and greenhouse gas emissions data to The Climate Registry.

Table 29 Natural Gas Adjusted Scenario Forecast Results by Forecast Year

Activity Data	2020	2025	2030	2035	2040	2045
Residential Gas						
BAU therms	12,548,434	13,265,203	14,536,590	15,531,261	16,588,613	17,717,949
Title 24 adjusted therms	12,545,157	13,211,753	14,394,143	15,319,186	16,302,524	17,352,806
Emissions factor (MT CO_2e/therms)	0.00531	0.00531	0.00531	0.00531	0.00531	0.00531
MT CO_2e	**66,621**	**70,161**	**76,440**	**81,353**	**86,575**	**92,152**
Nonresidential Gas						
BAU therms	10,866,899	10,944,859	11,098,872	11,386,006	11,577,168	11,771,539
Title 24 adjusted therms	10,865,813	10,938,315	11,081,547	11,348,582	11,526,362	11,707,128
Emissions factor (MT CO_2e/therms)	0.00531	0.00531	0.00531	0.00531	0.00531	0.00531
MT CO_2e	**57,703**	**58,088**	**58,849**	**60,267**	**61,211**	**62,171**

MT CO_2e: metric ton of carbon dioxide equivalent; BAU: business-as-usual

Waste Emissions

The forecast used a baseline emissions rate of 0.530 tons of solid waste per service population and 0.0601 tons of ADC waste per service population, calculated using 2017 inventory data for tons of waste divided by the 2017 service population, along with projected growth in Livermore service population from Plan Bay Area Projections 2040 to establish the estimated tonnage of waste being disposed yearly through 2045. A 2017 solid waste emissions factor of 0.286 MT CO_2e and a 2017 ADC waste emissions factor of 0.246 MT CO_2e, calculated using 2017 waste characterization data from CARB's California Landfill Emissions Tool, were used to project emissions consistent with service population growth. Emissions from the waste sector will likely be less than the projected totals due to decreasing rates of organic material in the waste stream and recent legislation such as SB 1383 discussed in previous sections. At this time no mandate exists for individual cities and the waste reductions from these bills are incorporated into the Climate Action Plan through City reduction measures to avoid double counting. A summary of the methodologies and data used to model waste emissions over time are provided in Table 30 and Table 31.

Table 30 Solid Waste Adjusted Scenario Forecast Methodology

Source Category	Forecasted Activity Data (Scaling Factor)	Emissions Factor[1]	Applied Legislative Reductions
Solid Waste	Service population growth	0.5778 tons solid waste per service person, 0.286 MT CO_2e/ton of solid waste	N/A
ADC Waste	Service population growth	0.0655 tons ADC waste per service person, 0.246 ADC MT CO_2e/ton ADC waste	N/A

MT CO_2e: metric ton of carbon dioxide equivalent; N/A: not applicable

[1] Waste per service person growth factors calculated using 2017 inventory data for tons of waste, divided by total service population in 2017. Emissions factors calculated using 2017 waste characterization data from CARB's California Landfill Emissions Tool.

Table 31 Waste Emissions Adjusted Scenario Forecast Results by Forecast Year

Activity Data	2020	2025	2030	2035	2040	2045
Service Population	139,813	145,385	155,338	163,866	172,424	181,522
Ton Solid Waste per Service Population	0.53	0.53	0.53	0.53	0.53	0.53
Ton ADC Waste per Service Population	0.06	0.06	0.06	0.06	0.06	0.06
Total Tons Solid Waste	74,087	77,039	82,313	86,833	91,367	96,188
Solid Waste Factor (MT CO_2e/ton)	0.286	0.286	0.286	0.286	0.286	0.286
Total Tons ADC Waste	8,402	8,737	9,335	9,848	10,362	10,909
ADC Waste Factor (MT CO_2e/ton)	0.246	0.246	0.246	0.246	0.246	0.246
MT CO_2e	**23,256**	**24,183**	**25,839**	**27,257**	**28,681**	**30,194**

MT CO_2e: metric ton of carbon dioxide equivalent

Transportation Emissions

Transportation emissions forecasts were developed consistent with the inventory methodology, through the determination of on-road annual VMT multiplied by a year-specific weighted emissions factor for emissions per mile travelled. VMT forecasts for the City of Livermore were obtained from the Bay Area MTC VMT data portal.[61] MTC's Traffic Demand Model was utilized to model VMT through 2045. Emissions factors were established for each year through the use of the EMFAC2017 GHG module, which established VMT and total emissions for each vehicle type in the County. These respective emissions factors were applied in each year to establish transportation emissions forecasts as shown in Table 32 and Table 33.

[61] Bay Area Metropolitan Transportation Commission (MTC) VMT Model. 2020. Available: http://capvmt.us-west-2.elasticbeanstalk.com/data. Accessed: April 19, 2020.

Table 32 Transportation Adjusted Scenario Forecast Methodology

Source Category	Forecasted Scaling Factor	Emissions Factor	Applied Legislative Reductions
On-road Transportation	MTC VMT Modeling[1]	EMFAC2017 model analyzing light duty (LDA, LDT1, LDT2, MDV, MCY) and heavy duty (LHD, T6, T7, PTO, MH, SBUS, UBUS, OBUS, Motor Coach, All Other Buses) vehicles.	EMFAC emissions factors account for legislative reductions from Advanced Clean Cars, Pavley Clean Car Standards, Tractor-Trailer Greenhouse Gas Regulation, and adopted fuel efficiency standards for medium- and heavy-duty vehicles.
Off-Road Transportation	OFFROAD2007 Model[2]	OFFROAD2007 Model	N/A

MT CO_2e: metric ton of carbon dioxide equivalent; VMT: vehicle miles traveled

[1] MTC VMT data portal incorporates data from the MTC's large-scale simulation model of daily travel behavior, used for its regional planning efforts and in Plan Bay Area. More information can be found on the MTC VMT Data Portal website at http://capvmt.us-west-2.elasticbeanstalk.com/about. Accessed: May 5, 2020.

[2] California Air Resources Board. OFFROAD2007. Available: https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/msei-road-archives. Accessed: April 1, 2020.

Table 33 Transportation Adjusted Scenario Forecast Results by Forecast Year

Activity Data	2020	2025	2030	2035	2040	2045
Population	91,474	96,699	105,967	113,218	120,925	129,158
Passenger VMT	545,893,360	566,412,825	586,932,289	595,803,761	604,675,234	613,546,706
Commercial VMT	97,108,456	98,428,891	99,749,326	101,291,552	102,833,778	104,376,005
Passenger EMFAC Emissions Factor (g CO_2e/mile)	310	262	228	210	201	198
Commercial EMFAC Emissions Factor (g CO_2e/mile)	1,301	1,168	1,058	986	946	928
Passenger MT CO_2e	**169,242**	**148,578**	**133,987**	**125,081**	**121,771**	**121,487**
Commercial MT CO_2e	**126,305**	**114,922**	**105,492**	**99,881**	**97,268**	**96,823**
Off-Road MT CO_2e	**62,867**	**69,559**	**76,252**	**84,025**	**91,799**	**99,572**
Total MT CO_2e	**560,632**	**529,879**	**510,512**	**499,456**	**495,646**	**502,737**

MT CO_2e: metric ton of carbon dioxide equivalent; VMT: vehicle miles traveled

Water and Wastewater Emissions

Due to the increased use of the water system attributed to increases in job and population growth in Livermore, service population was used as a scaling metric to determine water and wastewater service emissions through 2045, as shown in Table 34. Projections for water used a baseline activity factor of 110.7 kWh per service population per year, calculated using 2017 inventory data for electricity used for water processing and distribution divided by the 2017 service population based on Plan Bay Area Projections 2040. This emissions factor was multiplied by service population growth through 2045 to find total kWh usage. The RPS for electricity generation was then applied to water emissions, as described in the Legislative Adjustment Section, to determine final MT CO_2e emissions as shown in Table 35 and Table 36.

As wastewater emissions are calculated from both direct and process emissions sources. Wastewater projections used an emissions factor of 0.00693 MT CO_2e per service population per year, calculated using wastewater process emissions data from the 2017 inventory divided by the total service population in 2017 based on Plan Bay Area Projections 2040, and a growth indicator of service population to determine future wastewater emissions.

Table 34 Water and Wastewater Adjusted Scenario Forecast Methodology

Forecasted Activity Data (Scaling Factor)	Emissions Factor[1]	Applied Legislative Reductions
Service population (population and employment growth)	PG&E electricity emissions factors, 110.7 kWh per service population per year	Assumes an electricity mix of 44 percent, 60 percent, and 100 percent GHG-free by 2025, 2030, and 2045 respectively for PG&E emissions factors per RPS requirements.
Service population (population and employment growth)	0.00693 MT CO_2e per service person per year for wastewater	N/A

MT CO_2e: metric ton of carbon dioxide equivalent; kWh: kilowatt hour; PG&E: Pacific Gas and Electric; N/A: not applicable

[1] Growth factors based on 2017 inventory data, divided by the total service population in 2017 based on Plan Bay Area Projections 2040 data.

Table 35 Water Adjusted Scenario Forecast Results by Forecast Year

Activity Data	2020	2025	2030	2035	2040	2045
Service Population	139,813	145,385	155,338	163,866	172,424	181,522
kwh/Service Person	110.7	110.7	110.7	110.7	110.7	110.7
Total kWh	15,480,255	16,097,168	17,199,181	18,143,417	19,090,975	20,098,213
RPS Electricity Factor (MT CO_2e/MWh)	0.08603	0.06882	0.05162	0.03441	0.01721	0
MT CO_2e	**1,332**	**1,108**	**888**	**624**	**328**	**0**

MT CO2e: metric ton of carbon dioxide equivalent; kWh: kilowatt hour; RPS: renewable portfolio standard

Table 36 Wastewater Adjusted Scenario Forecast Results by Forecast Year

Activity Data	2020	2025	2030	2035	2040	2045
Service Population	139,813	145,385	155,338	163,866	172,424	181,522
MT CO_2e/Service Population	0.00693	0.00693	0.00693	0.00693	0.00693	0.00693
MT CO_2e	1,340	1,327	1,347	1,346	1,338	1,326

MT CO_2e: metric ton of carbon dioxide equivalent; kWh: kilowatt hour;